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JRC TECHNICAL REPORTS

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

1st draft report
Task 1-4

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Table of Acronyms

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

INTRODUCTION

Background

The European Commission has launched a preparatory study of Ecodesign and Energy Labelling implementing measures for High Pressure Cleaners (HPC).

The current report covers Task 1 of the Methodology for Ecodesign of Energy-related Products (MEErP)[1] used for this preparatory study. The methodology consists of seven well-defined tasks, where Tasks 1 to 4 have a clear focus on data retrieval and initial analysis, and Tasks 5 to 7 have a clear focus on modelling and modelling analyses aiming at providing sufficient background for deciding 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*

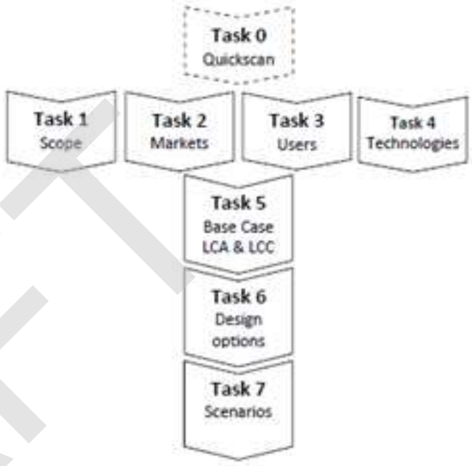


Figure 1. MEErP structure

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 wide consensus.

Stakeholder consultation throughout the study

During the preparatory study, continuous stakeholder consultation take place. An online communication system - BATIS - has been set-up for easy exchange of documents between registered stakeholders forming the Technical Working Group (TWG).

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 will be distributed to the TWG during the study process. Further, the project team will visit different manufacturers, test laboratories, recyclers and relevant trade fairs to investigate the overall product group, and product sub-groups in detail, and to be completely up-to-date with the latest technical and market developments. At a

[1] "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)

stakeholder kick-off meeting held in Brussels on 3rd May 2018, a first draft of the Task 1 report was presented and discussed.

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, both within the EU and internationally. Its results consist of a preliminary scope definition, with a special focus on the products' performance, in combination with 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 sections first provide an analysis of existing definitions of HPCs, as used for example in European statistics, EU legislation, and standards. The product scope is based also 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 a basis for discussion at the 1st stakeholder meeting.

1.1.1 Existing definitions and categories

This section describes existing definitions, categories and sub-categories 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 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[2], which means that the data registered for HPCs is part of 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 for 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.

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

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 scoping, 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 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 not 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 not 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;
- hand-held 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 of 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 implementing 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. To date 8 stakeholders have submitted their feedback on ''Task 1: Scope'' via this questionnaire. These stakeholders comprise: 2 trade organisations for the sector, 2 consumer/environmental organisations and 4 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 has pointed out that there is a segment of HPCs with operating pressures higher than 35 MPa (products specially designed for heavy duty industrial and agriculture applications). Thus, it would be premature to exclude such products from the HPCs product scope without an analysis. 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 without reasoning this exclusion. Another stakeholder proposed hand-held and transportable motor-operated electric tools (IEC 60745 series, IEC 61029 series, IEC 62841 series) to be excluded.

Regarding the question of whether HPCs with internal combustion engines should be included or excluded from the scope, most respondents have 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, as for example the energy and resource consumption, the environmental impact and use pattern of these HPC equipment. Two stakeholders are in favour of including HPCs with combustion engine in the scope. One respondent has estimated that the market share of HPCs with internal combustion engines is relatively small without giving estimates. In contrary, 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 of the market for HPCs with internal combustion engines.

Regarding the question of including battery-driven HPCs within the scope of the study, responses received until now in general indicate that currently there are few battery-driven domestic HPCs on the EU market. The project team noticed that there are battery powered HPCs already available on the market with low as well as medium range maximum water pressures. Three respondents are of the opinion that battery-powered HPCs are not a significant product sub-group, and that they do not expect this will change in the foreseeable future as current battery capacities can only support high pressure cleaners with low maximum pressure or short performance time. Large batteries with sufficient capacity would make the HPCs so heavy that it would not be considered mobile due to its weight. On the other hand, three stakeholders respond that they do expect more battery driven HPCs in the future.

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 industrial sector (they either are used in an industrial environment or in an environment with explosive atmosphere or in car wash facilities) and their use is very different from domestic and commercial applications. Furthermore, that it is a niche market with very low sales (first estimations from stakeholder place these unit sales at the level of few thousands units per year, however more detailed information will be provided in Task 2). On contrary, 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 mention 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 within scope. One stakeholder does not answer directly on 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 base of discussion for the 1st Technical Working Group held on the 3rd of May in Brussels, Belgium.

The proposed primary performance parameter or otherwise mentioned '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 the European consumers and commercial operators. An HPC has been defined by one source as: *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*[3].

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 that is let out 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 purpose.

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 driven 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 integrated a burner or boiler, which enables them to convert cold into hot water. Warm or hot water can also be supplied to some HPCs directly from the water connection without the need of internal heating.

HPCs may be mobile or stationary. Definition from the Outdoor Noise Directive[4] is:

- 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 hand held. Table 2 presents six typical product types of HPCs.

[3] Definition from the outdoor noise directive, see description of the directive in section 1.3
[4] Description of the Outdoor Noise Directive in section 1.3

Table 2. Typical high pressure cleaners.

Low performance HPC	Compact units, suitable for general cleaning duties including garden tasks and furniture. Typically electric powered. Very few units on the market are battery driven today. Only one manufacturer produces hot water units. Typical power range 1200W to 1600W. Typical pressure up to 11 MPa. Example product: Karcher K2	
Medium performance HPC	Compact units, often upright units, suitable for general cleaning duties including garden tasks, furniture, patio and paths and car washing duties. Typically electric powered. 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	
High performance HPC	More powerful units, often upright units and suitable for a broad range of demanding cleaning duties. Typically electric powered. 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. Alternate sources of power may include biodiesel and gas. Power range: 5-15 hp; 3 kW to 15 kW. Pressure is typically 16MPa and higher Example product: SIP Tempest PPG680/210 207 Bar Petrol Pressure Washer	
Hot water HPC	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 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 ^{O}C (in rare cases up to 150 ^{O}C for steam output) and input power of the pump at the level of 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 to 20 MPa or higher. Motor ratings are typically 2 to 8 kW and the units incorporate a fuel tank with low level warning. The mains supply may be 230V single phase for lower pressure units but above 15 MPa or 3.3 kW, units will typically require a 400V 3-phase supply. Temperatures 0-100^{O}C Example product: Mac International – Plantmaster	

1.1.3.2 Proposed product scope

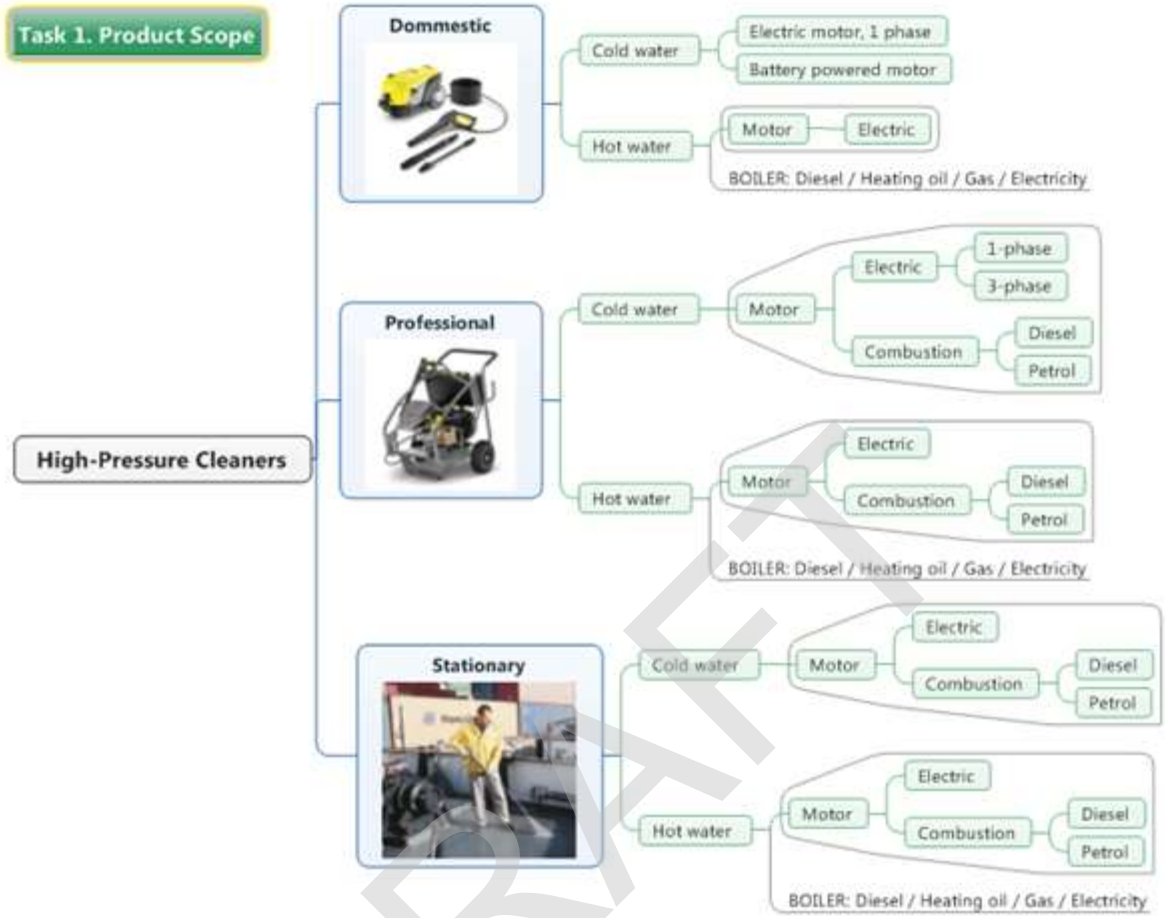
The preliminary scope of this study covers:

1. Cold water domestic high pressure cleaners.
2. Hot water domestic high pressure cleaners
3. Hot water professional high pressure cleaners
4. Cold water professional high pressure cleaners
5. Hot water professional high pressure cleaners
6. Cold water stationary high pressure cleaners
7. Hot water stationary high pressure cleaners

The above first, the third and the fourth sub-groups represent the three main categories which were preliminarily investigated in the Preparatory study to establish the Ecodesign Working Plan 2015-2017[5]. In addition, cold and hot water stationary hot 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.

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

Figure 2. HPC product scope



Preliminary scope proposed

High pressure cleaners without traction drive, intended for indoor or outdoor use, having a rated maximum water pressure not less than 2.5 MPa and not exceeding 60 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.

Exclusions proposed:

- 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 of ships or aircraft.

Definitions proposed:

- “High pressure cleaner” means a device that ejects water at high pressure (above 2.5 MPa and below 60 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 (cold or hot water) whose maximum power does not exceed 3.3 kW, single phase, and its intended use defined by the manufacture is domestic.
- “Professional high pressure cleaner” means a unit (cold or hot water) whose power is equal or exceed 2 kW, and its intended use defined by the manufacture is professional or industrial. Units driven by internal combustion engines, single or three-phase electric driven and hydraulic or pneumatic motors are considered professional, and its intended use defined by the manufacture is 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 are designed for steam cleaning only.
- “Agricultural sprayer” means a unit that is used to apply liquid fertilizers, pesticides, or other liquids to crops during their growth cycle.

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

Rationale for the proposed scope

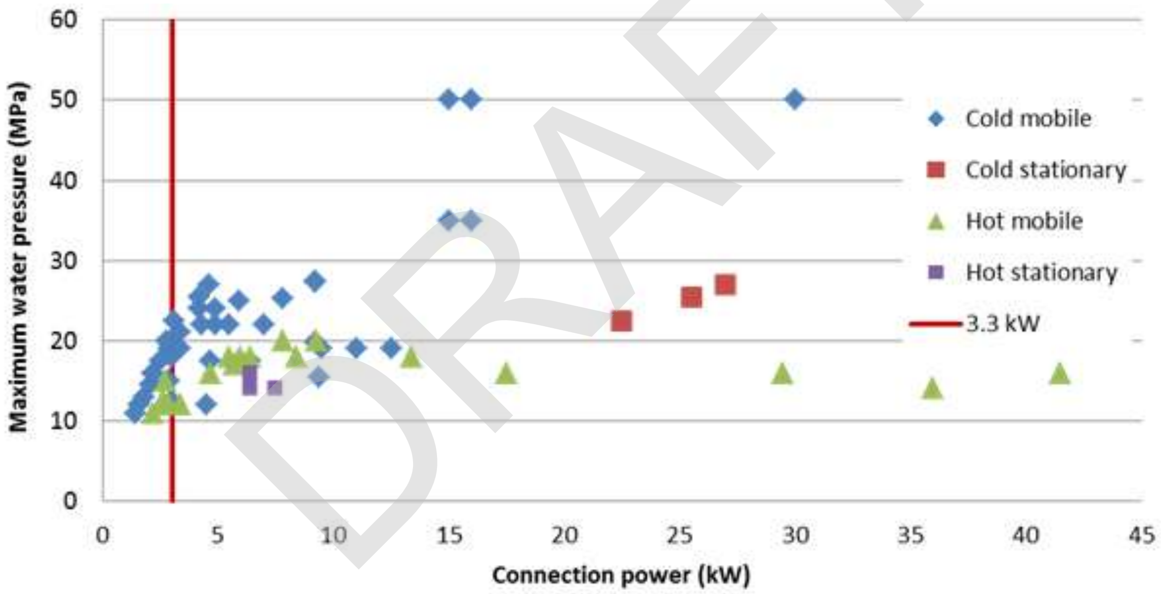
Stationary HPC: The study team would like to note that although the sales of stationary units can be much lower compared with the rest of the HPC sub-categories; their environmental impact is likely to be disproportionally higher compared to the rest of the HPC categories, as their use can be more intense and frequent (e.g. stationary units for car).

Maximum water pressure limits (2.5 MPa to 60 MPa): Below the 2.5 MPa pressure the product cannot be considered as HPC. This minimum pressure limit was selected to be in line with the EN 60335-2-79 safety standard. The maximum water pressure upper limit was selected at 60 MPa, to cover all available HPC in the market (see Figure 3) and be well below the low pressure limit of water jet cutting applications.

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 in 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 3 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, since 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 HPC: Generally, appliances with batteries are appreciated by the consumers and coming broadly on the market. Battery driven HPCs are already available in the market, however, in few numbers and for low performance applications. Furthermore, the battery technology is significantly improving over the last years (affected also by the fast development of electric cars) with new materials and technologies increasing their capacity and efficiency, lowering their weight; which results also in a price decreasing 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 most relevant existing standards where parts of the standard can be 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 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 not 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.

Standard	Title	Directive /Regulation	Content and scope
			The scope covers the safety of high pressure cleaners without traction drive, intended for household and commercial indoor or outdoor use, having a rated pressure not 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 35Mpa. 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-	High pressure	Harmonised	As above but relates to significant

Standard	Title	Directive /Regulation	Content and scope
2:2008	water jet machines — Safety requirements — Part 2: Hoses, hose lines and connectors	under: Machinery Directive (2006/42/EC)	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 household appliances, electric tools and similar apparatus. Emission	Harmonised under: EMC Directive: (2014/30/EU)	This is a product family specific standard that covers all aspects of EM emission from products such as HPCs.
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,	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.

Standard	Title	Directive /Regulation	Content and scope
	for equipment with rated current ≤ 16 A per phase and not subject to conditional connection		
EN 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	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, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers	Harmonised under: EMC Directive: (2014/30/EU)	This standard applies to the emission of electromagnetic energy which may cause interference to radio reception emitted, among 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	-	This standard is called up 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

Standard	Title	Directive /Regulation	Content and scope
	equipment		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 work station and at other specified positions from the sound power level	-	This standard is called up 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 of Outdoor Noise Directive	This standard is called up by EN 60335-2-79:2012 as one of 2 methods for the method for determining 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. ISO 3744:2010 is applicable to all

Standard	Title	Directive /Regulation	Content and scope
			types and sizes of noise source (e.g. stationary or slowly moving plant, installation, machine, component or sub-assembly), provided the conditions for the measurements can be met. The test environments that are applicable for measurements made in accordance with ISO 3744:2010 can be located indoors or outdoors, with one or more sound-reflecting planes present on or near which the noise source under test 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 of 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 sub-assembly), provided the conditions for the measurements can be met. The test environments that are applicable for measurements made in accordance with ISO 3746:2010 can be located indoors

Standard	Title	Directive /Regulation	Content and scope
			or outdoors, with one or more sound-reflecting planes present on or near which the noise source under test 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 with that of ISO 12001:1996, accuracy grade 3 (survey grade).
EN ISO 3743-1:2010	Acoustics - Determination of sound power levels and sound energy 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	-	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 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 under test may be a device, machine, component or sub-assembly. The maximum size of the source depends upon the size of the room used for the acoustical measurements.

It should be noted that whereas 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 1.2.1 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 60335-1:2010+A1:2013+A2:2016 (Ed. 5.2)	Household and similar appliances – Safety: Part 1: General requirements ([1])	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 not 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 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	The International IEC variant of the EN standard.

Standard	Title	Content and scope
	conditional connection	
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 the 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 the 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 the EN 55012:2007

([1]) 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.

It should be noted that there is a standard in development under an IEC Technical Committee (TC59), which is very relevant: IEC 62885-5 Ed. 1 Surface cleaning appliances - Part 5: High pressure cleaners and steam cleaners - Methods of measuring the performance. It is currently at the Committee Draft Vote stage (59F/340/CDV) up for vote in May 2018. As it is still in the CDV stage and therefore a draft version, the standard can be expected to be finalised in 18 months to 2 years from voting.

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 Commissions 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 under the Joint Research Centre, Seville[6], provides input to the standardisation under this mandate.

The following regulation covers all standardisation requests. The latest Union Work Program for standardisation was published in August 2017.

- 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.

1.2.1.2 Member States

The Safety and Electromagnetic compatibility (EMC) standards listed above are harmonised and are utilised as the basis of a Presumption of Conformity with the applicable directives by all member states.

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

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

1.2.1.3 Third country test standards

In Table 5 third country test standards are presented. Relevant standards have been found in 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, Edition 5.1 (Edition 5:2010 including corrigendum 1:2010, corrigendum 2:2011, and amendment 1:2013) issued 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, 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 of 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

Standard	Title	Content and scope
		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 15 Subpart B as a Class B digital device (as defined in Section 15 101) requiring an equipment authorization 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 a close proximity and therefore

Standard	Title	Content and scope
		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 STANDARD		
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 program 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 manufactures, 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 program. The certification is issued by CETA based on test data provided by the third party laboratory. The authorisation to use the CETA Performance Certified is granted by CETA.

The program 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 offer a voluntary certification program 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 engine or electric motor driven.

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 settable, 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 3 samples tested in accordance with the test method)

The test method includes:

- Test duration is 30 minutes of continuous operation
- Readings recorded at 5 minutes intervals and average values calculated
- Average values used to assess performance and compliance to ratings
- Pressure and flow ratings not greater than the average of 3 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 1.2 do not overlap on performance, resources use and/or emissions. All the standards listed in section 1.2 are called up in Annex CC of EN 60335-2-79. The 2 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

There are no current EN/IEC performance testing standards for HPCs.

As stated in section 1.2 regarding test standard prEN 62885-5:2018 Surface cleaning appliances - Part 5: High pressure cleaners and steam cleaners - Methods of measuring the performance (IEC 62885-5:201X) is currently under parallel vote in CENELEC and IEC. The intent in the standard is to serve the manufacturers in describing parameters that fit in their manuals. This may include all or some of 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 made in accordance with the document. The standard will focus 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.

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 test 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 a necessity to measure the speed and quality of removal of different kind of soiling from different kind 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 of course be performed using pre-soiled and aged surfaces that were available to the laboratory, such as concrete walkways, car parks and block paving around a building, but there is fundamental problem with this approach, which is that these surfaces by their nature tend to be rather variable. To counter the effects of this variability, techniques such as randomisation of the test areas, using multiple test assessors and statistical analysis of the results may be used. Unfortunately, this tends to lead to the need for a large number of test samples and the necessity of time and labour-intensive test work.

Artificial test surfaces

Amongst the manufacturers and product testing industry, it is occasionally necessary to 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 the 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 rather 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, that 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 / cleaned surface area for predefined soiled surfaces. This can then be translated also to environmental impact/m2 (LCA, when including life cycle impact) and EUR/m2 (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 will be 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 etc). 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 move 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[7]:

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 made (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.

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.

Performance criteria will need to consider cleaning performance levels similar to 'wash performance' with cleaning performance assessed to a defined soiling level.

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

1.3.1 European Union

EU Machinery Directive

The EU Machinery Directive[8] sets mainly safety requirements for machinery put on the market or put in service in all member states and aims to ensure their freedom of movement within the European Union. The directive embraces the Low Voltage Directive[9] requirements and its requirements must be met. However, any Declaration of Conformity for CE Marking purposes would be made to the Machinery Directive only.

EU WEEE Directive

The WEEE Directive[10] sets selective treatment requirements for the Waste of Electronic and Electrical Equipment and its components (including all types of electrical HPCs). The Directive 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 WEEE handling.

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

[8] Directive 2006/42/EC on machinery, and amending Directive 95/16/EC (recast)
[9] 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
[10] Directive 2012/19/EU on waste electrical and electronic equipment (WEEE)

EU RoHS Directive

The RoHS Directive[11] 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).

In January 2017, the Commission adopted a legislative proposal to introduce adjustments in the scope of the Directive, supported by the impact assessment. The respective legislative act amending the RoHS 2 Directive, adopted by the European Parliament and the Council, has been published in the Official Journal on 21 November 2017. The Directive covers HPCs with the amendment. The impact assessment and the legislation can be found on DG Environments website[12].

EU Battery Directive

The battery directive[13] applies to all types of batteries and sets rules regarding 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 was 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 [14] 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 implementing measures.

EU Ecodesign Directive

The Ecodesign Directive[15] 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.

The Ecodesign Directive is a framework directive, meaning that it does not directly set minimum requirements. Rather, 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 measures:

- 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

[11] Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast)

[12] http://ec.europa.eu/environment/waste/rohs_eee/index_en.htm

[13] Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators

[14] Regulation 2017/1369/EU on setting a framework for energy labelling and repealing Directive 2010/30/EU

[15] Directive 2009/125/EC on establishing a framework for the setting of ecodesign requirements for energy-related products

motors with amendment (Commission Regulation (EU) No 4/2014 of 6 January 2014)

Commission Regulation on Ecodesign requirements for electric motors[16]

Electric motors are subject to EU Ecodesign requirements that establish minimum requirements for the products in 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 1000 V;
- have a rated power output between 0,75 kW and 375 kW;
- are rated on the basis of continuous duty operation.

The regulation covers part of the motors present in the market, although some motors designed for specific conditions, for example those that operate immersed in a liquid such as in a sewage system, are excluded from the requirements. The regulation is currently under revision. The review study was finished in 2014 and includes analyses of resource efficiency, re-use and recycling and the level of measurement uncertainty as well as an analysis of possible inclusion of more types of motors[17].

Outdoor Noise Directive

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

This directive is currently under revision. 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 has been launched on 23 January 2018 and will run until 18 April 2018. The study and document on the public consultation can be found on DG Growth 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 & farming machinery (harvesters, cultivators, etc.)
- railcars, locomotives and inland waterway vessels.

[16] COMMISSION REGULATION (EC) No 640/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for electric motors

[17] https://www.eceee.org/ecodesign/products/special-motors-not-covered-in-lot-11/

[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

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.

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 Directives are to ensure:

- The compliance of equipment (apparatus and fixed installations) with EMC requirements when it is placed on the market and/or taken 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.

Pressure Equipment Directive

The Pressure Equipment Directive[22] applies to the design, manufacture and conformity assessment of stationary pressure equipment with a maximum allowable pressure greater than 50 kPa. The Pressure Equipment Directive aims to guarantee free movement of the products in its scope while ensuring a high level of safety.

Radio Equipment Directive

The Radio Equipment Directive[23] 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[24] 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.

EU Packaging Directive

The Packaging Directive[25] provides a definition of the term 'packaging' and sets targets for recovery and recycling of packaging waste. The directive aims at providing a high level of environmental protection and ensuring the functioning of the internal market by avoiding obstacles to trade and distortion and restriction of competition.

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[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 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment

[23] 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

[24] 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

[25] Directive 1994/62/EC on packaging and packaging waste

1.3.2 Third countries

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).

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[26].

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.

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 sought improved in the now 20 years old Danish "EDIP" project (Environmental Design of Industrial Products)[27]. It was 5-year collaboration between Danish Industry association, several companies, Danish EPA and DTU (Technical University of Denmark).

The method consists of 6 phases:

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

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 studied systems
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 to 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 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 large improvement by a new design of the nozzle, a combined hydraulic and mechanical shaping of the water jet implying a large improvement of the pressure drop profile of the jet. As result about 30% savings of water and energy was achieved without reduction in 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[28] 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 missing data for some countries, particularly for production. However, it represents the official EU source and provides valuable qualitative information about the roles played by each country in this sector. This is further detailed in the following sections.

2.1.1 EU28 Production 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 HPCs produced in EU member states and EU28 totals in the years 2009 to 2016 according to Eurostat.

The figures suggest that Italy and Denmark are the main Member States producing steam, 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 listed production in single Member States and the EU 28 totals production volume. This data gap corresponds to the production for which there is not data (NA).

[28] 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 EU28 between 2009 and 2016 (Eurostat). The sum of the individual member states does not correspond to the EU28 totals due to lack of data from some member states.

Country	2009	2010	2011	2012	2013	2014	2015	2016
Austria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Belgium	NA	NA	NA	NA	NA	NA	NA	NA
Bulgaria	NA	NA	0.00	0.00	NA	10.00	10.00	NA
Croatia	0.00	0.00	0.00	0.00	61.00	49.00	79.00	85.00
Cyprus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Czech Republic	NA	NA	302.00	1,062.00	978.00	NA	1,574.00	2,791.00
Denmark	83,651.00	90,363.00	185,263.00	154,093.00	92,693.00	75,053.00	32,857.00	12,531.00
Estonia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Finland	33.00	24.00	31.00	17.00	5.00	28.00	0.00	0.00
France	3,196.00	52,280.00	NA	NA	74,128.00	NA	NA	NA
Germany	NA	NA	NA	NA	NA	NA	NA	NA
Greece	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Hungary	NA	NA	NA	NA	294,300.00	314,951.00	310,129.00	29,347.00
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	NA	NA	NA	NA	NA	NA	NA	NA
Italy	686,533.00	784,608.00	906,212.00	87,237.00	112,034.00	145,562.00	201,161.00	146,620.00
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	4,758.00	1,197.00	477.00	377.00	356.00	205.00	2,451.00
Luxemburg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Netherlands	8,424.00	234.00	NA	1,641.00	809.00	NA	12,400.00	1,043.00
Norway	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poland	NA	438.00	518.00	769.00	800.00	2,200.00	2,056.00	1,948.00
Portugal	145.00	149.00	116.00	81.00	115.00	278.00	137.00	NA

Romania	0.00	0.00	0.00	0.00	0.00	0.00	NA	0.00
Slovakia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slovenia	NA	NA	NA	NA	NA	85.00	107.00	99.00
Spain	4,805.00	4,224.00	4,179.00	1,619.00	1,745.00	2,176.00	2,488.00	2,474.00
Sweden	NA	NA	NA	NA	NA	NA	NA	NA
United Kingdom	3,597.00	4,713.00	7,345.00	9,395.00	8,397.00	5,356.00	6,831.00	6,794.00
EU25 TOTALS	4,000,000.00	2,800,000.00	3,972,261.00	2,000,000.00	NA	NA	NA	NA
EU27 TOTALS	4,000,000.00	2,800,000.00	3,972,261.00	2,000,000.00	NA	NA	NA	NA
EU28 TOTALS	4,000,000.00	2,800,000.00	3,972,261.00	2,000,000.00	2,000,000.00	4,000,000.00	2,000,000.00	2,800,000.00

"NA" means data not being available

2.1.1.2 Value of EU production

Table 7 provides an overview of the value corresponding to the number of units produced in certain member states and EU28 totals. The main producer seems to be Italy, but data for Germany is not available.

The total value of produced household HPCs in EU28 increased from 641 million Euros in 2004 by 46% to 938 million Euros 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 Euros) of steam or sand blasting machines and similar jet-projecting machines in the EU28 between 2009 and 2016 (Eurostat). The sum of the individual member states does not correspond to the EU28 totals due to lack of data from some member states.

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
Netherland s	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
EU25 TOTALS	808,066,398	752,115,214	976,987,612	937,882,093	NA	NA	NA	NA
EU27 TOTALS	808,276,398	752,515,214	976,987,612	937,882,093	NA	NA	NA	NA
EU28 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

"NA" means data not being available

As can be observed, there are many data gaps in the form of "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 as the Netherlands and Lithuania with dramatic 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 Annex 2 and 3. While import values are consistent, export values show remarkable 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. On the other hand, France, Germany and UK are the main importers.

Table 8. Value 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
Lituania	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
EU28 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 + Import – Exports

Note that for several EU member states, import and export data have been reported in PRODCOM but production have 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[29] 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 EU28 the value of apparent consumption was around 810 million Euros of steam or sand blasting machines and similar jet-projecting machines in 2016.

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

Table 9. Calculation of apparent consumption (in Euros) 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
EU25 TOTALS	520,826,938	461,657,664	571,811,072	449,017,063	NA	NA	NA	NA
EU27 TOTALS	536,493,868	475,299,604	587,038,052	467,979,083	NA	NA	NA	NA
EU28 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

"NA:" means data not derivable as input data (mostly production data) not being available

2.1.4 EU sales and Intra/Extra-EU28 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 EU28 is a net exporter of steam or sand blasting machines and similar jet-projecting machines. Germany and UK are the main importers of from outside EU28, followed by Belgium and Italy, while Germany and Italy are the largest exporters. Germany and Italy have also the largest values of exports to other EU Member States (Intra-EU exports), being France, Germany and UK the main destinies of EU internal trade.

Table 10. Intra- and Extra-EU28 trade of Member States with steam or sand blasting machines and similar jet-projecting machines in 2016 (Eurostat).

	EU28 EXTRA (Euros)		EU28 INTRA (Euros)	
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

	EU28 EXTRA (Euros)		EU28 INTRA (Euros)	
Country	Imports	Exports	Imports	Exports
EU28 Totals	275,426,544	519,069,771	-	-

2.1.4.1 Extra EU28 trade

Table 11 gathers the figures of extra-EU28 trade with selected countries: Australia, Canada, China, Hong Kong (China), Indonesia, Japan, South Korea, Mexico, Norway, Russia, Saudi Arabia, Singapore, South Africa, Turkey and United States. These countries represent 60% of extra-EU28 exports and 96% of extra-EU28 imports.

The main destinies of European exports are Russia, China and United States. On the other hand, China is by far the largest exporter to the EU28 (84% of extra EU28 imports). It is the only country of the group with which extra-EU28 trade results in a negative balance.

Table 11: Value (in Euros) of Extra EU28 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 HPC

2.2.1.1 Historical sales and projections

Detailed market information regarding domestic and professional HPC sales in EU have been purchased from GfK[30] (data gathered from retailers), as well as market information provided by stakeholders. These market data cover the following EU7 countries: Belgium,

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

France, the Netherlands, UK, Italy, Spain and Germany. In total the above seven countries represents around 50% of the EU28 households and accounts **2.5 million units sales**. Regarding professional HPCs, additional detailed market information have been provided by stakeholders, and together with the GfK dataset, have been double-checked and used as main source of data for professional HPCs. For both domestic and professional HPCs (as defined in Task 1), the above market information compilation has been considered as a sufficiently representative sample to be extrapolated to EU28. More specifically, for scaling up the market data to EU28 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 (EU28) 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 in south and central-north Europe. For example, Spain was used as proxy country to estimate the number of domestic HPC units for Portugal considering also the above 2 parameters.

Regarding the extrapolation, the HPC sales for each country lacking of data has been done by normalising the gathered EU7 data with the number of households of its country and its PPS that reflects the purchase consumers' ability. The aggregated EU7 sales, representing nearly half of the EU28 households, were used as proxy for all other EU27 countries apart from the south European countries where data from Spain were used as proxy (to also capture geographical patterns).

Figure 4 presents the summation of HPC sales calculated for EU28 as well as the forward and backward projections, starting from the year of 1987 to 2050. In 2017, the domestic HPC sales (in units) are calculated at the level of **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 of 2025 and from 2026 to 2050 was estimated a minor decline in the growth trend assuming a minor decline in growth of the EU market in the decade after 2040, as the market penetration rates are gradually increase. By 2030 the domestic HPC sales are expected to increase at the level of **4.9 million units per year** and by 2050 to **5.7 million units per year**.

Figure 4. Estimated historical sales of domestic HPC for EU28 for 2007-2017 along with forward and backward projections covering in total the period 1997-2050.

2.2.1.2 Lifetime calculations

The lifetime of a product varies by many factors such as the utilization/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[31], 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] the following Equation 1 was used.

Equation 1:

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

Where γ is the shape parameter; λ is the scale parameter; v is the delay parameter. With 'retiring' is meant the probability of an HPC to fail in a given year and by survival the probability to survive in a given year. The breakdown probability (or Probability Density Function), which corresponds to the probability of a product to fail in a given year, is calculated for a period of 50 years as follows by Equation 2.

[31] 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

Equation 2:

$$\% \text{ retiring } (t) = \frac{\gamma}{\lambda} * \frac{t-v}{\lambda}^{\gamma-1} * e^{-\frac{t-v}{\lambda}^{\gamma}}$$

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

On the other hand, the survival probability or Cumulative Distribution Function, which corresponds to the probability of a product to survive in a given year, is calculated for a period of 50 years as follows by Equation 3.

Equation 3:

$$\% \text{ surviving } (t) = e^{-\frac{t-v}{\lambda}^{\gamma}}$$

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

The survival for the next year is calculated based on the evolution of the survival probability as follows by Equation 4:

Equation 4:

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

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

A delay period of 2 years was selected (v=2) for the analysis, as the EU law require 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 from the consumers and repaired or replaced by the manufacturers at their expense.

The Weibull stochastic approach was selected. By 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 % of the survivals). These correction factors avoid an overestimation of the stock as they further reduce the probability of an aged to remain in the stock. A Belgian study[32] found an average estimated life time of 12 years at end-of–Life for domestic high pressure cleaners. Sources amongst manufactures and consumer organisations indicate that expected lifetime is 10-12 years. To better define

[32] Confidential

the lifetime Weibull distribution of HPC, information regarding the failure rate were considered.

More specifically, according to a survey performed by 'Which?[33]' among their members who owned an HPC (sample size of 2,277); the faults in the first nine year was identified as follows:

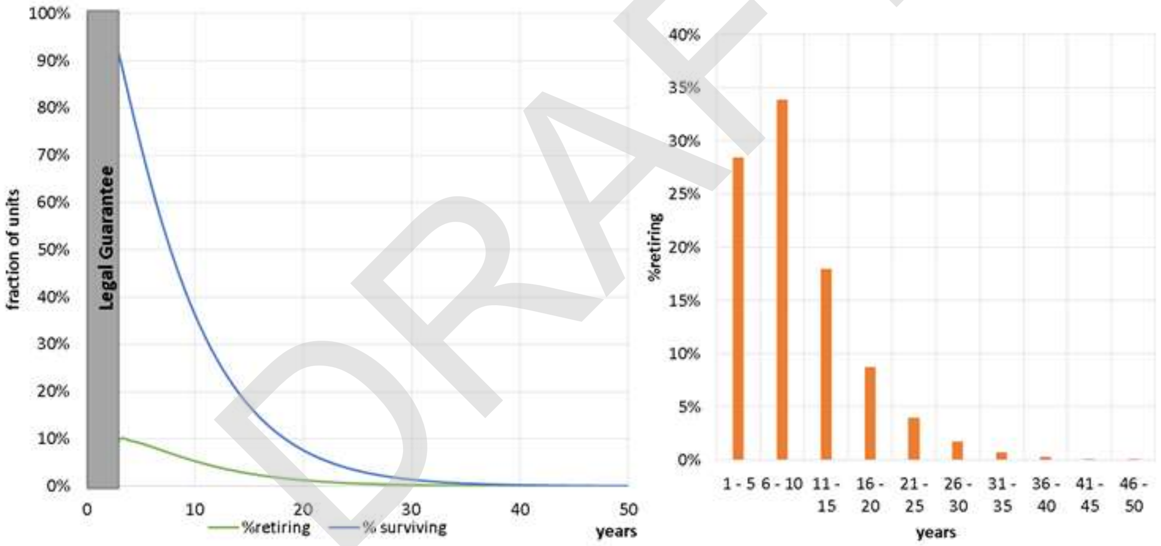
- Faults after the 1st year at the level of 3% (covered by the legal guarantee)
- Faults after the 3rd year at the level of 9%

Feeding these information (average lifetime to be around 10 years with faults the first years) in the EcoModelling tool[34]; a HPC specific lifetime Weibull distribution is produced and presented in

Figure 5. For domestic HPC, 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 % retrieving HPC for the 50 years period per 5-years periods.

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



2.2.1.3 In use stocks at EU28 level and WEEE generated*

Based on the estimated sales for the period 1997-2050 in combination with the lifetime Weibull distribution (presented in

Figure 5) as defined for the case of domestic HPC and described in the above section; the stock in domestic HPC at EU28 level was calculated for the same period utilising the JRC EcoModelling tool[4].

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

[34] This tool commissioned by the DG JRC has the objective to facilitate the development of studies in support of EU Environment and Sustainability policies. It includes a bottom-up stock and cash flow model that provides quantitative information underpinning product policy impact assessment (IA). The policy areas of potential use of the model are ecodesign, energy label, ecolabel, green public procurement (GPP), extended product responsibility and product end-of-life policy.

Figure 6 presents the in-use stock of domestic HPC at EU-28 indicating the survival units (the units that survive each year) together with the new sales. For the year of 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** at 2050.

The units for each year that fail (based on the Weibull lifetime) were considered as Waste Electronic and Electrical Equipment (WEEE). Domestic HPC have very low reparability potentials (1-5% of them are repairable according to stakeholders), thus, a second lifetime was not considered and instead failed units end as WEEE stream.

Figure 7 presents the estimated WEEE fraction per year at EU-28 level for the domestic HPC. 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 at 2030** and **5.4 million units** per year at 2050.

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

Figure 6. Estimated 'Survival' and 'New Sales' of domestic HPC units at EU28 level.

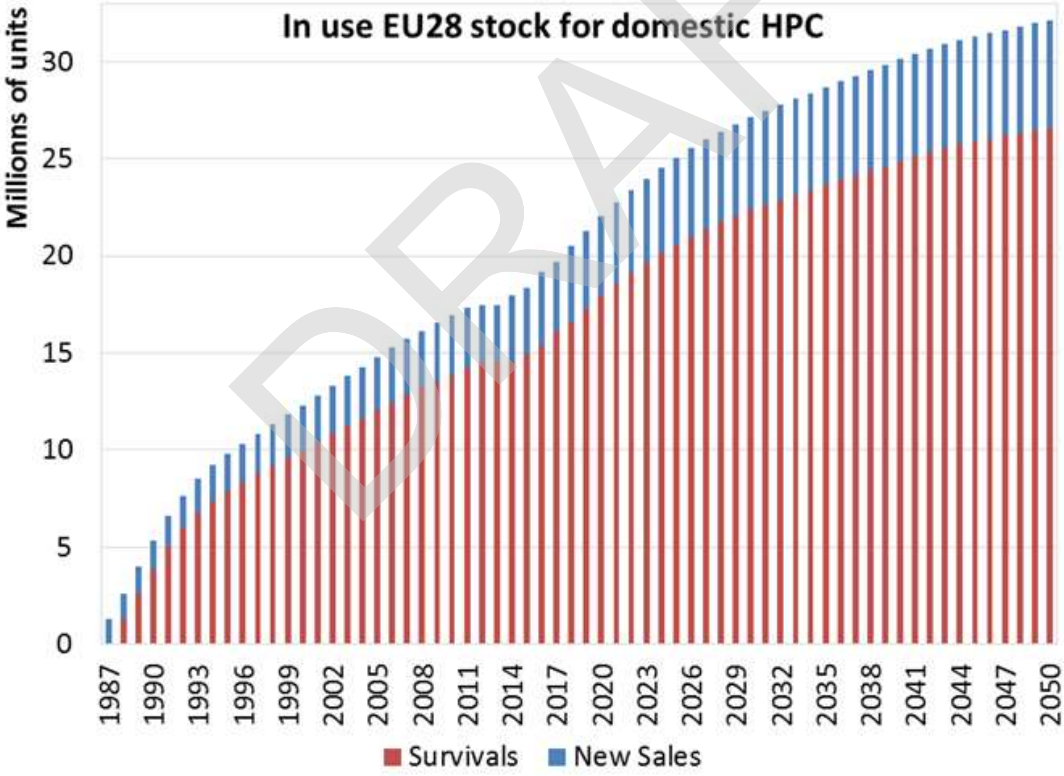
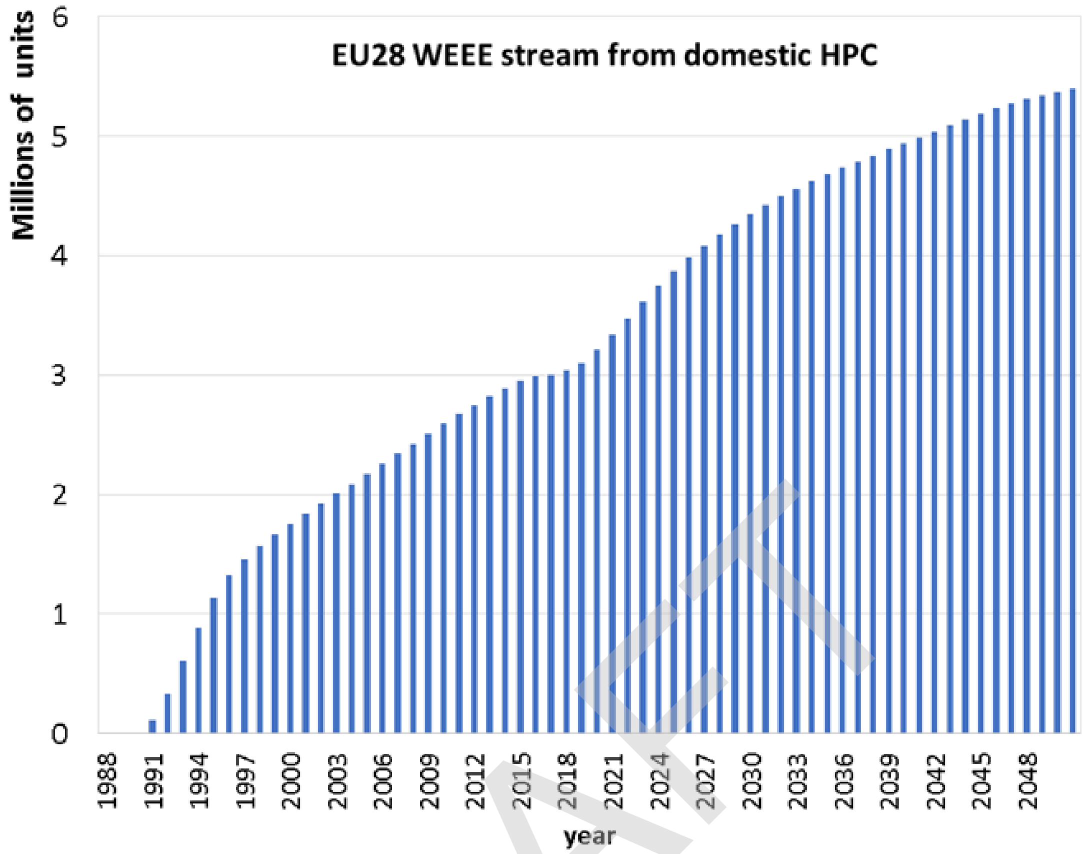


Figure 7. Estimated WEEE fraction generated by domestic HPC at EU28 level.



2.2.1.4 Market penetration of domestic HPC at EU28 level

Figure 8 presents the market penetration rates (%) of domestic HPC at EU28 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 EU28 households. In 2017, 8.3% of EU28 households have a domestic HPC in use. Within a 9 years 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 HPC will not be extended, it is not expected that the EU market will saturate until 2050. However, the estimated market penetration rate is a EU28 average, it is expected that among the EU28 countries there are significant variations as the purchase power, the number of households and the climatic conditions (impacting the needs of an HPC) differ from country to country. Countries as Belgium for example have much higher penetration rates based on a report from GfK.

Figure 8. Estimated market penetration (%) at EU28 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 HPC

2.2.2.1 Historical sales, projections and market segmentation

Professional HPCs are analysed as a separate market from domestic HPC, 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 were also confirmed and complimented by purchased market data from GfK

.

Figure 9 presents the market segmentation as it is for 2017 for professional HPC. Cold water professional HPC had 78% market share of the professional HPC in 2017. More specifically for the year 2017 cold water electric driven single phase had 56% market share; 3-phase had 16% market share and combustion engine driven had only 3% market share. Hot water professional HPC single phase had 12% share of the professional HPC market; 3-phase (industrial) had 10% market share. Less than 1% of the market (few hundreds of units) is hot water combustion engine driven. In total hot water HPC have a significant market share, 22% of the professional market and need to be analysed separately from cold water.

Figure 9. Market segmentation for professional HPC for 2017.

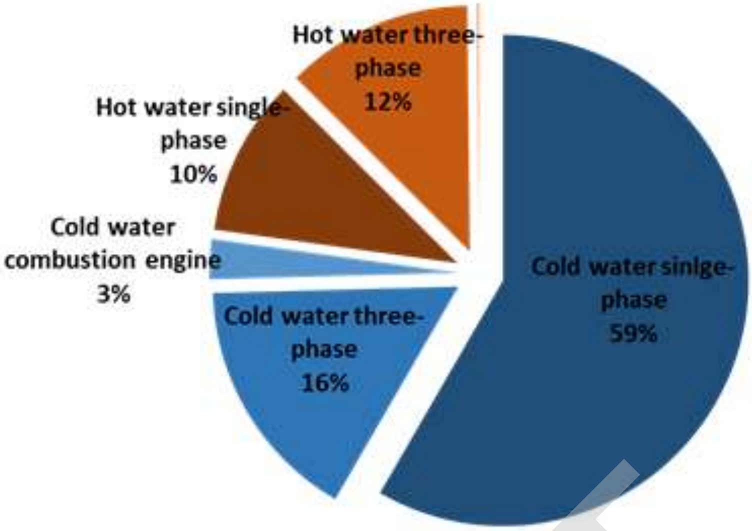
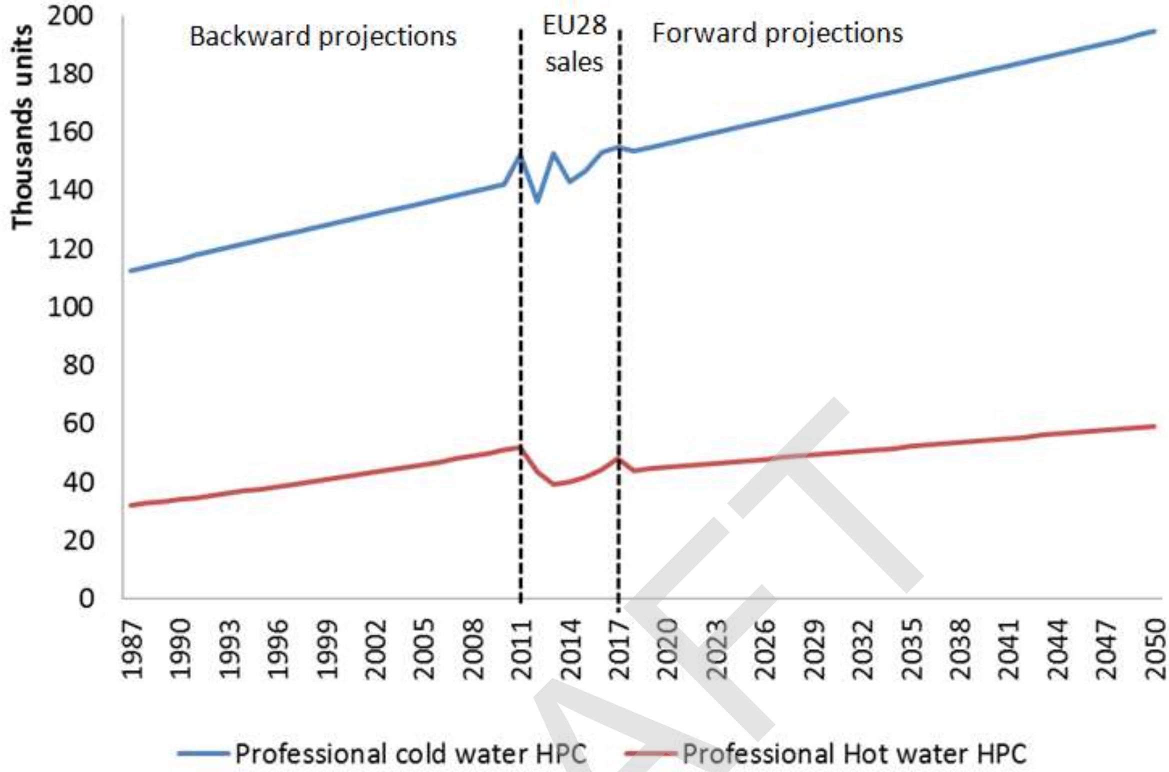


Figure 10 presents the aggregated sales of professional HPC, cold and hot water, for the years of 2011-2017; as well as the backward and forward projection/forecast of the market evolution performed with curve fitting regression analysis. Overall cold and hot water professional HPC sales are at the level of 200 thousands units over the last years; with **203 thousands units** sold in 2017 from which **155 thousands units** was cold water professional HPC and **48 thousands units** was hot water. Hot water professional HPC currently account around 68,000 units sales per year. Cold water HPCs projections show a steady increase for the following years while hot water HPCs shows a slighter increase rate. Cold water professional HPC sales are expected to grow to 269 and 194 thousands unit at 2030 and 2050 respectively. Hot water professional HPC sales are expected to grow to 50 and 59 thousands units at 2030 and 2050 respectively.

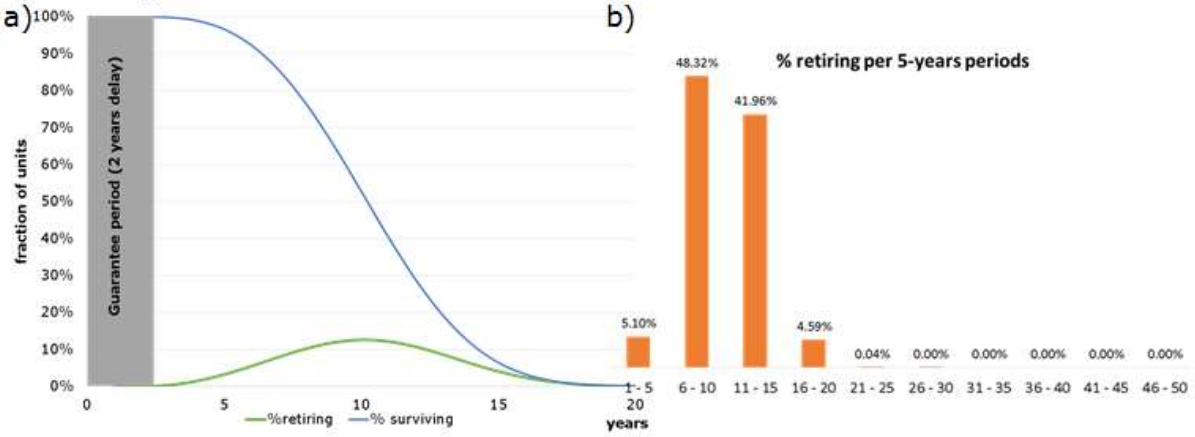
Figure 10. EU28 estimated sales for cold and hot water professional HPC for 2011-2017 along with forward and backward projection covering the period 1997-2050.



2.2.2.2 Lifetime calculations

Input from stakeholders regarding the lifetime of professional HPC indicates that it is at the level of 10 years (or 1500 working hours). Most of the professional HPC are easily repairable, since their components can be removed and repaired, in contrast with the domestic HPC where the repairability potential is much lower. In professional HPC 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 ν=2 (associated with the minimum guarantee). The average lifetime (Weibull) is calculated as 10.30 years. Figure 11 also presents the % retiring HPCs for the 50 years period per 5-years periods.

Figure 11. The professional HPC Weibull lifetime distribution with information on the % of retiring product and the % of survivals.



2.2.2.3 In-use stock and WEEE calculations

The stock analysis has been done separately for professional HPC cold water and for professional hot water HPCs in the EcoModelling tool 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 and Figure 13 present the estimated in-use stock (composed each year by the 'survival' units and the 'new sales') for the period 1997-2050 at EU28 level for cold and hot water respectively.

Figure 12. Estimated 'Survival' & 'New Sales' in-use stocks of cold water professional HPC at EU28

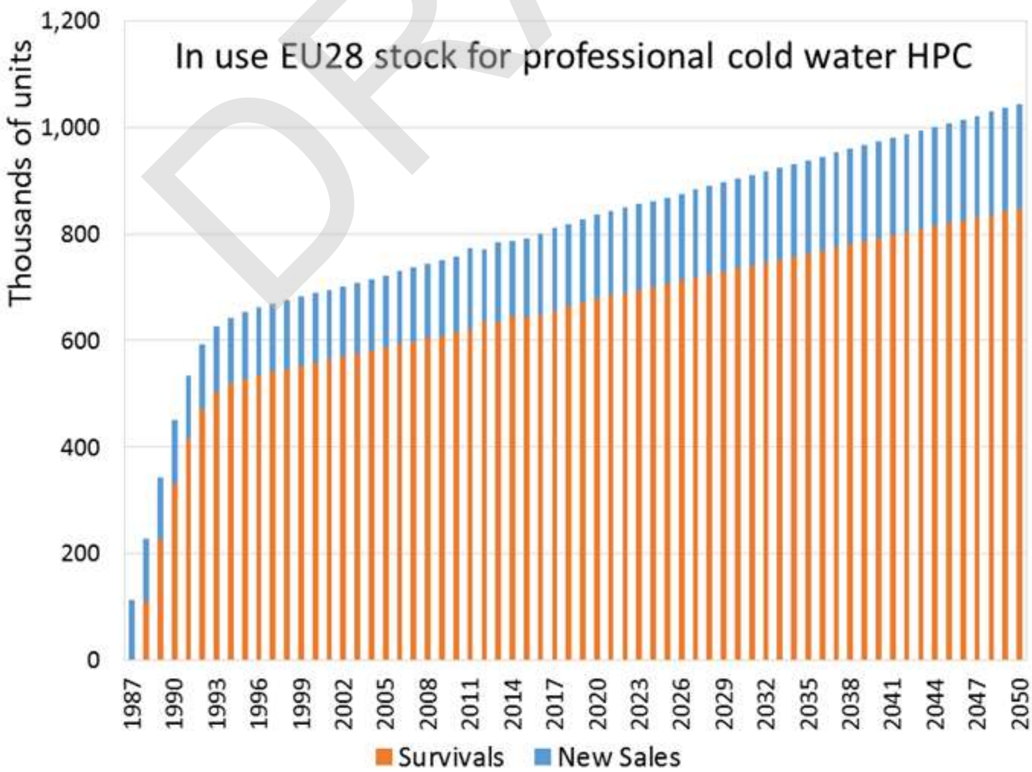
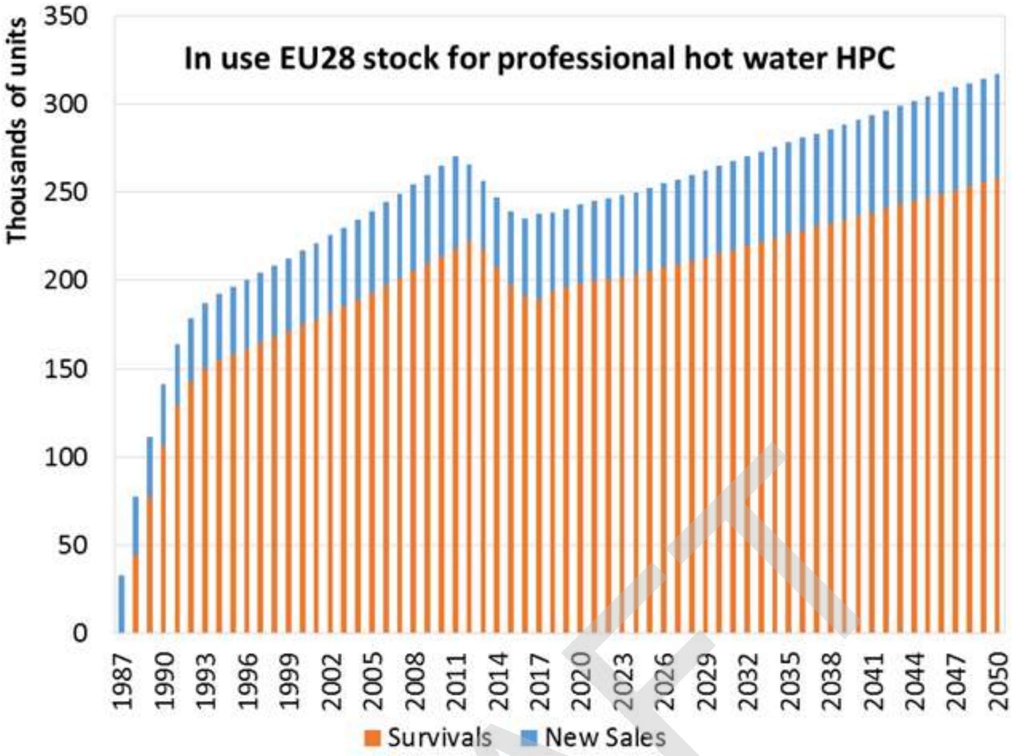


Figure 13. Estimated 'Survival' & 'New Sales' in-use stocks of hot water professional HPC at EU28



In 2017, cold water professional HPCs accounted for 656 thousands units as 'survivals' and 155 thousands units as new sales, in total **811 thousands unit** in-use stock. The in use stocks is expected to increase to **904 and 1042 thousands units** for 2030 and 2050 respectively.

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

2.3 Market trends

This section will present the analysis of the main market trends and evolution of the main HPC characteristic, both domestic as well as professional, for a 10 years period (2007-2017) based on the market data gathered.

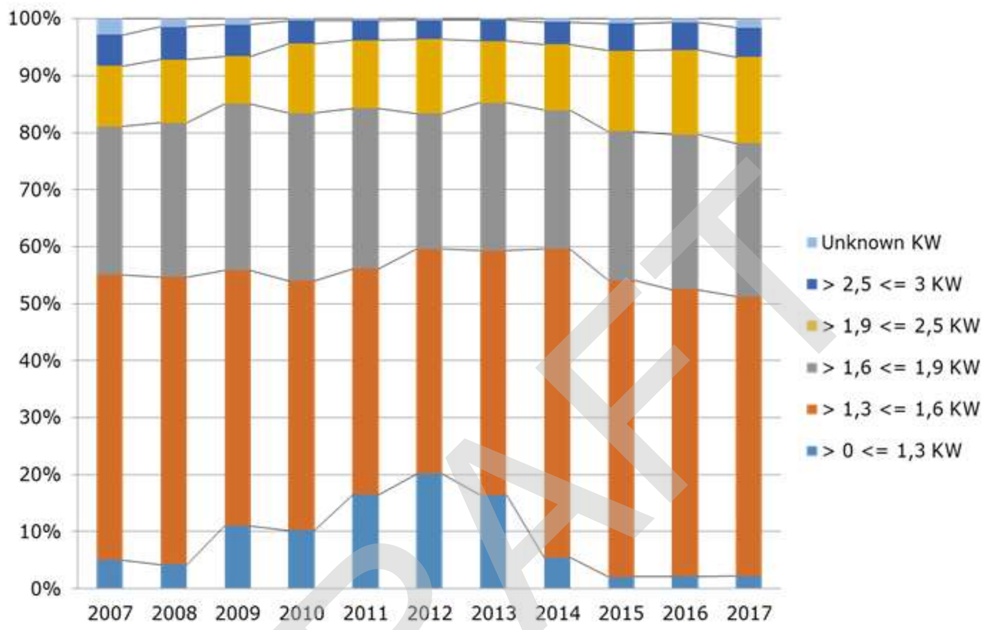
2.3.1 Input power (for domestic HPC)

The input power is a main performance characteristic of HPC equipment as described also in Task 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 made:

- A general trend is that the domestic HPC market slightly moves to more powerful units.
- Main power category is the >1.3 and <=1.6 kW with a market share at the level of 50% in 2017; followed by the >1.6 and <=1.9 kW with nearly 30% market share in 2017.

- The low power units <= 1.3 kW) represents the smallest fraction, with decrease the last years. This market share was absorbed in the higher power categories.
- Upper input power for domestic HPC is defined as 3.3 kW (3.3 kW is the typical limit for single phase 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.

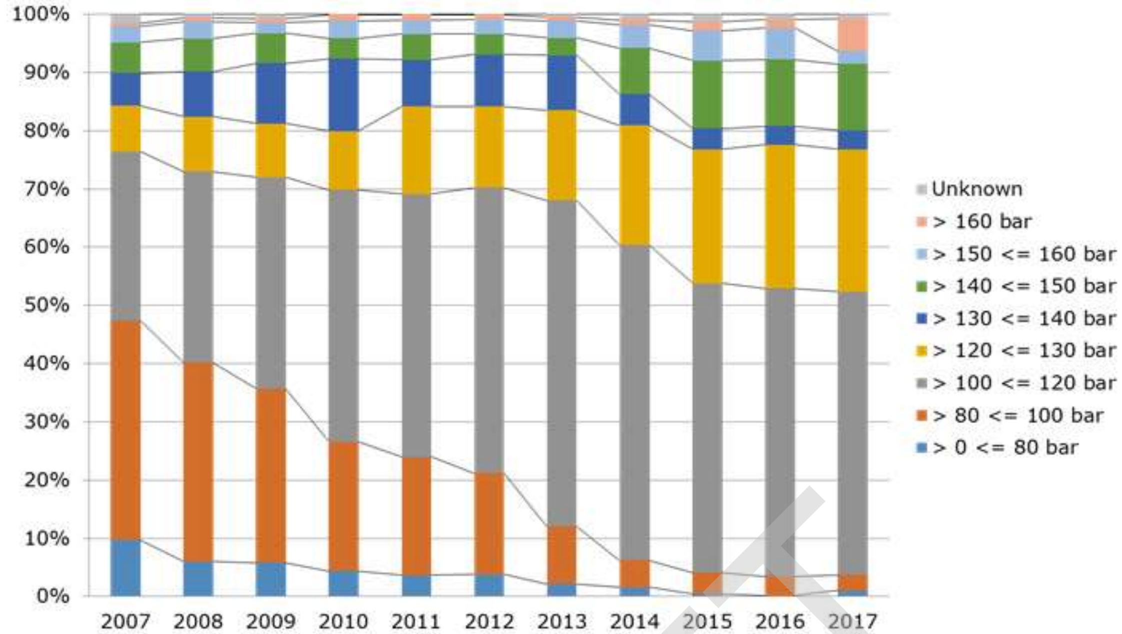
Figure 14. Market share % of input power categories for domestic HPCs for the years 2007-2017.



2.3.2 Maximum water pressure

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

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



The following conclusions can be made:

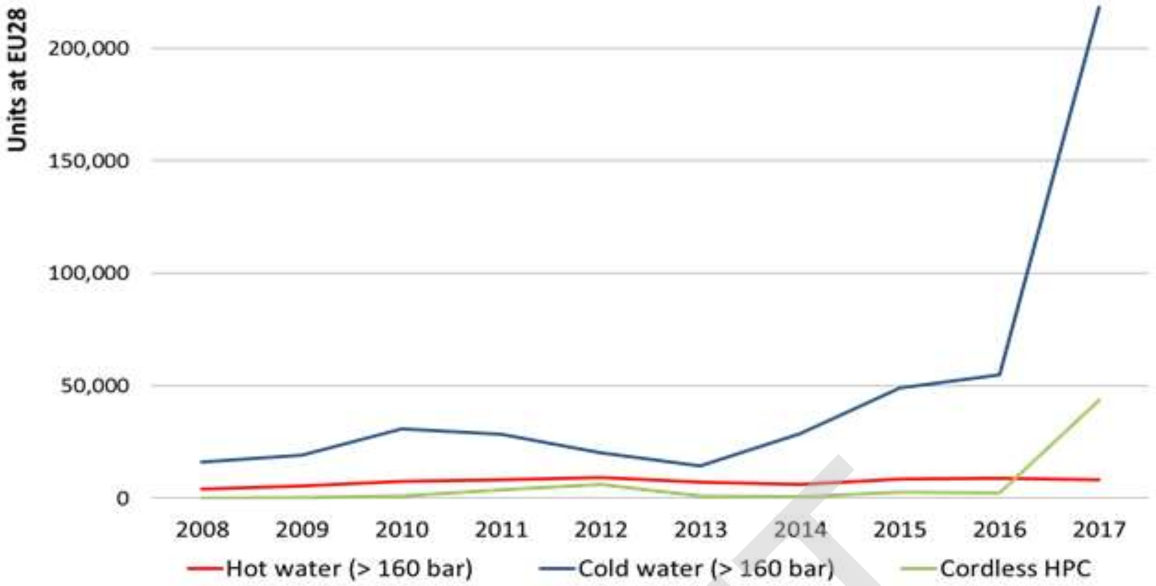
- The maximum pressure over the last years has generally increased.
- The categories <=80 bar was representing nearly 50% of the market at 2007, but over the following years, this share was decreasing and absorbed in more powerful categories until 2017 where their market share dropped significantly to less than 5%.
- The category >100 bar and <= 120 bar currently has the largest market share (around 55%) representing the low performance domestic HPC. The category >120 <=130 bar has the second largest market share the last years (around 25% in 2017) and around 10% is the market share of the >140<=150 bar.
- The category > 160 bar in 2017 had around 8% of market share. 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 160 bar maximum pressure and cordless HPCs

As observed in the previous section, over the last 5 years HPCs with maximum water pressure >160 bar (or 16 MPa) increased significantly their market share from 1-2% to 8% in 2017. Focusing more on this category (>160 bar), this increase can be attributed also to cold water professional and domestic HPC increase in sales, as can be seen at Figure 2.12. The sales information confirms that HPC capable of maximum water pressure >160 bar were at the level of 230,000 unit in 2017. Hot water HPC with maximum water pressure >160 bar is stable over the last years at the level of 7-9 thousand units.

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

Figure 16. Unit sales for the period 2008-2017, hot and cold water HPCs capable of maximum water pressure above 160 bar as well as the sales of cordless HPC of low water pressure.



2.3.4 Price trends

Please see for more information regarding the trend on prices on the following Section 2.4.1.

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). These data will be an 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, is assessed in Task 5.

2.4.1 Average unit values of HPCs produced in EU28

The average unit prices of HPCs highly varieties 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:

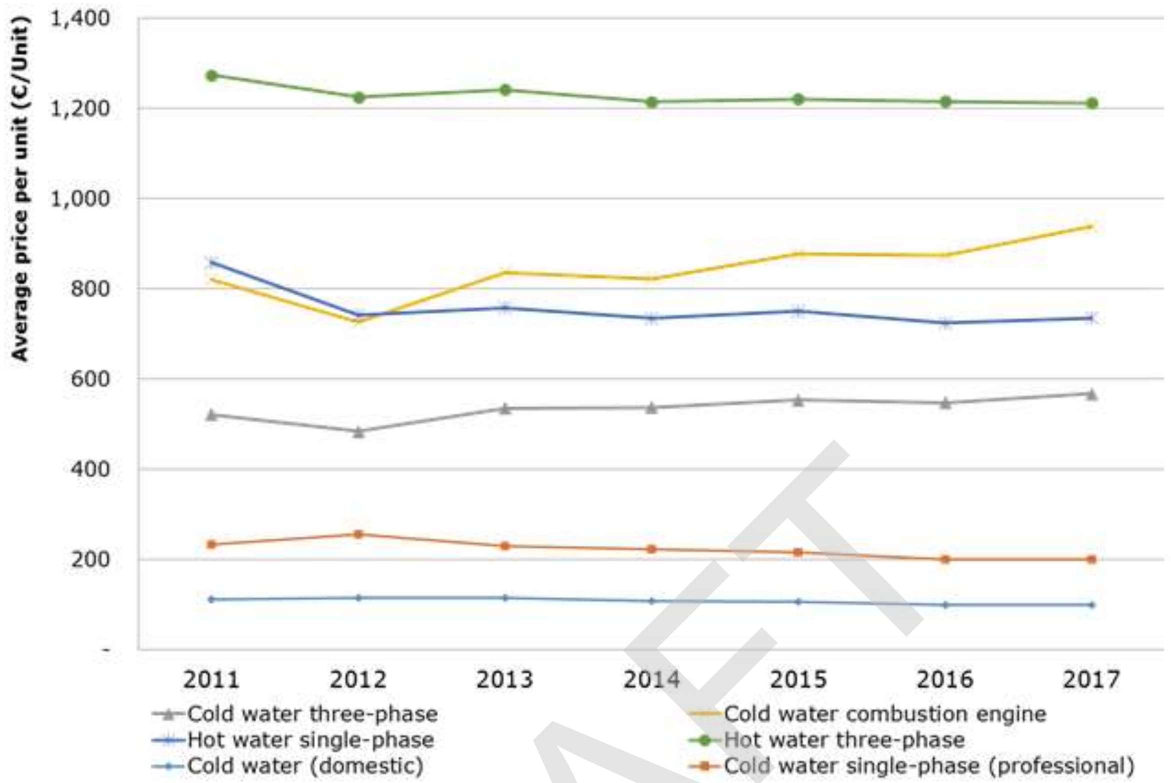
- Cold water single phase (domestic use)
- Cold water single phase (professional use)
- Cold water three-phase (professional use)
- Cold water with combustion engine (professional use)
- Hot water single phase (professional use)
- Hot water three-phase (industrial or semi-industrial use)
- Hot water with combustion engine (professional use)

Figure 17 presents the price evolution for the years of 2011-2017 based on stakeholders' inputs and commercial market report for the above categories. Hot water HPCs with combustion engine have much higher average price/unit compared to the rest of categories, at the level 6,000 EUR/unit. 2017 has been used as reference year for the average prices, all prices are converted to 2017 prices. For better illustrating the price evolution of the rest of the HPC categories, the average unit prices of hot water HPC with combustion engine 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 600 million EUR.
- The overall value of the professional HPC EU market for 2017 has been estimated at 120-140 million EUR.
- Combustion engine driven hot water HPC is a niche product (with average price per unit at the level of 6,000 EUR per unit).
- Single phase professional cold water HPCs have around double the average price per unit of the domestic cold water HPC units.
- The average HPC prices are relative constant with no large changes, apart from the combustion engine cold water HPCs which show increasing price trend over the last years.

The average prices are not overlapping, as they are discrete for each HPC category. The second and third most expensive HPC categories are the hot water HPC (3-phase) and the cold water combustion engine HPC, respectively. The average prices are relative stable the last years, with a small increasing trend for the cold water HPC with combustion engine, and the cold water 3-phase professional HPC.

Figure 17. Average price per unit historical evolution & forecasts per HPC sub-category.



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[35]. Table 12 displays this information for the different types and formats of detergents identified.

[35] 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

Table 12. Retail prices of detergents (incl. VAT) in Spain 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
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 EU, at national and regional levels, and it is subject to very diverse taxation[36]. 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[37], which provides the prices referred to the year 2013. 2017 prices have been calculated using the inflation rates mentioned in the next section. Both 2013 and 2017 prices are shown in Table 13.

[36] https://www.eea.europa.eu/data-and-maps/indicators/water-prices

[37] https://ec.europa.eu/clima/policies/strategies/analysis/models_en#PRIMES

Table 13. Annual prices of energy products

	2013 END USER PRICE (in c€/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
	2017 END USER PRICE (in c€/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 c€/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
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
	2017 END USER PRICE (in c€/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 will be made with 2017 as base year, as this is the latest year for which complete data is available. Inflation rates from Eurostat[38] (see Annex 4) will be applied to scale purchase price, electricity prices etc. to 2017-prices. A discount rate of 4% will be used in accordance with the MEErP methodology.

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. As a starting point, it is assumed that the installation cost can be equivalent to the installation of a compressor. According to

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

the preparatory study on Low pressure & Oil-free Compressor Packages[39], the installation cost of a compressor is proportional to its power and can be estimated applying the following Equation 5.

Equation 5: Installation costs [EUR] = 10*Input power [kW] + 800

As this is just a very rough and uncertain estimate, it will need to be confirmed or, otherwise corrected by the stakeholders.

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 get defective
- Bearings of the pump get defective
- Leakages

These failures are not repairable without breaking the housing; hence, they cause the end of life of the product. Retailers offer several spare parts for domestic HPCs, meaning that they may require a replacement along the lifetime of the product. However, the failure rates of these parts have not been evaluated in the endurance tests covered by this study. The user guides provided by manufacturers recommend the cleaning of the filter in the water connection and the nozzle, which suggest they may be damaged. An internet search shows the retail prices of the spare parts, gathered in Table 14[40].

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

[39] VHK, 2017. Preparatory study on Low pressure & Oil-free Compressor Packages (http://www.eco-compressors.eu/downloads/FINAL_REPORT_LOT31_LP-OF_20170607.pdf)
[40] https://www.fiyo.es/hidrolimpiadora; https://www.erepuestos.es/hidrolimpiadora/catalogue.pl?path=984134

In the case of professional high pressure cleaners, manufacturers indicated that the pump is the crucial component that requires more maintenance. A search in internet shows that there are retailers specialised offering pumps and repair kits with the spare parts that are needed more frequently. The prices of the sample collected in this study[41] are displayed in Table 15.

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

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

If the repair or maintenance requires a professional service, the average EU average 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 relate to total average hourly labour costs[42].

Table 16. Average total labour costs for repair services in euro per hour.

Year	2000	2004	2008	2012	2013	2014	2015	2016
EU28 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 HPC are covered by the WEEE Directive and producers are responsible for paying a WEEE tax or in some other way finance the EOL treatment, it is assumed that end-users will not experience any further EOL costs. The WEEE tax paid by manufacturers is assumed to be reflected in the sales prices of vacuum cleaners to end-users. In the end-user life cycle cost calculations, EOL cost will therefore be set to zero.

[41] https://www.accesoriosaltapresionagm.com/ accessed 27 August 2018

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

2.5 Recommendations

2.5.1 Refined product scope from the economical / commercial perspective

Hot water combustion engine HPCs are very expensive and niche products (average price per unit at the level of 6,000 euros), which is also reflected in the low sales volumes at the level of few hundred units at EU28. Cold water combustion engine HPCs account only 3% of the professional HPC market. Hot water domestic units do not reach sales to have an apparent representation in the market.

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

Barriers:

- There seem to be a trend towards the increase of power and water pressure of domestic products. This means that the demand of 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 have no concerns about the environmental performance of high pressure cleaners, and it even may be regarded 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 characteristic with a variety of cleaning activities.

Opportunities:

- Extending the lifetime and/or the repairability potentials of domestic HPCs can have significant positive effects that will be examined in the following tasks.
- While this product is far from being ubiquitous like e.g. washing machines, the penetration rate shows a clear increasing tendency. 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.

3 USERS

3.1 Introduction

3.1.1 Scope of the task

The scope of Task 3 is to analyse and report the consumer behaviour for use of high pressure cleaners (HPC) 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 report of:

- System aspects use phase, for ErP with direct energy consumption effect
- System aspects use phase, for ErP with indirect energy consumption effect
- End-of-life behaviour regarding life, repair, maintenance, disposal, recycling, reuse etc.
- Local infra-structure 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 at 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, was received anonymised test data 32 HPCs provided by the team member Intertek and was used 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 these data, the study team collected technical specifications data of domestic and professional HPCs from public web sites of 5 major manufacturers (Kärcher, Nilfisk, Bosch, Stihl and IPC), totally 160 models.
All these data are the main data source for the use phase analyses in Task 3 and Task 4 sections.

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

High pressure cleaners have direct energy consumption effect 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 effect is also relevant to include, see next section. In addition to energy, the HPCs also use water, cold or hot, for the cleaning, and in some cases also detergent assisting in the cleaning process.

The purpose of this sub-task is to collect and analyse data that are relevant for the 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 in which amount are the various cleaning tasks needed, which result 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. E.g. if the HPC is suited for car cleaning, it would be used more often and if it is cleaning more efficiently, the usage time would be decreased assuming the cleaning tasks constant.
- Time in idle, standby and off modes (dependent on type of HPC) i.e. how much 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, caravans and generally removing dirt.

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

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

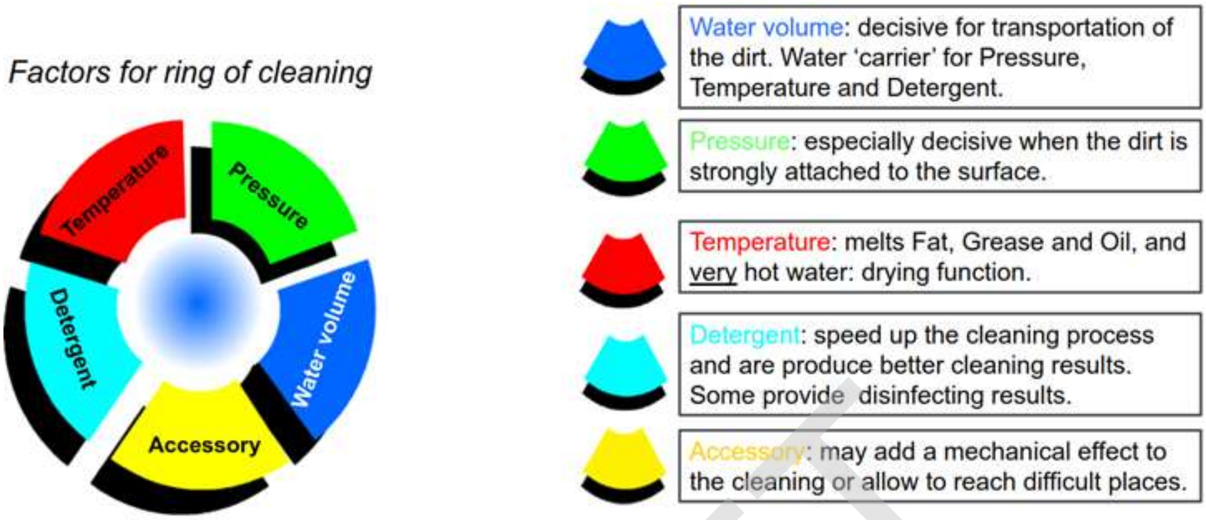
For some cleaning tasks special nozzles and attachments should be used. More information is gathered in Task 4 section.

The cleaning performance depends on several parameters, mainly:

- 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: Higher volume is needed for transporting the dirt away from the area to be cleaned
- Water pressure: 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 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 type subject to be cleaned

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

Figure 18. Cycle with the basic factor 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 hot water HPC), detergent dosage and possible accessory.

3.2.2 Frequency and time of use

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

Table 17: Stakeholder information on usage patterns.

Type of HPC	Stakeholder 1	Stakeholder 2	Stakeholder 3	Stakeholder 4
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 h per 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

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

As observed in table, there is an apparent gap between the stakeholders replies, ranging from 2 - 8 hours per year, and up to 50 hours per year. It is assumed that the largest values include the time that the HPC is idle during its usage. The energy consumed at idle mode is negligible, and therefore, the lowest ranges of the figures provided by the stakeholders are considered in this study.

Based on above figures, the study team established the assumptions of active annual use for domestic and professional HPCs presented in Table 18. Due to the uncertainty in the assumptions – which will influence considerably the following analyses – we provide a range of usage times and the average, which will be used in all the analyses in this report.

The battery driven cold water domestic HPCs left out because they are for special purposes and we assume that the usage time would be very low. Furthermore, the battery HPC constituted less than 1% of total sales in 2017.

Stationary cleaners are used for a variety of purposes in agriculture, industry, shipping and the food industry with very different usage pattern. Neither information, nor data were received on the usage. The study team has assumed the same usage pattern as for professional HPC, however, we have additionally added a car washer stationary HPC as a special case of cold water stationary HPC and where the usage is stated as number of cars cleaned per year.

Table 18. Assumptions of annual hours of active use and of cars washed per year.

Type of HPC	Annual usage Range and average, hours/year
Domestic HPC	2-8, average: 5
Professional HPC	100-200, average: 150
Stationary HPC	100-200, average: 150
Car washer stationary HPC	2000-8000, average 5000 cars / year

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.

These two usage situations are described in the following. The water heating technology is detailed in Task 4 section.

3.2.3.1 Use of hot water internally heated

When cleaning tasks require hot water, the solution would most often be an HPC with a hot water heater built in. In our data set of marketed products, there is only 1 hot water HPC, which is characterized by the manufacturer as domestic (i.e. "DIY and gardening").

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 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 uses. 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 hot water externally heated

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 and often the plastic components used on 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 buildings' hot sanitary water system. In our data set of products on the market, 90% of all products (160 totally) allow water supply of 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 of 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 in use of 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 usually does not take place. Apart from expert opinions, no data were available. The study team has estimated a relatively low share of use of hot water externally heated, namely 5%.

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 (%) 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)	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

Aim and precautions

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

Dosage systems and size

Task 4 section describes details of the dosage 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.

40 of the 160 HPCs in the dataset of marketed HPCs informed about the maximum detergent dosage in litres/min. With this figure, we calculated maximum dosage as % of 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 the maximum dosages for them was 20% lower than for the professional HPCs, but having only 4 data points for domestic, the sample is too low to use this figure for all domestic HPCs. Based on this we use 5.5% of as average maximum dosage. We assume furthermore that when detergent is needed for a particular cleaning task, maximum dosage is added due to the imprecise regulation.

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 for universal type of cleaning and specialised for cleaning specific materials such wood or natural stone, vehicles exterior, grease removal, paint removals (e.g. for graffiti) disinfecting 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.

3.2.5.1 Energy consumption

The HPCs consumes energy for the motor and control systems and in 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 sub-category in this section.
- Fuel (combustion) motor
- Fuel (combustion) motor and fuel heater

I.e. for the electric motors, the energy consumed may be both electricity and fuel, while for the combustion motors, only fuel is consumed. The battery HPCs are left out as previously described due assumption of low usage time and due to low sales.

Only consumption during active use is included, i.e. energy consumption in off and standby modes and an on-idle mode is not included. For domestic HPCs, laboratory test data that have been provided by a stakeholder show no energy consumption in off mode and in on with spray off. All had a 'deadman' trigger switch, i.e. when leaving the handle un-pressed, the HPC is not spraying and not working. The professional types would also have such a function, though some machines would still be 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 the Task 4 section.

In Table 21 and Table 22, we present the calculated annual use phase energy consumption for an average model in each category with electric motor and combustion motor, respectively. After the tables, the assumptions and the calculations are shown.

Table 21. Calculated use phase annual energy consumption 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	
Domestic hot water	1.8	2-8, average: 5 (50% with hot water)	4-14, average: 9	30-118, average: 74
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
Car washer stationary HPC	13.9	2000-8000, average 5000 cars / year	745-2980, average: 1863	

Assumptions and calculations:

- Average load motor: The load is calculated from the maximum connected load (nameplate power, for HPCs with electric heater, the heat load is subtracted) reduced with 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 actual power load was measured at maximum working pressure.
- Annual hours of use: Assumptions presented in Table 18.
- Annual electricity consumption: Multiplication of average load and annual hours of use. For the electric heater HPC, the figure is corrected for only 50% hot water use, see Table 19.
- Annual fuel consumption: It is calculated using the full load heating oil consumption (kg/h) from the dataset, multiplied with 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[43]).

Table 22. Calculated use phase annual energy consumption for the range of annual usage and average model in each category with 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 litre/hour petrol for delivering 5.1 kW (continuous rated power) at max rpm corresponding to 0.3486 kg/h/kW. Only data for petrol motor is used because 8 of 11 combustion motor HPCs are petrol types.
- Fuel consumption heating: From the dataset of products on the market
- Annual hours of use: Assumptions presented in Table 18.
- Annual fuel consumption: It is calculated with the sum of motor fuel consumption multiplied with annual hours of use plus fuel (gas oil) consumption heating (kg/h) from the dataset, multiplied with 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]).

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

3.2.5.2 Water consumption

The calculated annual water consumption in the use phase for an average model in each category is shown in Table 23. After the table, the assumptions and the calculations are shown.

Table 23. Calculated use phase annual water consumption 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
Domestic hot water	450	2-8, average: 5	1-3, average: 2
Professional cold water 1-phase	540	100-200, average: 150	54-108, average: 81
Professional cold water 3-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 1-phase	463	100-200, average: 150	46-93, average: 69
Professional hot water 3-phase	969	100-200, average: 150	97-194, average: 145
Professional hot water 3-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
Car washer stationary HPC	68 l/car	2000-8000, average 5000 cars/year	136-544, average: 340

Assumptions and calculations:

- Average in-use water flow: Base on dataset of marketed HPCs combined with the dataset from laboratory tests of domestic HPCs. These tests show:
  - Average of rated maximum flow (l/h) of all products: 429 l/h
  - Average of in-use maximum water flow with standard nozzle: 375 l/h

The in-use maximum water flow is 13 % lower than 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 lack of specific data for the other categories. This figure is used to calculate the in-use water flow based on the average of rated maximum flow (l/h) from the dataset of marketed HPCs.

- For the car washer data is from a study of a Spanish gas station with a car washing facility[44].
- Annual hours of use: From Table 18
- Annual water consumption: The water flow per hour is multiplied with the annual hours of use per year

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 removals. This organisation also states that an HPC in general use more detergent than needed due to poor regulation of amount added and that in many areas it is forbidden to clean car 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 is shown in Table 24. After the table, the assumptions and the calculations are shown.

These figures are of course very general approximates and input from the industry and other stakeholders are sought for.

Table 24. Calculated use phase annual detergent consumption 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	20	8-34, average: 21
Domestic hot water	1-3, average: 2	10	4-17, average: 11
Professional cold water 1-phase	54-108, average: 81	10	297-594, average: 446
Professional cold water 3-phase	99-198, average: 149	10	545-1091, average: 818
Professional cold water combustion engine	69-137, average: 103	10	378-756, average: 567

[44] LIFE11 ENV/ES/000569. Acción A5. Parte 2 – Estudio de consumos de agua en la Estación de Servicio de Miramón, San Sebastián (País Vasco). June 2014.

Professional hot water 1-phase	46-93, average: 69	10	254-509, average: 382
Professional hot water 3-phase	97-194, average: 145	10	533-1066, average: 800
Professional hot water 3-phase, electric heater	65-129, average: 97	10	355-711, average: 533
Professional hot water combustion engine	71-141, average: 106	10	388-776, average: 582
Stationary cold water	253-506, average: 379	10	1391-2781, average: 2086
Stationary hot water	89-178, average: 133	10	489-978, average: 733
Car washer stationary HPC	136-544, average: 340	100	2244-8976, average: 5610

Assumptions and calculations:

- Annual water consumption: From Table 23
- Proportion using detergent: We have assumed that domestic users use detergent for cleaning of cars, motor bikes and bikes and that about one third of the usage is car, motor bike and bike cleaning and that two thirds of this specific use is with added detergent, i.e. totally 20% of all pressurized water is with added detergent. Domestic hot water units are assumed to consume half detergents than cold water. For professional users, we have assumed that they use detergent for all kind of vehicles and for a variety of other specific cleaning tasks such as disinfection in food processing and graffiti removals and we assume that about 10 % of all cleaning tasks are with added detergent. For car washers we assume that 30% of the total water consumption is with added detergent.
- Annual detergent consumption: The annual water consumption is multiplied with the proportion using detergent and with the average dosage (5.5% as indicated in Section 3.2.4.2)

3.3 System aspects 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 this section calculated the energy consumption effect.

According to the preparatory study for eco-design of water heaters[45] an assumption for the energy calculations is a temperature of cold water supply 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[46]:

- 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 25. After the table, the assumptions and the calculations are shown.

Table 25. Calculated use phase annual energy consumption for externally heated hot water 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 consump-tion Range and average m^3/year	Natural gas consump-tion Range and average kWh/year	Electricity consump-tion Range and average kWh/year
Domestic cold water HPC	1-3, average: 2	5	0.038-0.153, average: 0.096	2-7, average: 4	1-4, average: 2
Professional cold water 1-phase	54-108, average: 81	5	2.701-5.402, average: 4.052	118-236, average: 177	63-126, average: 94
Professional cold water 3-phase	99-198, average: 149	5	4.958-9.915, average: 7.436	216-432, average: 324	115-231, average: 173

Assumptions and calculations:

- Annual water consumption: From Table 23
- Proportion of hot water externally heated: From Table 19
- Annual heated water consumption: Annual water consumption multiplied with proportion of hot water externally heated.
- Natural gas consumption: Calculated as heating the water 50 °C with 80% (referred to net calorific values) boiler efficiency multiplied with 60% (proportion for natural gas, see above).

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

- Electricity consumption: Calculated as heating the water 50 °C with 100% efficiency multiplied with 40% (proportion for electricity, see above).

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 to be used by the HPC. The amount of water to be disposed is less than the water supplied because not all water used will go into the sewage system but be soaked into the ground and soil.

For the purpose of this study, reduction of water consumption will be analysed and reported as 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. See also MEErP p. 66, 3.4 Example shower head or water tap[47].

[47] Methodology for Ecodesign of Energy-related Products. MEErP 2011. Methodology Report. Part 1: Methods.

3.4 Total use phase resource impacts

Table 26 shows the total resource impacts 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 figures are totals of the figures of the previous tables.

Table 26. Total use phase annual electricity, fuel, water and detergent consumption 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	8-34, average: 21
Domestic hot water	4-18, average: 11	30-118, average: 74	1-3, average: 2	4-17, average: 11
Professional cold water 1-phase	356-713, average: 534	118-236, average: 177	54-108, average: 81	297-594, average: 446
Professional cold water 3-phase	882-1764, average: 1323	216-432, average: 324	99-198, average: 149	545-1091, average: 818
Professional cold water combustion engine	0	3457-6914, average: 5185	69-137, average: 103	378-756, average: 567
Professional hot water 1-phase	254-507, average: 380	1801-3603, average: 2702	46-93, average: 69	254-509, average: 382
Professional hot water 3-phase	674-1348, average: 1011	3545-7090, average: 5318	97-194, average: 145	533-1066, average: 800
Professional hot water 3-phase electric heater	1695-3390, average: 2543	0	65-129, average: 97	355-711, average: 533
Professional hot water combustion engine	0	6537-13074, average: 9805	71-141, average: 106	388-776, average: 582

Stationary cold water	1385-2770, average: 2078	0	253-506, average: 379	1391-2781, average: 2086
Stationary hot water	683-1366, average: 1024	3888-7776, average: 5832	89-178, average: 133	489-978, average: 733

3.5 Cleaning performance test methods reflecting typical usages

3.5.1 Opportunities for cleaning performance test methods

As described in Task 1 section, no commonly used cleaning performance test method in the industry exists. Some manufacturers use a test method developed by themselves when designing new products, others just use different kinds of dirty surfaces.

When establishing energy policy measures, it is preferable to base them on efficiency i.e. how much resources (energy, water and detergent) is consumed for a certain amount of cleaning tasks performed. The cleaning tasks in tests should reflect an average use and at the same time be sufficiently simple to run for the test laboratories 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 is simulating 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 vacuum cleaners and define a number of different surfaces with different kind of soils and define a certain cleaning pattern. The resource consumptions for removing the soils should be measured and a method to decide the amount of dirt removed within a given time or to decide the needed time to remove all the dirt.

The surfaces would need to be artificial test surfaces thoroughly defined in order that the tests can be reproducible over 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 is passed over the surface, water pressure, temperature, detergent etc. A time-based element may also be included because users' expectation of cleaning performance would include how fast they can clean surfaces. Furthermore, potential damages to the surface due to too high jet impact should be measured or assessed.

Another and simpler way of assessing the cleaning performance is to measure a potential cleaning performance based on measurement of HPC output parameters such as the system force (the force of the water flow leaving the nozzle), the pump force (the force of the water before nozzle) and the spray pattern (in a certain distance from the nozzle). A combination of these factors into an index would provide an approximation of the cleaning impact the HPC has a capability to achieve.

A third and even more simple way would be to calculate an index based on a few important parameters such as maximum pressure and maximum water flow.

The test methods may also include measurement of the temperature of the water leaving the HPC for the hot water units.

Independently of the test method, the resulting cleaning performance figures or indexes would obviously be very different for a small domestic HPC and a large professional HPC. These differences should be taken into account when preparing possible policy measures such as ecodesign requirements and/or an energy labelling scale e.g by use of well-defined sub-categories with dedicated requirements or by including an energy / cleaning performance index the product sub-category.

3.5.2 Examples of test methods

In the following we describe briefly four different real-life test methods used in tests of HPCs for inspiration. The methods are only briefly described in this section.

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.

Intertek UK

Intertek UK uses defined test surfaces by painted insulation panels with matt black paint (simulating soil) applied in a standardised way so the soil level is consistent. The HPC is fixed in a rig at a defined height to optimise 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. I.e. if a pressure washer was able to clean a large width, this would translate to clearing a large area in a given period of time and in a practical situation would be cleaning 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.

Cleaning performance and durability laboratory tests for domestic HPC

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 pre-defined speed over the panel. The width of the paint removed was measured with two figures: All paint removed and some paint removed. Uniformity of the cleaning was also measured. The test is done with spray nozzle and with 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 dirty pavement recording and assessing time for cleaning, quality of cleaning, water consumption etc. Energy consumption can be calculated through 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 standard nozzle and rotating nozzle for all tests with sufficient and similar cleaning quality according to a qualitative assessment by two experts carrying out the tests.

Figure 19 and Figure 20 show 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.

Figure 19. Water and energy consumption for cleaning 1 m2 pavement with standard nozzle. Average values are 10 l/m2 and 48 Wh/m2.

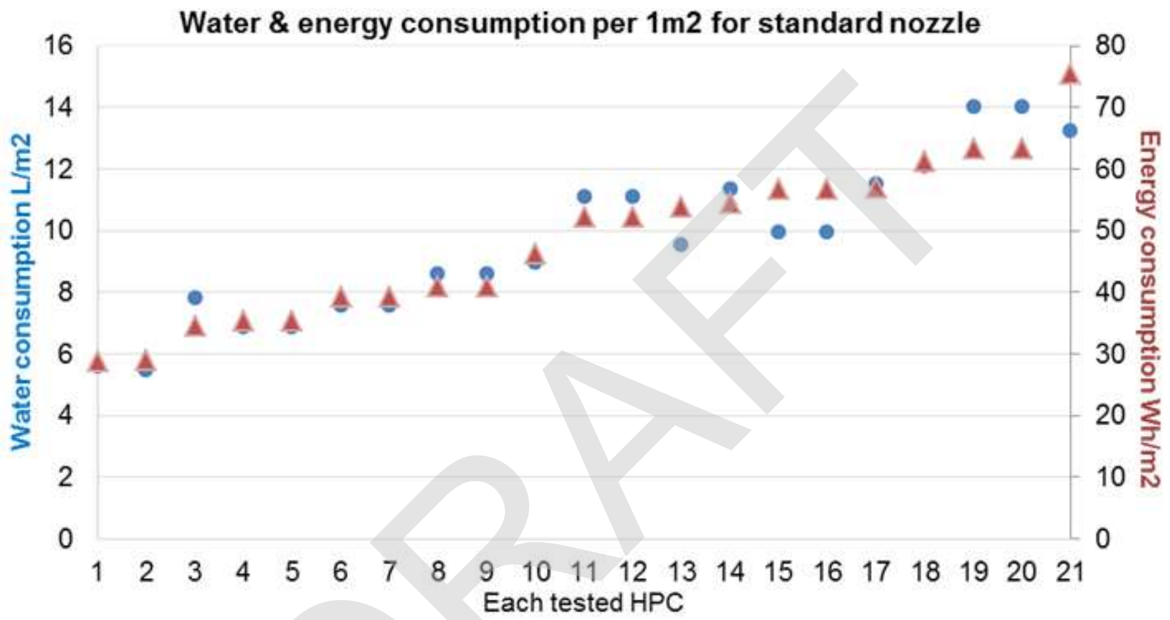
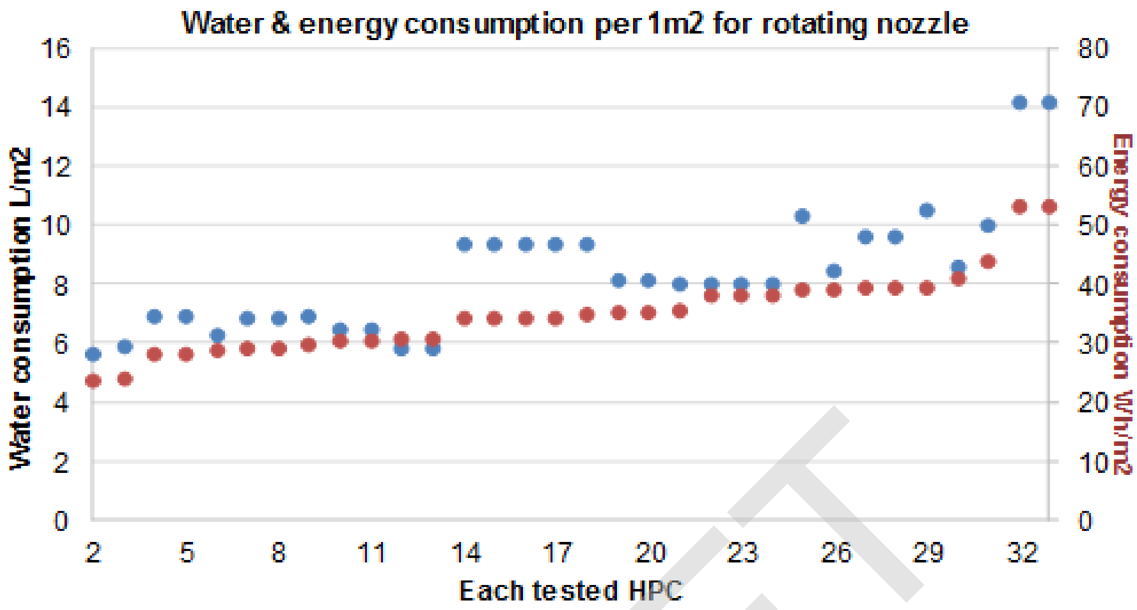


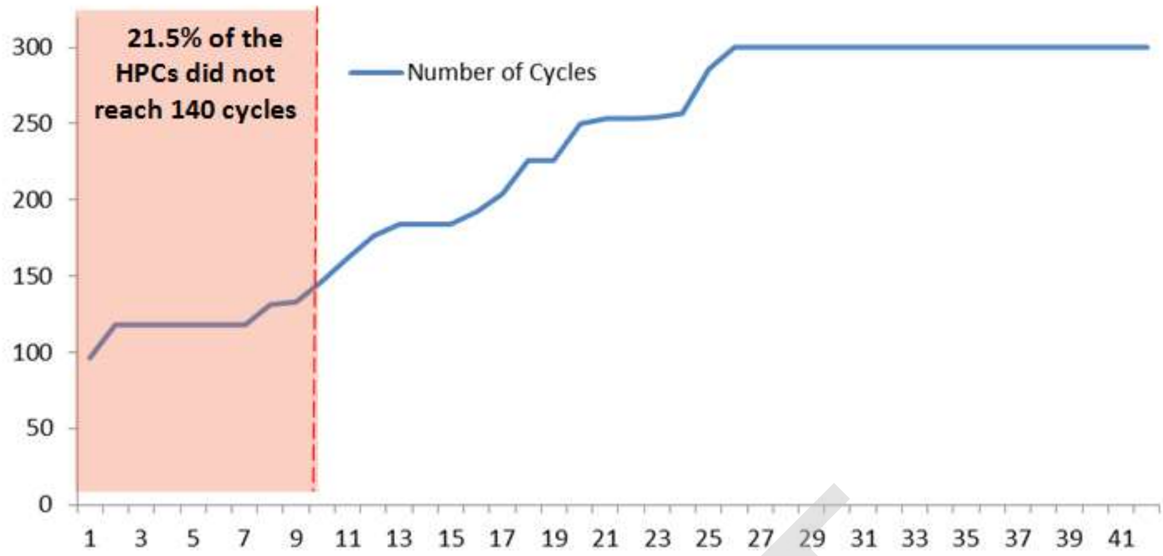
Figure 20. Water and energy consumption for cleaning 1 m2 pavement with rotating nozzle. Averages are 8 l/m2 and 35 Wh/m2.



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 durability tests consisting of 300 cycles, each of them with 40 minutes of duration: 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 and 10 minutes pause. The durability tests are performed with standard as well as with rotating nozzle. As can be seen from Figure 21, not all HPCs survived the 300 cycles, 21.5% even failed prior reaching 140 cycles. This fact indicates the large variation in durability performance of domestic HPCs.

Figure 21. Durability tests of domestic HPCs for 300 cycles.



Which?

Which? (independent UK consumer organisation) regularly test domestic HPCs in relation to their consumer information[48]. Their performance test consists of manual test by experienced testers. They wash 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.[49]

[48] https://www.which.co.uk/reviews/pressure-washers
[49] https://www.which.co.uk/reviews/pressure-washers/article/how-we-test-pressure-washers

3.6 End-of-life behaviour

The user end-of-life behaviour influences substantially 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 is not disposing of the HPC correctly as electrical waste, it will have a negative environmental impact. This is further described in the following.
In Task 2 is described the lifetime used for the modelling, 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 overall life cycle impacts imposed by them. With a longer lifetime the impacts of consumption of raw materials is reduced since the impacts of mining, production, transportation etc. are spread over a longer period of time and displaces the need for new equipment[50]. The product lifetime can be interpreted in numerous ways. Different definitions exist (see Table 27) from other ecodesign studies[51].

Table 27. 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.	Is defined as the number of years until the device is replaced for other reasons 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[52] identified the HPC penetration in Belgian household to be 39 % in 2015, where the households with HPC each had 1.1 in average. This could indicate that they some households had one or several older HPCs, which probably was not in use. The study further found that defected HPCs were not always disposed and might have been counted as in use.

3.6.2 Collection rates by fraction

Following the framework of the WEEE Directive, high pressure cleaners must be collected at end-of-life and sent to suited facilities for reprocessing. Illegal trade and sales of scrap challenge the collection rate for some product categories. The statistics from Eurostat present products placed on the market and waste collected for large household equipment[53]. No statistics are available specifically for high pressure cleaners collected so the actual collection rate is difficult to quantify.

[50] Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV
[51] https://www.eceee.org/ecodesign/products/airco-ventilation/
[52] GFK & Recupel Belgische huishoudens: 1-meting. Confidential.
[53] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waselee&lang=en

From 2019 onwards, the minimum collection rate to be achieved annually shall be 65% of the average weight of Electrical and Electronic Equipment (EEE) placed on the market in the three preceding years in each Member State, or alternatively 85% of Waste Electrical and Electronic Equipment (WEEE) generated on the territory of that Member State[54]. Table 28 shows the collection rate for large household appliances calculated based on the WEEE collected in 2014 and the average weight of EEE placed on the market in the three preceding years.

[54] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=EN

Table 28. Calculated collection rate of large household equipment in Europe, 2014

Country	Average EEE put on the market 2011-2013 Tonnes/year	WEEE collected 2014 Tonnes/year	Collection rate
Austria	77,662	31,199	40%
Belgium	107,115	50,781	47%
Bulgaria	38,664	30,286	78%
Croatia	23,445	5,275	22%
Cyprus	8,350	1,222	15%
Czech Republic	72,575	27,828	38%
Denmark	65,210	32,890	50%
Estonia	8,223	1,854	23%
Finland	71,690	33,917	47%
France	918,570	292,730	32%
Germany	748,121	239,662	32%
Greece	86,162	27,317	32%
Hungary	45,004	28,682	64%
Iceland	3,305	1,696	51%
Ireland	38,306	23,797	62%
Italy	501,190	142,666	28%
Latvia	8,728	2,490	29%
Liechtenstein	36	75	208%
Lithuania	15,352	12,429	81%
Luxembourg	4,690	2,586	55%
Malta	6,206	971	16%
Netherlands	112,119	64,496	58%
Norway	70,451	49,402	70%
Poland	244,980	81,082	33%
Portugal	73,738	33,154	45%
Romania	75,341	20,465	27%
Slovakia	25,087	11,590	46%
Slovenia	17,030	4,535	27%
Spain	355,992	101,827	29%
Sweden	107,447	71,306	66%
United Kingdom	708,172	296,520	42%
Total	**4,638,962**	**1,724,730**	**37%**

The average collection rate for large household equipment at EU level was just below 40% in 2014. This value should be improved to 65 % in 2019 according to EU targets. The low collection rate of products cannot be directly addressed in the Ecodesign Regulation but should be addressed by each Member State regarding their obligations with regard to the WEEE Directive.

The collection rate of high pressure cleaners is assumed to correspond to the collection rate of large household equipment, i.e. around 40% for EU.

3.6.3 Second hand use and second product life

No data were available on second hand use and second product life. However, a quick internet search showed many HPCs for second hand sale[55]. Furthermore, a Belgian study[56] identified that 10% of the HPCs in people's homes are never used.

One manufacturer of professional HPC informed that the market for reused and remanufactured products or components are mostly applied to professional HPCs due to their higher price and more extensive use. E.g. fuel-based hot water HPCs are in general refurbished.

3.6.4 Best practice in sustainable product use

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

- Purchase:
    - Identifying properly the cleaning tasks to be covered by an HPC. For new domestic consumers to the HPC area, this may require assistance from consumer organisations (magazines, web sites, counselling, etc.), shops, neighbours, etc., while professionals would seek assistance from technical sales people, suppliers, shops etc.
    - Identifying 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 needed 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 including reading the manufacturer's manual
    - 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 water hose are not sufficient or would require larger amounts of water
    - Proper handling of the HPC after use according 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 a second hand sale
- End-of-life situation:
    - If the HPC is defect and it is not possible to repair it, it should be disposed of according through the public collection scheme or similar complying with the WEEE directive

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

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

3.7 Local infrastructure

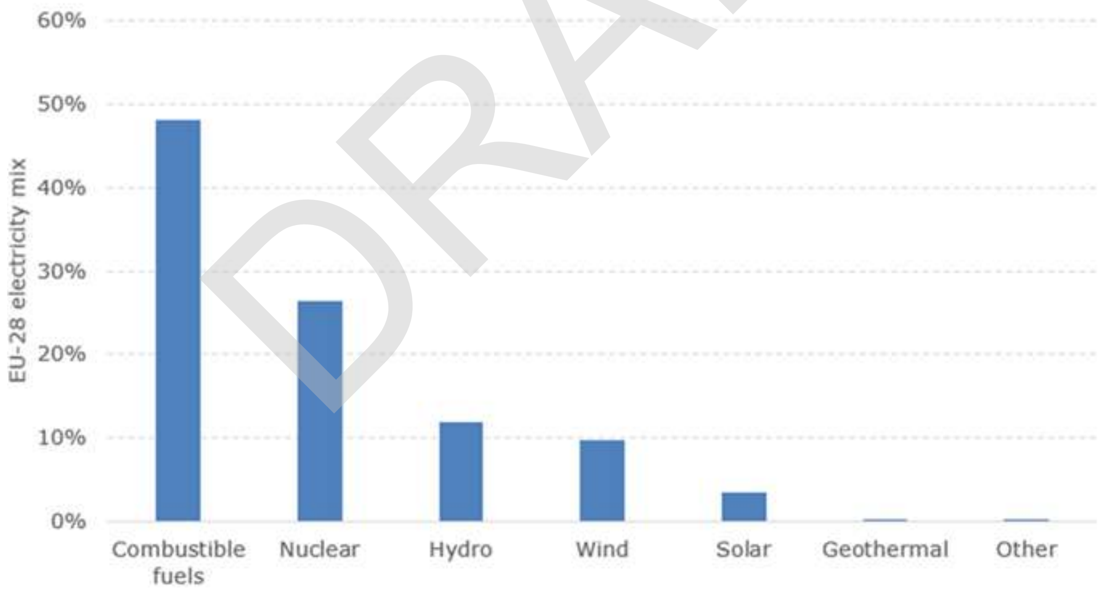
3.7.1 Energy: Reliability, availability and nature

Electricity

The power sector is in a transition state moving from fossil fuels to renewable energy. The origin of the electricity is a very important factor to consider both regarding the environmental impact by using an HPC and how it may affect the consumer behaviour. Within the EU there are a number of renewable energy targets for 2020 set out in the EU's Renewable Energy Directive[57]. The overall target within the EU is 20% of final energy consumption 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[58]. To achieve this goal of 20 % from renewable sources the different EU countries have committed to set their own individual goal ranging from 10 % in Malta to 49% in Sweden. In 2015 the share of renewable energy was almost 17%[59]. See also the EU Reference Scenario 2016[60].

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, 2015 (% of total, based on GWh)[61]



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

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

The reliability of the electricity grid could in 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 it is not in use). Renewable energy production can vary greatly from hour to hour and day to day.

Due to technological development, 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 is ranking the different countries on their ability to deliver secure, affordable, sustainable energy. In recent years European countries have dominated the top spots (see Table 29[62]).

Table 29. 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

Diesel, petrol and LPG

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

3.7.2 Water

The public water grid is available and reliable in most places. There are however differences between the water quality and mainly calcium, which may impact the maintenance and lifetime of the HPCs. This is very regional 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 than tap water for example rain water and water from ponds or lakes if they are equipped with water filters.

Task 4 section is detailing the issue about water hardness and the influence on the lifetime.

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

3.7.3 Installation and installers

All mobile units would not require any installation, just availability of the needed input of energy and water, i.e. for the HPCs supplied with electricity, a 1- or 3-phase mains connection with sufficient power capacity, and a water tap unless water from other supplies are needed.

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

3.7.4 Rentals and sharing arrangements

Due to very low use frequency in households, domestic HPC would be very suited for sharing with family members, neighbours, colleagues, etc. The product can also be rented at several suppliers[63]. 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 the HPCs are under such arrangements.

3.8 Recommendations

3.8.1 Refined product scope

The study team believes that the product scope is suitable with 2 observations:

- Additional sub-categories 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 1 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 quite low for domestic HPCs, but this should be seen in connection to water and detergent consumption. 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 or a harmonised standard.

The conclusion is that based on the user aspects analysed in this section, there are no significant barriers, and good opportunities for ecodesign and/or energy labelling regulation(s).

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

4 TECHNOLOGIES

4.1 Introduction

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
- Recommendations for refined product scope, barriers and opportunities for Ecodesign from a technical perspective including 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 HPC, electricity

HPCs aimed at domestic use are primarily segmented by power and pressure. Each manufacturer typically offers a range of models geared towards a range 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 an area performance. More details about the main parameters of domestic cold water HPCs are presented in Table 30.

Table 30. Typical main parameters for domestic cold water, electricity 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

For domestic hot water HPCs, only one model was found in the market, whose technical specifications are shown in Table 31.

Table 31. Parameters for domestic hot water, electricity HPCs

Parameter	Parameter value
Power	2000 W
Pressure	12 MPa
Flow rate	7.5 l/min (450 l/h)
Weight	55 kg
Temperature	90 ^{o}C
Heating oil consumption	2.45 kg/h

Professional HPCs, general description

Professional HPCs are also primarily segmented by power and pressure. For upright 2-wheeled models, there is some crossover 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 e.g. reduced kick-back, 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:

- 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 from brass.

- Low speed motors with improved cooling and more advanced controls (including improved pressure relief) to extend life and address increased duty requirement.
- 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 2-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
- Unions 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 kick-back when operating trigger to reduce operator fatigue

Professional cold water, electricity 1-/ 3- phase(s)

1 phase professional cold water HPCs are quite similar to domestic models but with higher operating time and higher weight due to being built to daily uses. More details about the main parameters of professional cold water HPCs are gathered in Table 32.

Table 32. Typical main parameters for professional cold water, electricity 1 / 3 phase(s) HPCs

Parameter	Parameter value range	Comments
Power	1 ph: 2800-3000 W 3 ph: 7000-10000 W	Rated power but usually just stated as unit ‘power’
Pressure	1 ph: 14-18 MPa 3 ph: 20 MPa	Stated Maximum or Working Pressure
Flow rate	1 ph: 9-20 l/min (540-1200 l/h) 3 ph: 15-20 l/min (900-1200 l/h)	Stated Maximum Flow Rate
Operating time	1 ph: 1-2 h/day 3 ph: 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

This category is different from the previous category by having 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 33.

Table 33. Typical main parameters for professional cold water, combustion engine HPCs

Parameter	Parameter value range	Comment
Power (engine)	4000-10000 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, 1 / 3 phases, fuel heater

The category is based on the professional cold water machine, where a fuel heater with a burner is added. Some HPCs may also deliver steam. Compact units are upright 2-wheeled models, normally single phase with 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 3 phase, 230 V supply is required. More details about the main parameters of these HPCs are gathered in Table 34.

Table 34. Typical main parameters for professional hot water, 1 / 3 phases, fuel heater HPCs

Parameter	Parameter value range	Comment
Power	1 ph: 2000-3600 W 3 ph: 3800-15000 W	Rated power but usually just stated as unit 'power'
Pressure	1 ph: 11-18 MPa 3 ph: 20 MPa	Stated Maximum or Working Pressure
Flow rate	1 ph: 9-20 l/m (540-1200 l/h) 3 ph: 15-20 l/m (900-1200 l/h)	Stated Maximum Flow Rate
Temperature	60-150 ^{o}C	Of the water/steam leaving the nozzle
Heating fuel	2-15 kg/h	Heating oil or gas

consumption		
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, 3 phases, electric heater

The category is based on the professional cold water machine, where an electric heater is added. The nameplate power is much higher and only 3 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 35.

Table 35. Typical main parameters for professional hot water, 3 phases, electric heater HPCs

Parameter	**Parameter value range**	**Comment**
Power	18000-42000 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, fuel heater

This model corresponds to the cold water combustion engine category, where 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 36

.

Table 36. Typical main parameters for professional hot water, combustion engine, fuel heater HPCs

Parameter	Parameter value range	Comment
Power	4500-7500 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 ^{o}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

The stationary is a special category of professional units, which typically are larger and can operate more hours a day. More details about the main parameters of these HPCs are gathered in Table 37.

Table 37. Typical main parameters for stationary cold water HPCs.

Parameter	Parameter value range	Comments
Power	1 ph: 3000 W 3 ph: 4000-55000 W	Rated power but usually just stated as unit 'power'
Pressure	1 ph: 20-22 MPa 3 ph: 15-27 MPa	Stated Maximum or Working Pressure
Flow rate	1 ph: 10 l/m (600 l/h) 3 ph: 10-150 l/m (720-9000 l/h)	Stated Maximum Flow Rate
Operating time	1 ph: 2-3 h/day 3 ph: 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, fuel heater

This category is like the cold water stationary models just with a water heater added. The models are 3 phase types. See Table 38.

Table 38. Typical main parameters for stationary hot water, fuel heater HPCs.

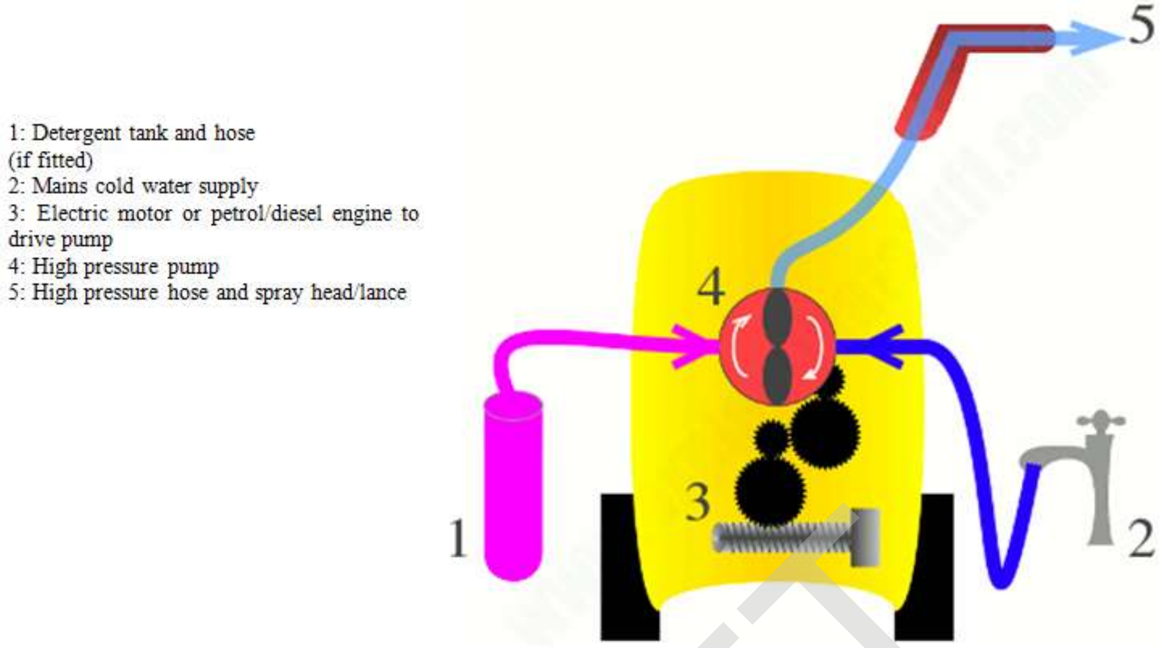
Parameter	Parameter value range	Comments
Power	6000-10000 W	Rated power but usually just stated as unit 'power'
Pressure	14-18 MPa	Stated Maximum or Working Pressure
Flow rate	10-20 l/m (600-1200 l/h)	Stated Maximum Flow Rate
Heating fuel consumption	2.8-4.5 kg/h	Heating oil, diesel, bio-diesel
Operating 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 an HPC in a schematic way. The components are further detailed in the following paragraphs.

Figure 23. Main components of a high pressure cleaner[64]

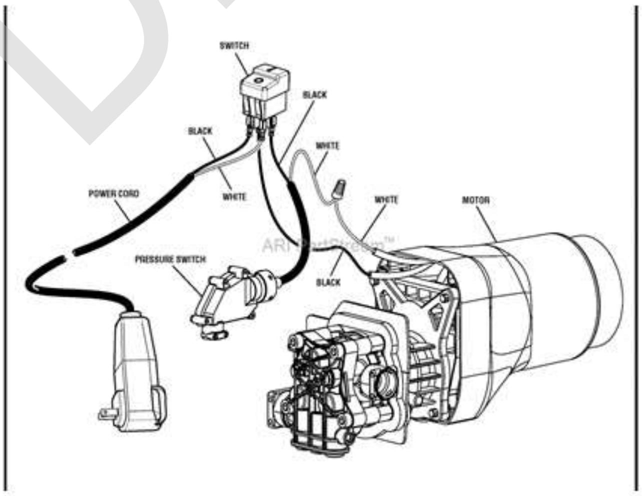


On/off switch

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 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 in order that the pump will only run when the lance trigger is activated.

Figure 24. Example of series connected pressure switch.



[64] 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 induction based. 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:

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

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 produces 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:

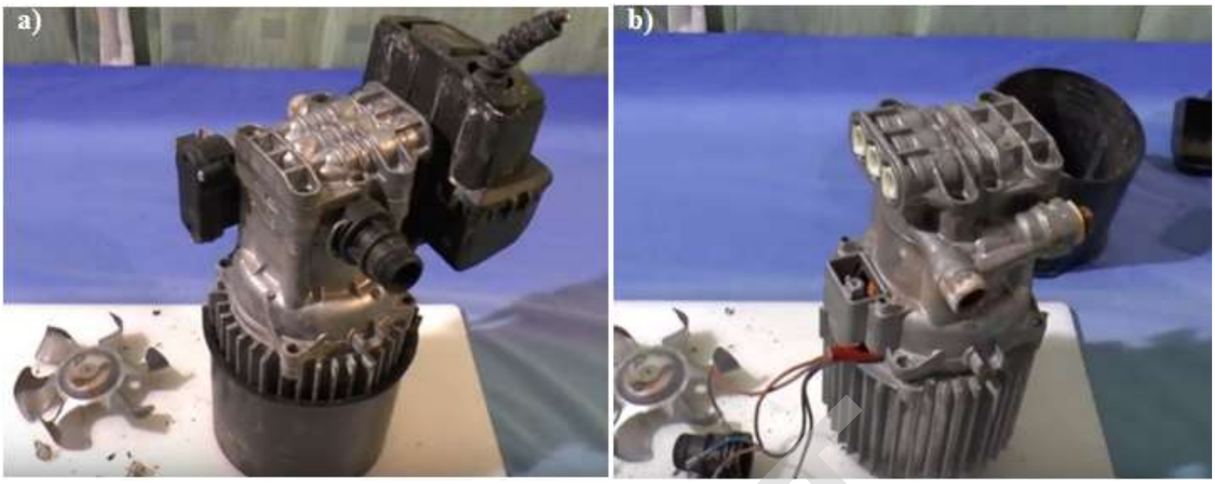
$$\% \text{ slip}, s = ((N_s - N)/N_s) \times 100$$

Slip is typically 3-5% at full load.

The simplicity of the induction motor makes it 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.

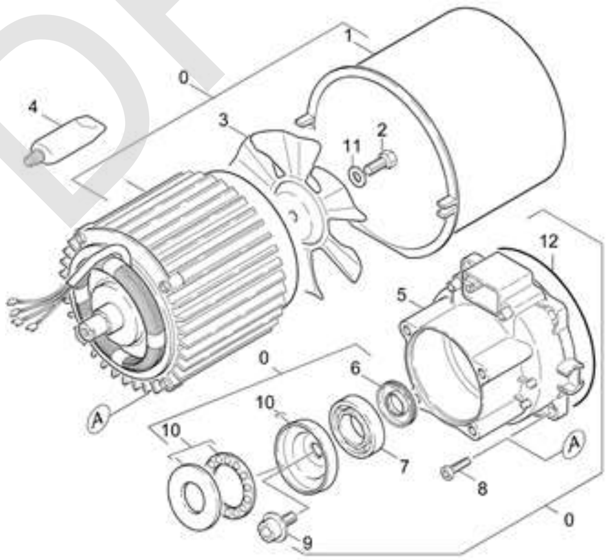
The motor/pump assembly is normally an integral unit with the pump being driven directly. The pump and motor are typically bolted together. See motor details in Figure 25.

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



In the case of combustion engine driven machines, the engine may be 2-stroke or 4-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.

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



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 27. Typical shaft driven arrangement. 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.

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 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 economic for repair. They have the advantage of relatively long life (200-800 hours, the professional ones in 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 every approximately 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 and 200 mg of calcium carbonate per litre
- Hard water between 200 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[65] sets the following classification:

- 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 decaling 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.

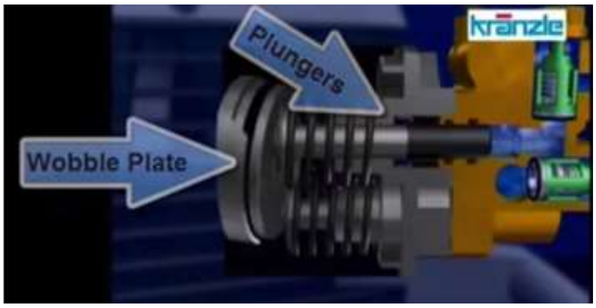
Figure 28. Water pump with a manifold assembly that houses the chemical injector, a pressure check valve (unloader valve), the and the inlet and outlet tubes.

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 mixes 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.

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

Three types of pump technology are employed as presented in the following Figure 29 to 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 in 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. Life is typically 500-800 hours (the cost of such a pump starts from 80 euro[66], at 2017 prices).

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

Figure 31: Typical Triplex Pump.

The Triplex pump is typically used in professional HPC applications and utilises 3 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 1000s 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. 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. A typical cost of a triplex pump[67] starts from 200 euro in 2017 prices.

Built-in hot water heater

Cleaning using hot water is generally considered to improve cleaning efficiency by 30-35%[68] and for greasy or oil cleaning applications including automotive, hot water is essential for 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 on industrial or professional HPC. Figure 32 presents typical examples of hot water HPCs with diesel burner and electric boiler.

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

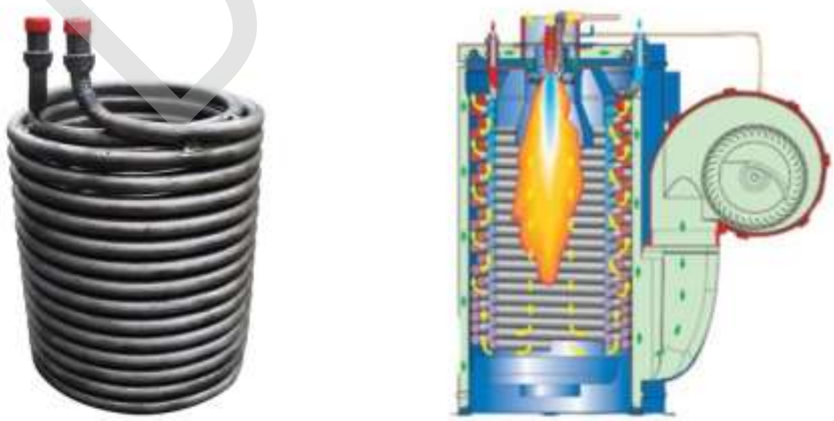
[68] https://www.kaercher.com/uk/professional/pressure-washers/benefits-of-hot-water-high-pressure-cleaners.html

Figure 32. Hot water HPCs with diesel burner (left) and with electric boiler (right). All have electrically driven motor-pump assembly.

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 3phase 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 flow sensing and water level are included to prevent damage in the case of low flow or 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[69].



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 shut down sequences. For a professional hot water HPC, it is normal practice to start the unit up delivering cold water before activating the burner. This

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

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 (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 minimized 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 life 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 flame sensor (to ensure that fuel is only injected when 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 effects water heating efficiency, maintaining hot water production and can restrict water flow or pressure, resulting in 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% (dependent on the thickness of limescale deposit) and has a similar effect on life reduction. 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 machines 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 available in the market professional HPC units with a built in limescale remover. Manufacturers offer limescale reduction chemicals and details including Safety Data Sheets are available via the manufacturers website.

In order to inform consumers and professionals for the burner efficiency improvements/environmental performance, the cleaning machines association EUnited has created a High Pressure Cleaner burner efficiency label[70]. 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.

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

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

- 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)

These numbers can be compared with Germany emission criteria in the occupational regulations[71]. e.g. the maximum CO emission from diesel exhaust is 30 ppm.In this specific criteria 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 main fed water supply but other sources including water butt, tank or lake may be possible on 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 has normally 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-siphon 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 nozzles type can be divided into 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 spray angle and pressure of the spray.

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

- 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 lets water through only 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 on the tank or on the attachment.

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

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

The dosage control on most machines is very limited and detergent may be added either upstream or downstream of the pump. 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, others require that the undiluted detergent is added to the integrated tank and yet others require dilution before use. Detergent usage or dosage are 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 setting to be adjusted +/- but do not 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 maxim flow rates of 7-8.3 l/min. This gives a typical dosing 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 included to ensure safe operation of the appliance and to protect the appliance in the case of misuse or a fault condition.

The safety components include:

- 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 build up temperature over time and a pressure vent or temperature vent may release this 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*:* The 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 will 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 Operator Presence Control (OPC), which secures that water is not pressurized, 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 3 meter cable while larger products can be supplied with 10 meter cable.

Casing and wheels

The casing of products used on domestic HPCs is normally of plastic construction 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.

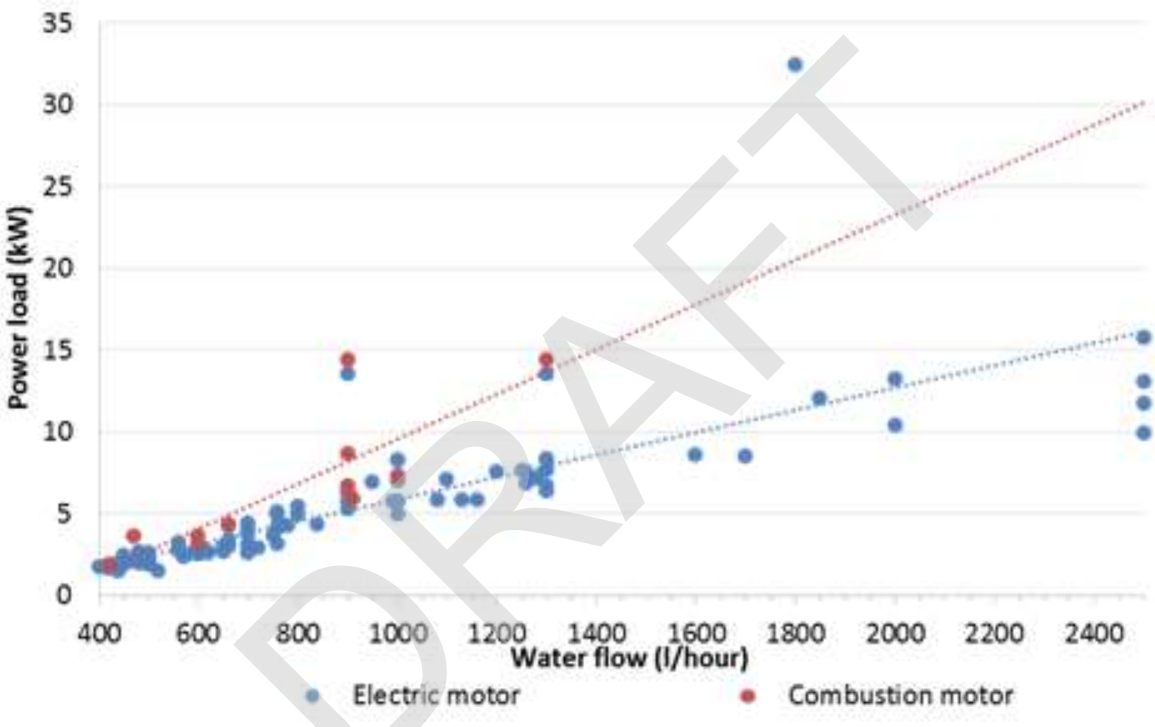
4.2.1.3 Analysis of main performance parameters

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

The analyses above are repeated where the energy consumption is compared with the maximum flow rate instead of working pressure. 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.

Figure 34. Power load vs. maximum water flow (l/hour) for professional HPCs (excluding stationary HPCs and deducting power for electric heated hot water HPCs) based on the technical specifications. HPCs with electric motor and with combustion motor are shown separately. Trendlines are added for each type of motor.



The power load is calculated from the nameplate power deduced with 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 HPC; 5.8 Wh/l for Professional HPC electric driven; and 8.6 Wh/l for combustion engine professional HPC.

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

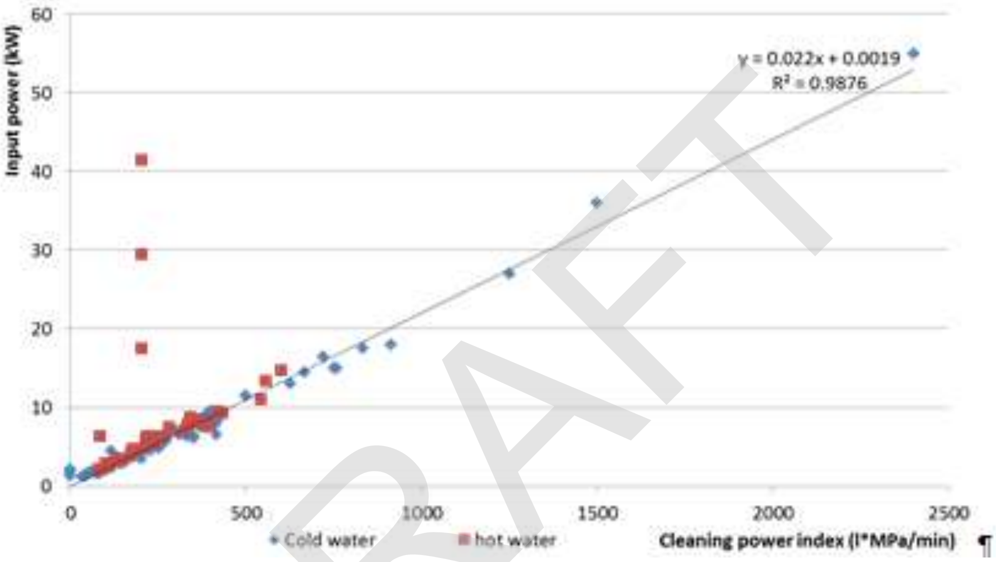
Combined working pressure, water flow and rated power

In the previous sections, the water flow correlation with input power has been analyzed. Both water flow and pressure are important for a good cleaning result: The water pressure is for loosening the dirt from the surface, while the water flow is for removing the dirt after it has been loosened. Therefore, it is proposed a single performance parameter which includes both of them. Several internet resources[72,73,74,75] report a simple combination by multiplying water pressure and water flow – by sources called "cleaning units". In this report we will define this index as 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 = max water flow x maximum flow pressure (liters*MPa*minute^{-1})

Figure 35 presents the relation of CPI with the input power of an 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 conclusion can be drawn:

- There is a clear relation among CPI and input power, they correlate very well (R^2=0.988). The relation is:

  Input power = 0.022xCPI +0.0019

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

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

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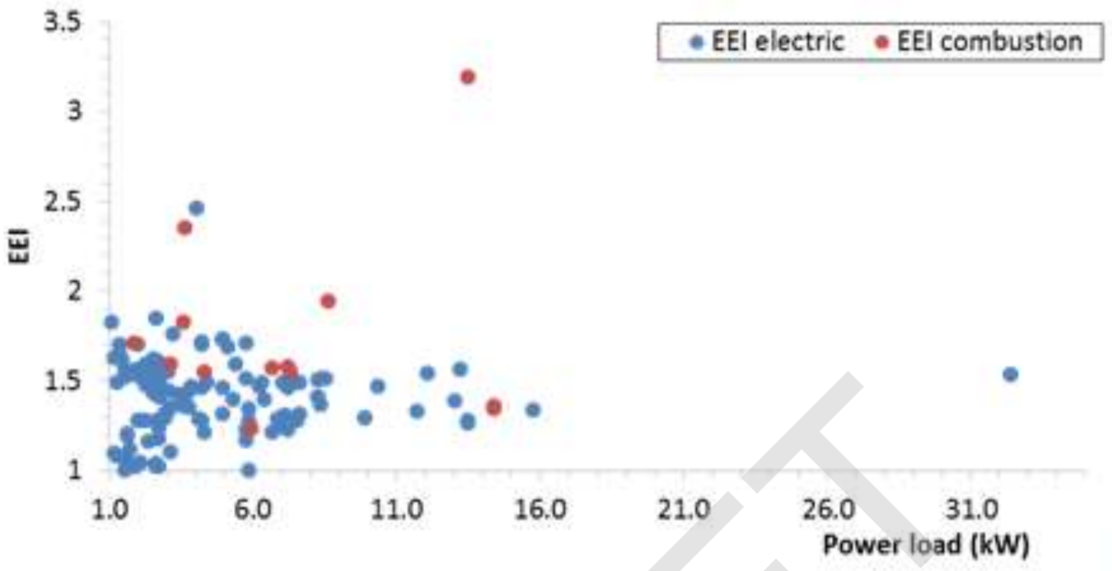
72 https://www.goodway.com/hvac-blog/2011/03/flow-rate-is-key-when-choosing-a-pressure-washer/
73 http://www.rentalmanagementmag.com/Art/tabid/232/ArticleId/17838
74 https://www.thoroughclean.com.au/factors-influence-high-pressure-cleaning-constitutes-cleaning-power/
75 https://simpsoncleaning.com/tips/2016/psi-vs-gpm-what-matters-most/

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

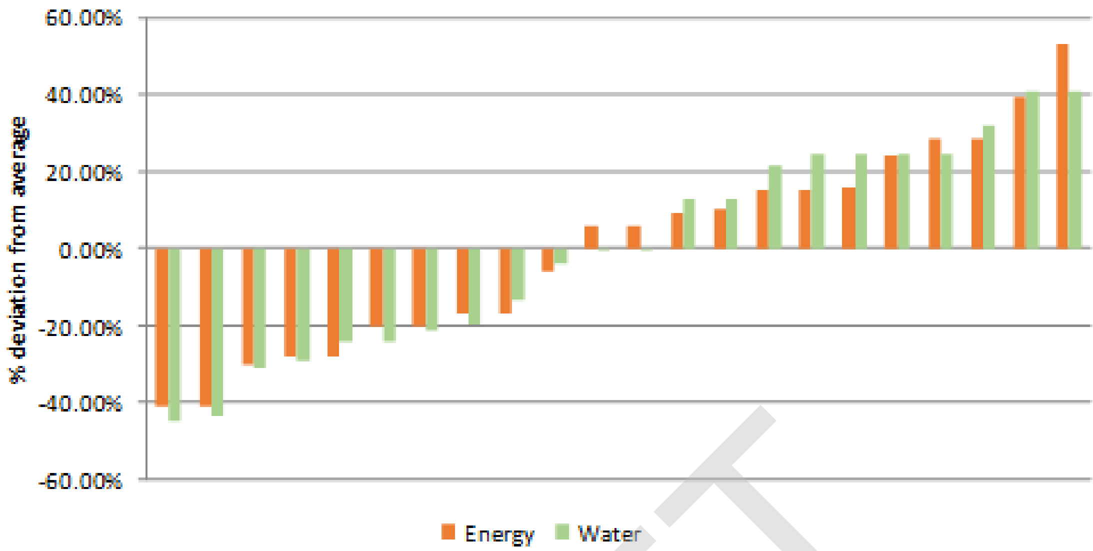


The figures show only limited correlation with power loads and mainly for the electric motors with downsloping tendency in EEI with increasing power loads. For combustion motors, there are only 13 data points and therefore much more uncertainties and no conclusion is made here.

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 between them, the HPCs selected performed 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. Only the results for standard nozzle have been included. Figure 37 shows the energy and water consumption of the HPCs expressed as percentage of deviation from the average. Negative values mean that the unit consume 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, t 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 different. From the group of 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). From the group of 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 consume above 50% more energy and 40% more water.

Figure 38 gathers the values of energy and water consumption with the rated input power (as percentage of deviation from the average). From the group of HPCs that consume less than 20%, all but one performs larger input power (7% larger). The HPCs that consume more water perform lower and higher input power, without any apparent pattern.

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

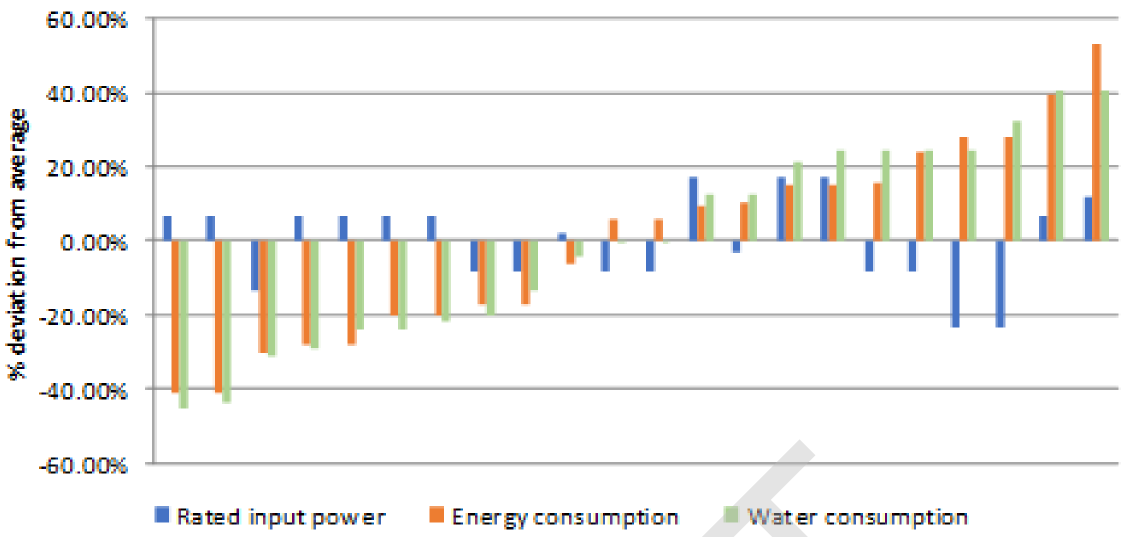


Figure 39 shows the values of energy and water consumption with the rated pump pressure (as percentage of deviation from the average). The profile is very similar to input power, except that the variations are larger. This is the result of the different pump efficiencies of the units.

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

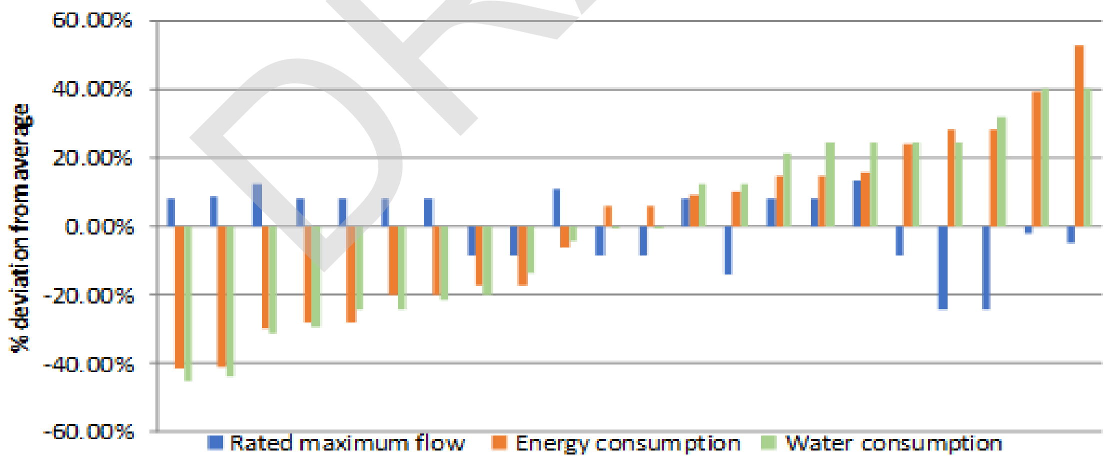


Figure 40 shows the values of energy and water consumption with the rated maximum flow (as percentage of deviation from the average). The profile is very similar to input power, except that the variations are larger. All the units that consume 20% less energy and water show a rated maximum flow at least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

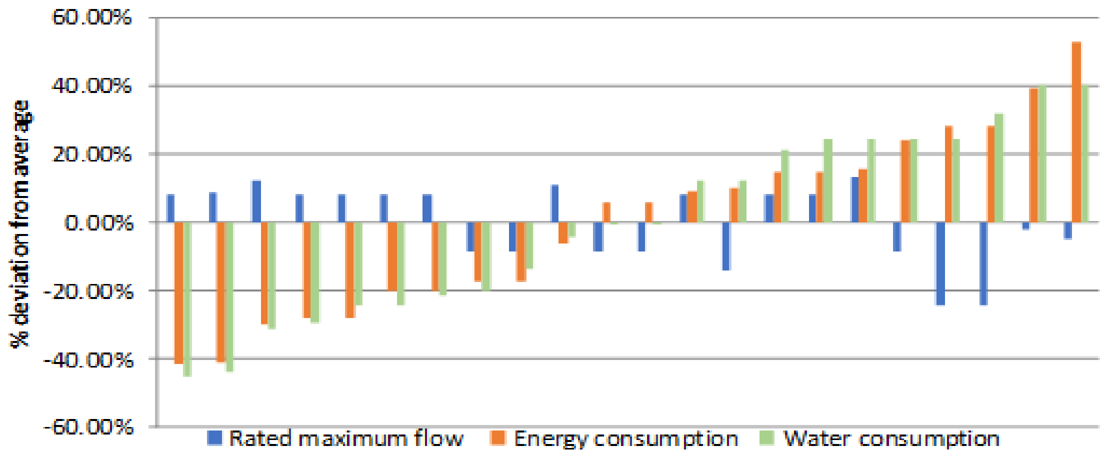
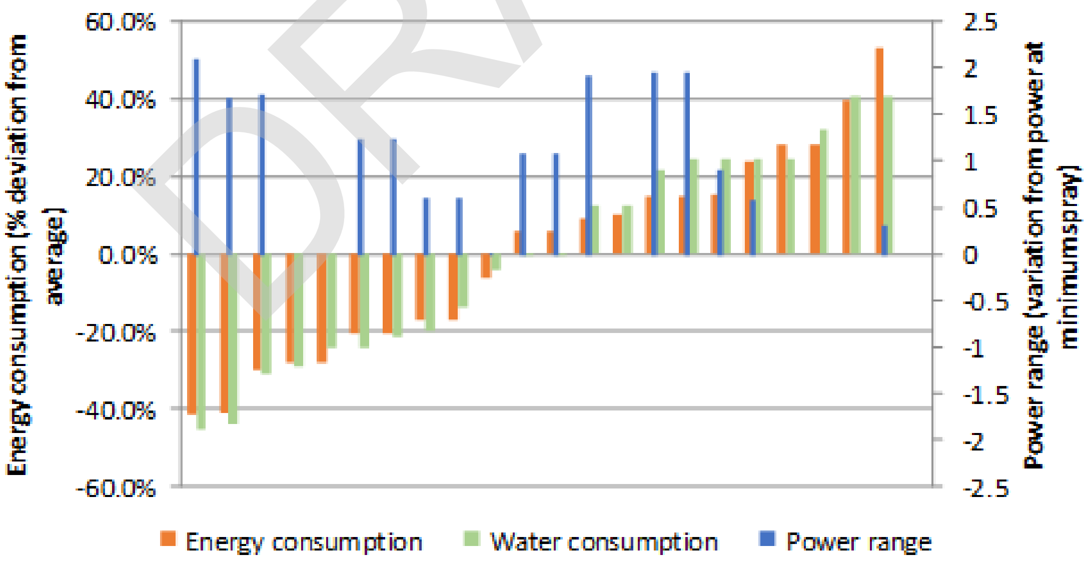


Figure 41 shows the capability of units to vary their power at maximum and minimum spray. 7 out of the 10 best performing HPCs are able to vary their power up to 50%, while in the worst there are units both capable and not capable of power variation.

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



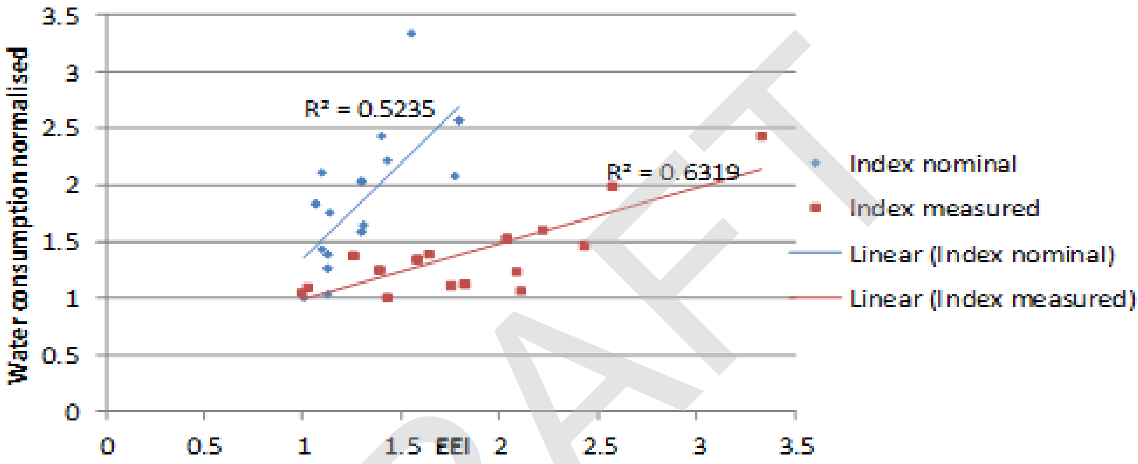
The energy and water consumption have been evaluated in relation with the EEI defined in the previous sections. For this, the following indexes have been defined:

- EEI nominal: This corresponds to the EEI shown in Figure 14
- EEI measured: This is a normalized index based on measured power load divided with measured water flow and measured force.

- Water consumption normalized: This is a normalized index of water consumption for cleaning 1 m^2 pavement including only test points with sufficiently high quality (at least 4 on a scale 0.5-5.5)
- Energy consumption normalized: This is a normalized index of energy consumption for cleaning 1 m2 pavement including only test points with sufficiently high quality (at least 4 on a scale 0.5-5.5)

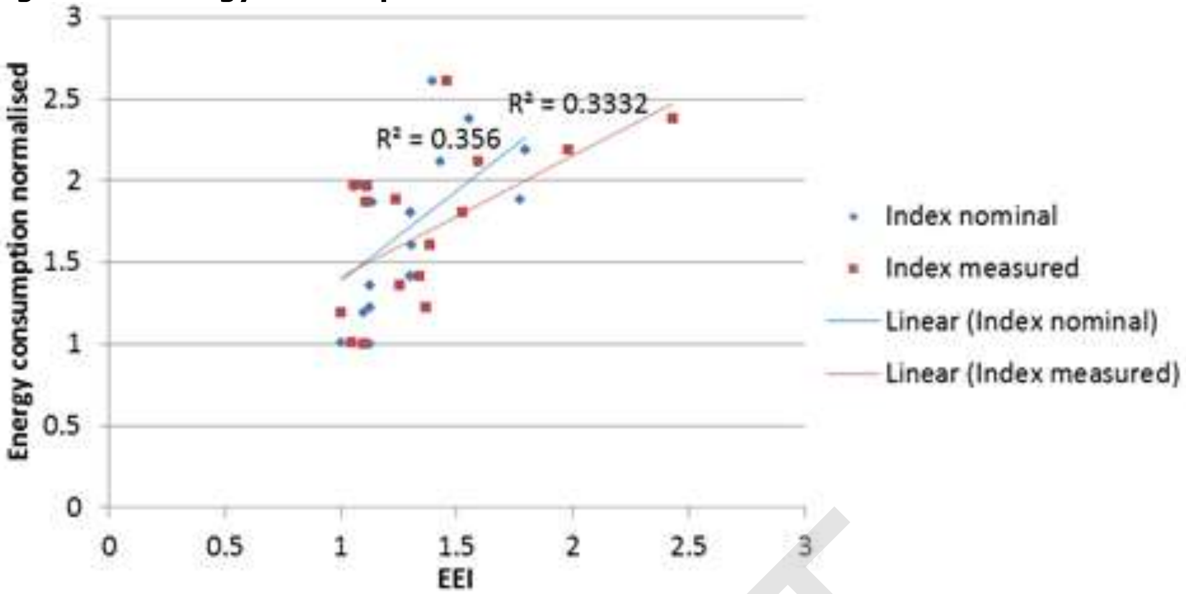
Figure 42 shows certain correlation between the EEI measured and the water consumption. Being a real life test for the measured indices, there are uncertainties involved even though the tests were performed by test experts and done twice for the water and energy consumption tests (results averaged).

Figure 42. Water consumption versus EEI nominal and measured



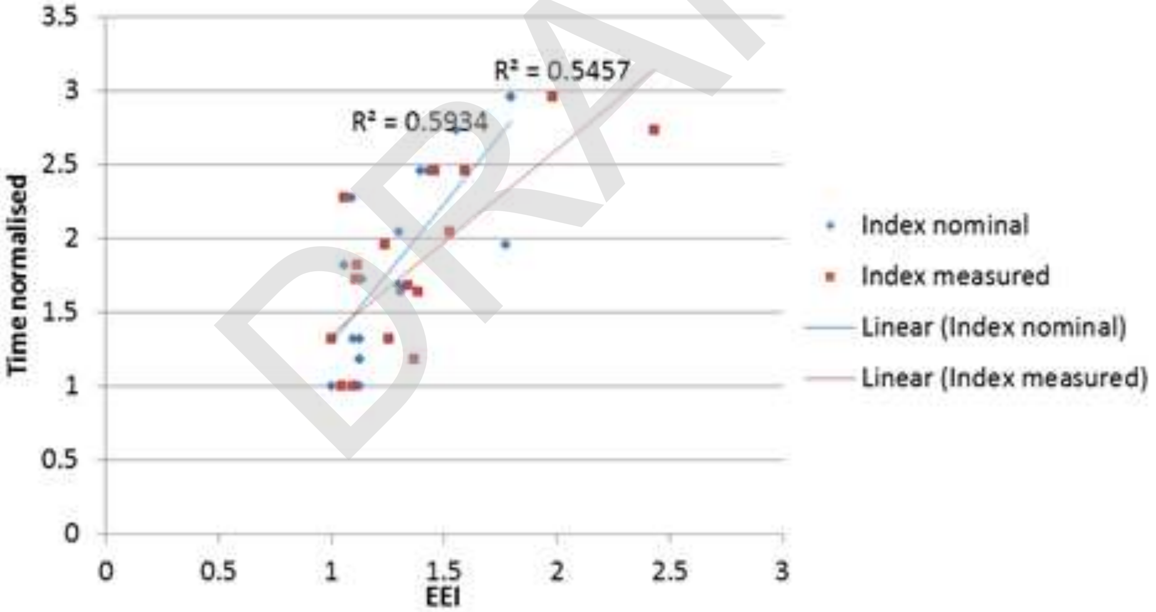
As can be observed in Figure 43, the correlation between EEI and energy consumption is much weaker. Apart from the uncertainties about real life test mentioned above, the energy consumption is calculated multiplying time per measured power at maximum spray.

Figure 43. Energy consumption versus EEI nominal and measured



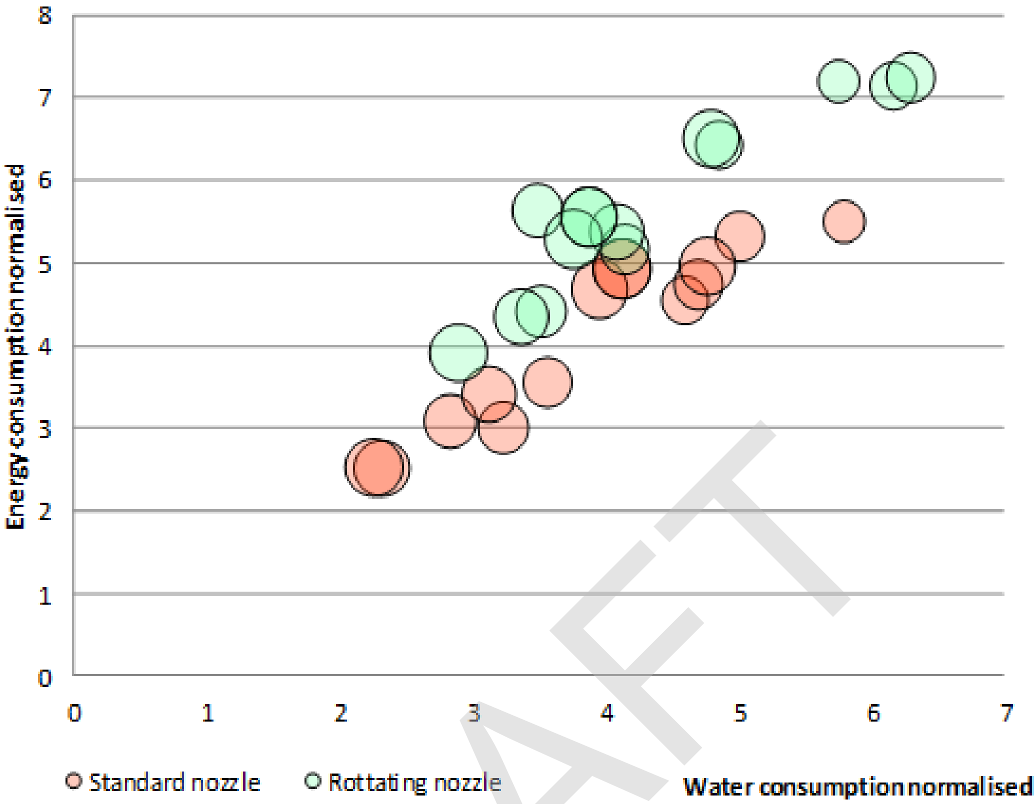
The correlation between cleaning time and EEI is better as Figure 44 shows, which suggests that the variation of power along the test cycle plays a role.

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 nozzle and rotating nozzle. The size of the bubbles is related to the cleaning units.

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



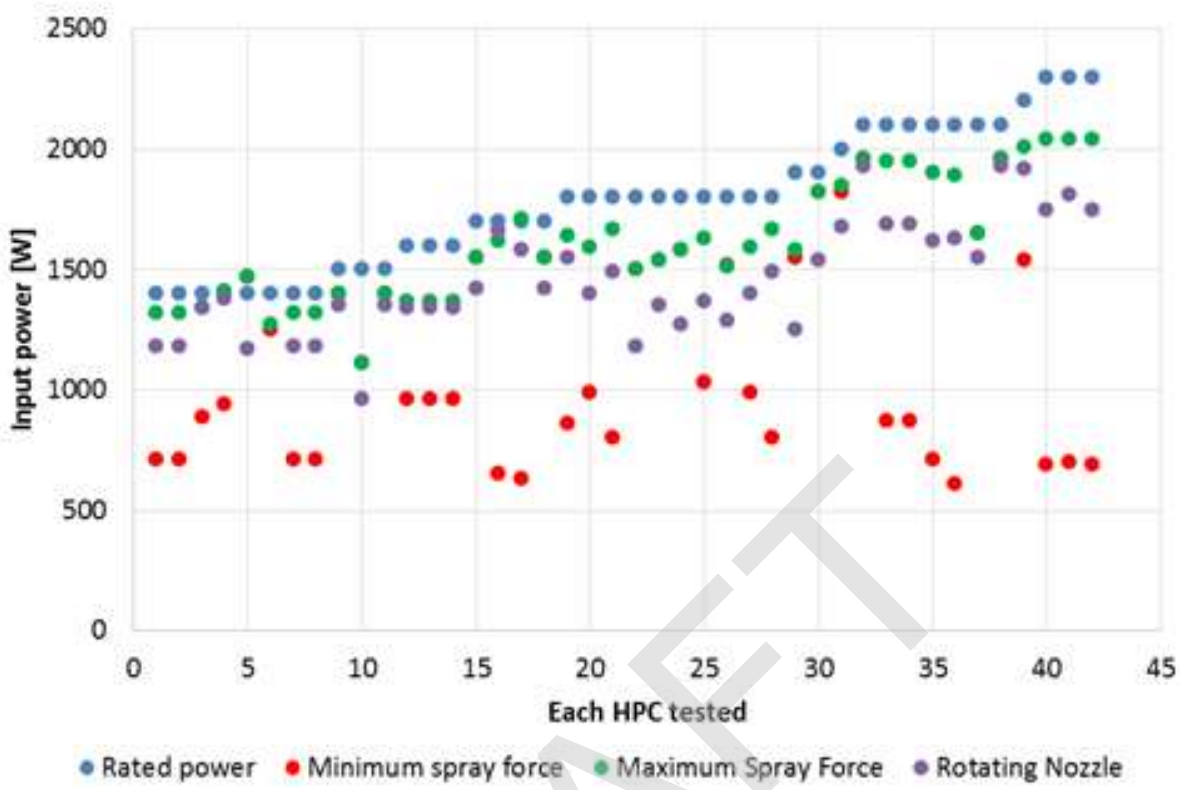
As can be observed, rotating nozzle setting consumes lower energy and water per m2 compared to the standard nozzle setting. The average value for energy consumption of standard nozzle is 50% higher than rotating nozzle. The average water consumption of standard nozzle is 28% higher than rotating nozzle. There is significant variation in both water and energy consumption for similar cleaning quality for different units. This indicates that there potentials for energy and water savings improvements. There is no clear correlation of 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 analyzed the ability of HPCs to reduce the energy consumption when reducing the spray force. If a product has a high ability of reducing 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 43 HPCs tested the rated power and power draw at minimum and maximum spray force and with rotating nozzle. Where the red dots (minimum spray force) are low compared to then blue and green dots, the HPC has high ability to reduce power draw and thereby the energy consumption.

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



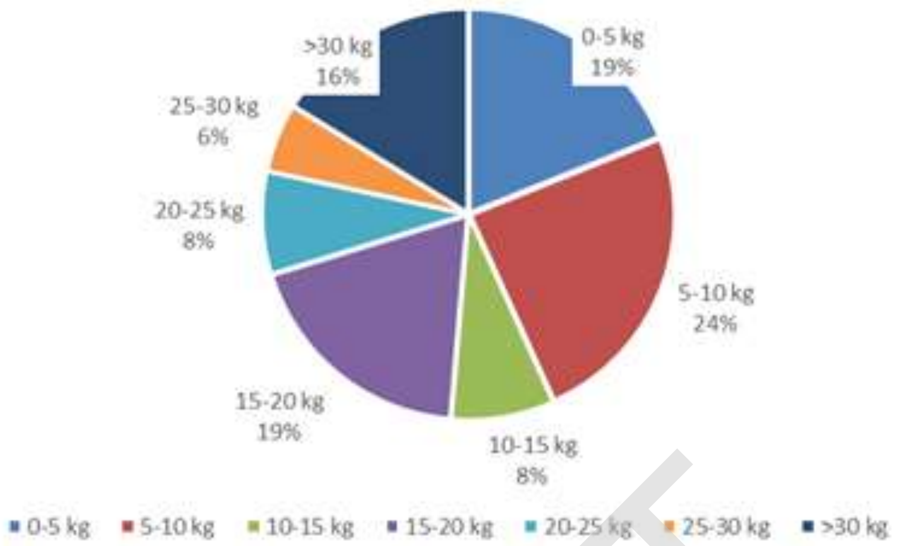
In average, the HPCs reduced the power draw 35 % at minimum spray force compared with rated power, while the best reduced with 70 % and the worse with 4 %. This indicates clearly a large market spread of power reduction ability.

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 have also more types of form factors such as with 2 or 4 wheels, caged to be moved with a fork-lift, wall-mounted and stationary.

Domestic HPCs are more standardized as mobile types with 2 wheels though they often exist in 3 basic series: An entry level line, a sturdier and higher quality line and a compact line. The study team has analyzed the weight of domestic products based on the technical data collected from the web sites. Professional products have not been included due to having many different applications that makes it difficult to compare the products on equal terms. The weight of the domestic products has been divided into 7 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.

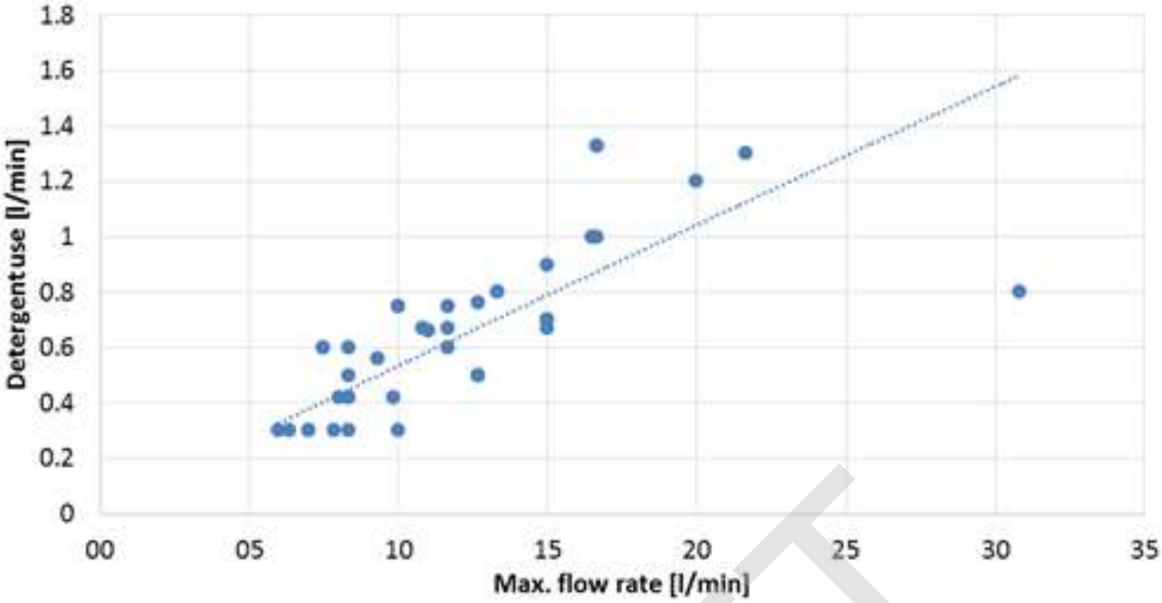
Figure 47. Weight distribution of the sample included in the analysis.



4.2.1.6 Analysis of detergent use

The amount of detergent that the HPC use in operation is stated for some of the HPCs (approx. 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 stated specifically. Many of both the domestic and professional models also have a build-in function where the amount of detergent can be manually adjusted. In the operation and maintenance manual, a manufacturer states that foam detergents can be adjusted to between 1-5 % of the water consumption and low-foaming detergents can be adjusted to between 1-8 % of the water consumption. The detergent use for those HPCs where the amount of detergent use is specified versus the maximum flow rate is shown in Figure 48.

Figure 48. Detergent use vs. max. flow rate

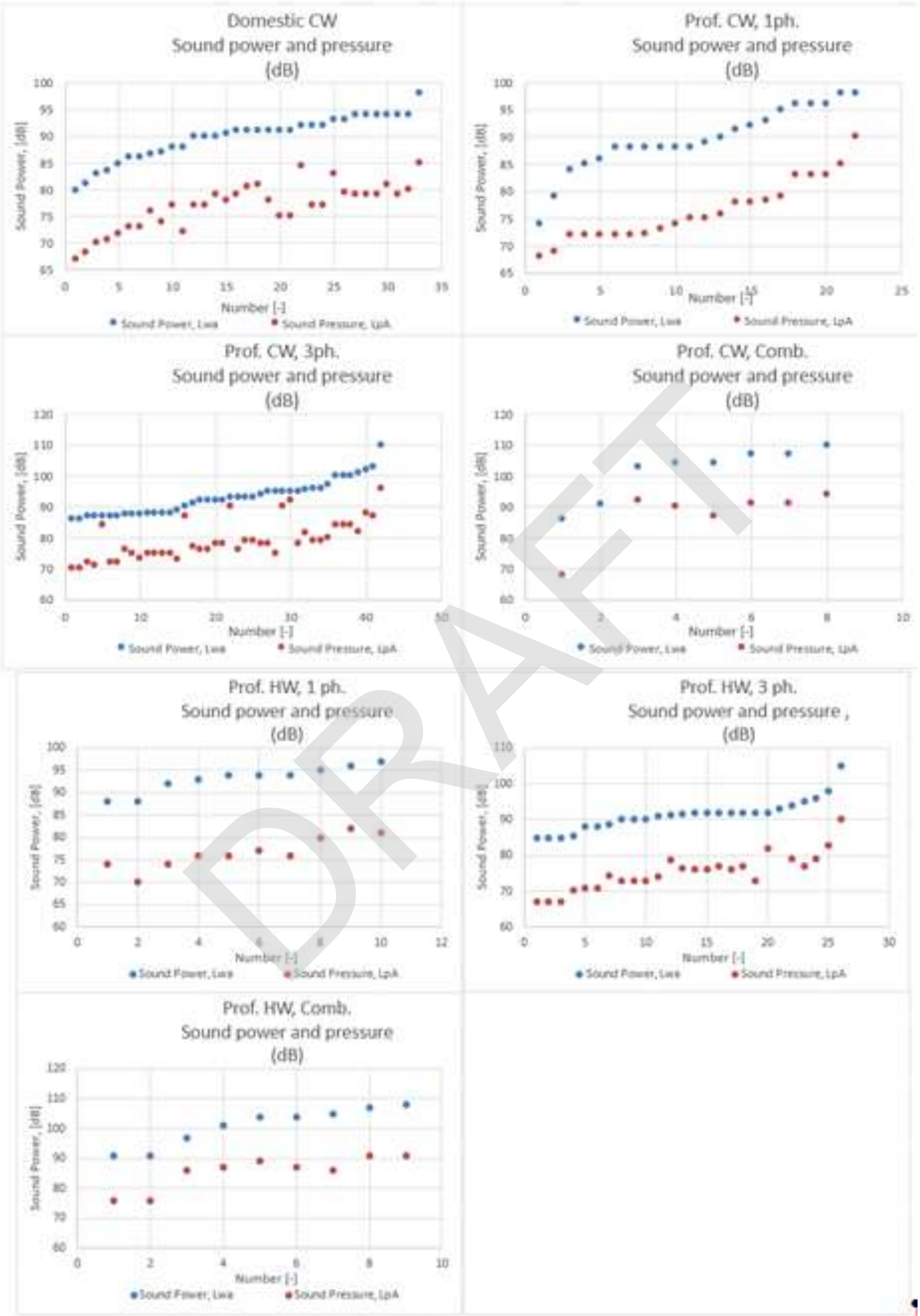


The use of detergent compared to the maximum flow rate shows a good coherence and approximately follow a linear trend. A calculation of the ratio shows that all, except one, have a detergent use between 4-8% of the maximum flow rate which is in line with what one of the manufactures stated in the operation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

4.2.1.7 Analysis of noise

In this section an analysis of the sound power (L_{wa}) and the sound pressure (L_{pA}) is carried out based on the technical specifications. The sound power and pressure figures are presented for HPCs in each of the 7 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 increase slightly 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 resources 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).

Energy efficiency in pumps and motors

Motor-pump automatic shut-down (standard)

Most HPCs have automatic 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 swashplate 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 saving compared to other constant flow pumps in systems where prime mover/diesel/electric motor rotational speed is constant and required fluid flow is non-constant. However, alternate pump arrangements include rotary vane, radial piston and Archimedes screw.

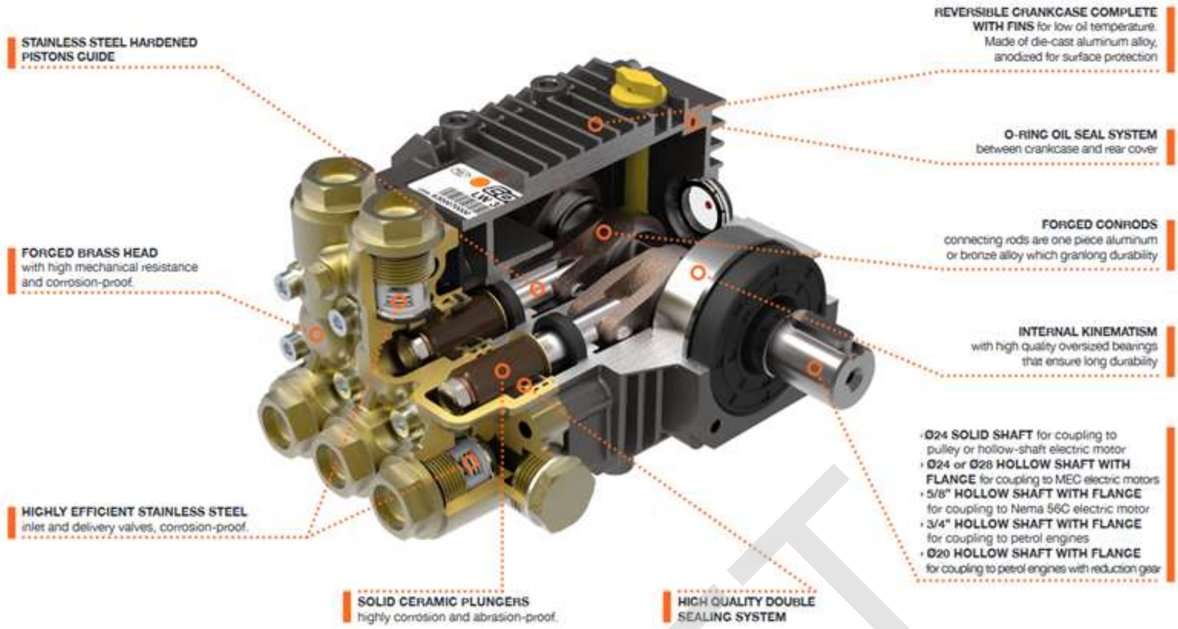
Energy efficient water pumps (BAT)

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 5 times operating life improvement), better surface finishes and reduced frictional losses.

Deployment of better and more efficient pumps such as Triplex type in consumer products would increase costs and weight but can benefit in terms of longer life time and less 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 polishing 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 products with a higher roughness 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 manufactures find that increased cost of investment 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 max pressure but higher flow rate may outperform a product with higher pressure. This is especially the case where the amounts of dirt require 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 been deployed in the HPC application and is thus a BNAT. In particular, increased demand for cordless, battery operated products such as vacuum cleaners have resulted in significant developments within this sector. Additionally, ecodesign measures in categories such as ventilation fans have driven deployment of BLDC.

BLDC offers high efficiency but is generally deployed in continuous applications such as cleaning, ventilating or blowing applications due to the higher energy efficiency gains here. A very high power to size 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 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 although the technology might be deployed in portable, battery operated units. Control of BLDC 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 of 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). E.g. reducing motor speed to 80% of maximum can save up to 50% energy. However, the reduction depends on the use profile, i.e. the annual operational time and required flow-pressure the high-pressure cleaner needs from the pump to supply water and pressure compared to full load flow-pressure.

Variable Speed Drives (VSD) 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 via suitable measurement transducers and control via the VSD. Packaged off the shelf VSDs typically range from 0.25 kW up to 1000 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 vs. increased costs and complexity require consideration and therefore it is mostly a BNAT.

Technologies for combustion engine powered HPCs (BNAT)

All current products utilise readily available small garden machinery 4 stroke, single cylinder petrol or diesel engines. Advantages include ease of maintenance, no requirement for specialist tools, 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 petrol or diesel HPC is primarily based upon:

- Petrol engines are powerful, reliable and generally lower acquisition cost compared to diesel machines.
- Diesel running costs are lower and better durability meaning longer life
- 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 (2-stroke) with

2 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 bio-diesel may be more appropriate. Diesel fuel consumption appears similar across a range of machines reviewed.

- Increased noise of diesel engines

Commercial petrol 4-stroke engines have a typical efficiency of 20-30%, while commercial diesel engines have typical efficiency of 45%. Diesel has higher durability cf. petrol typically double lifetime. Diesel oil assists cylinder bore and piston ring lubrication reducing wear. Furthermore, diesel engine has greater weight, though it is offset by improved reliability), simplified controls (direct fuel injection, no electronic ignition), potentially high emission rates and offers bio-diesel 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[76]. This utilises a modification of the Otto cycle formerly deployed in automotive applications (Wankel engine) and claims a 20% reduction in fuel consumption and 30% reduction in material compared to conventional petrol combustion engines.

The HEHC 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.[77] Though this is BNAT for small machinery, it is not expected to have any importance for the developments of energy efficiency of HPCs in near future.

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 efficiency on boiler/burner that 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 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 water inlet of the temperature available and needed of the outlet water.

Improved heat exchanger (BAT)

The pressurised water is heated by circulating in a coil inside the burner chamber, see previous Figure **33**. 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 stand by losses from the tank and save energy. All tanks are insulated but a further improvement in insulation could yield savings in losses by typically 80% 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 ^{o}C) whilst maintaining maximum flow rate.

Use of waste heat from motor (BAT)

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

[77] http://liquidpiston.com/

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.

Spraying technology

Improved nozzle designs (standard / BAT)

Improved nozzle design improves the cleaning performance and may also yield water savings. The nozzle design includes 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 task need high water flow to remove loosened dirt and low water flow attachments cannot be used for these tasks.

Some top brands design their own improved-design nozzles, while low and medium brands normally purchase it from the suppliers.

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

Water and consumables efficiency

Use of water saving attachments (BAT)

See above under improved nozzle designs.

Use of alternative water resources (standard)

Some HPCs have self-priming pumps and can use other water sources 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 standard option for commercial car wash machines

Precise detergent regulation (BAT)

Detergent consumption can be improved by a better regulation of the amounts of detergent added to the water and better instruction to the users.

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 products 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.

Figure 51. Two examples of pressure control. The example to the left is an advanced regulation via a display, while the example to the right is a manually settable pressure regulation.

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, losses control from the hydraulic circuit, maintenance time, temperature control.

An example of best of class controls may be seen in HPCs that include mode selection and matching 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.

Resource efficiency

Design improvements (standard / BAT)

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

- Use of materials which provided longer 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 break down 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
- Use of recycled materials for packaging materials

Furthermore, dedicated user information regarding use, maintenance and storage under no-use may increase 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 later task.

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

The list of the main components of the typical products have been identified according to different data sources[78,79,80,81,82,83], expert judgment and stakeholder input. In Table 39 this list is provided for each typical 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[84] 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 product weight declared 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 what shown in an LCA study done in 1998[78], where the weight of the product assessed was 6.135 kg including packaging. However, the study doesn't show the performance parameters of the product assessed.

Table 39. List of components and materials for the typical domestic and professional HPC

Component	Materials
Motor[79]	Steel, aluminium sheet/extrusion, copper winding wire, plastics types

[78] 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.
[79] EUP Lot 11 Motors. Final report. 2008. University of Coimbra (Task 4).
[80] Pressure washers description. Accessed June 2018: https://www.explainthatstuff.com/pressurewashers.html
[81] 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).
[82] Review study on vacuum cleaners – Draft interim report. Viegand Maagøe and VHK. January 2018. Available at: https://www.review-vacuumcleaners.eu/documents
[83] Kãrcher 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
[84] http://www.ultimatewasher.com/electric-pressure-washer/index.htm

Component	Materials
Water pump & piston chamber[81]	Stainless steel, brass, aluminium, different plastics types
Housing[78,83]	ABS, other plastics types
Water inlet[85]	PP, brass, other plastics types
High-pressure hose[78,80,83]	HDPE, stainless steel, brass, PVC, different plastics and rubber types
Cleaning attachment (i.e. lance) [78,80]	Brass, stainless steel, different plastics types
Detergent hose and tank[78,80,83]	HDPE, PVC, PP, LDPE
Fuel tank	HDPE
Burner	Steel, aluminium, brass, ceramic, copper, different types of refractory materials
Electric cable & plug[82]	PVC, copper winding wire
Casing[78,82]	ABS, HI-PS, steel sheet, other plastics types
Wheels[82]	PP, other plastics types and rubber
Safety components[78]	Brass, stainless steel, different plastics types, aluminium
Integrated circuit board[82]	ICs avg., 5% Si, Au
Packaging[86]	LDPE, cardboard, wooden pallet

The material composition has been classified according to the resource use input required in Eco – Modelling Framework Tool.

[85] 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
[86] Expert judgment

Table 40. 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
Ferro (kg)	3.88	14.94
Non-ferro (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
Ferro (%)	26.4	44.8
Non-ferro (%)	27.3	24.4
Electronics (%)	0.2	0.1
Misc. (%)	10.2	6.7
TOTAL WEIGHT INCL. PACKAGING (%)	**100**	**100**

Overall, it can be noticed a dominance of bulk plastics and metals (ferro and non-ferro) 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 in comparison to other material groups. Whilst for professional high pressure cleaners, it is the ferro metals. According to desktop research[87], this is because professional cleaners typically use larger and heavier motors as they provide more power compared to the smaller motors in the 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 the 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 into 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 transport. They are then sorted by the end-user and sent for disposal. Cardboard is generally well sorted, collected and recycled both at households and business. Low density plastic is likely to be incinerated with different percentages of energy recovery throughout the EU.

87 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 the 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, sub-assemblies and finished products

For distribution it is assumed that 70% of the 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, it is assumed a transport distance of 10,000 km by ship and 3,000 km by truck and for cleaners transported only by truck, it is assumed a transport distance of about 3,400 km (conservative assumptions considering the many transport scenarios). However, transport by ship and by truck are often negligible in life cycle assessments since the impact often is small compared to the environmental impact of the rest of the product.

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

Caspersen and Sørensen[78] established an end-of life materials distribution for packaging, plastic and metal materials as it is shown in Table 41.

Table 41. End-of life scenarios according to Caspersen and Sørensen[78].

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. E.g. the default values for the relevant material groups shown in Table 39 in the Eco – Modelling Framework Tool are shown in Table 42, which have been adapted slightly to reflect scenario routes for the vacuum cleaners review study[82] and those used for the water pumps review study[81]. 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 it can be seen from both tables, the share of relevant materials to landfill has been greatly reduced from the 1998 study, while fractions to re-use/recycling are quite different (probably because in the 1998 study re-use accounted for material recycling).

End-of-life routes shown in Table 42 are those to be considered as input data for modelling in the Eco – Modelling Framework Tool, but they will be reviewed with stakeholders to assure consistency. Moreover, differences may exist between domestic and professional products which will be consulted with stakeholders.

Table 42. Default end-of-life routes for relevant material groups in EcoReport tool (version 3.06).

End-of-life route	Bulk & Tec plastics	Ferro & Non-ferro	Electronics	Misc. (packaging)
EoL mass fraction to re-use	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 performed by a stakeholder of 42 domestic HPCs, 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 get defective
- The bearings of the pump get defective
- Water leakages

Consumer surveys carried out by Which?[88] revealed that common problems were:

- Water leaks from the HPC body 30%
- Lance failed 17%
- Loses pressure 15%

Which? stated that some of the problems were caused by not properly use. E.g. water leaks frequently appear after a pressure washer has been left idle over the winter and is 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 it might also be problems related to the low use for example valves and seals in motors and pumps. Blockage of inlet filter and of 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, where the pump needs to be refurbished or replaced. Leaving water in the pump can result in mineral build-up and corrosion; this means that high pressure cleaners that are not use on a daily or very regular basis should be emptied from water. The product should also be protected against freeze damage.

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

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

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:

- 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 a applicable
- For 18.102 the machine is operated under normal operation and at rated voltage for 96h**.**
- 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 10s 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

- Most of the technical measures for reducing in-use consumption of energy, water and detergent require design changes or different components, which would be too expensive compared to the marginal gains due to infrequent usage pattern for domestic products, and even for some of the professional products.

Opportunities

- Existing Ecodesign measure for electric motors and pumps do not apply to single phase motors and pumps used in domestic HPCs and part of the professional HPCs. Therefore, there is an opportunity to develop measures for those components.
- Differences in water and energy consumptions 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.

ANNEXES
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	What the source of energy powering water pump of the appliance: • Electrical – Mains • Electrical - Battery • Combustion – Petrol • Combustion – Diesel • Hydraulic or Pneumatic What 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)

Parameter	Definition	Source (Standard (Clause))
Maximum Flow rate (l/m)	The highest possible flow rate at the nozzle. Typically, the maximum flow rate occurs at working pressures lower than rated pressure and with a nozzle designed for spraying of cleaning agents.	EN 60335-2-79 (3.106)
Area performance (m2/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
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 form 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

Parameter	Definition	Source (Standard (Clause))
Application	No formal definition. A relative term for describing how the HPC is used and to provide a relative indication of 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 the 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)
Maximum supply feed length	No formal definition – only applicable if pressure drop via long hose cause performance degradation.	-

Parameter	Definition	Source (Standard (Clause))
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 but which 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 (%)												
geo\time	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	:	:	:	:	:	:	:	:	:	:	:	:
Former Yugoslav Republic of Macedonia, the	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

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