Review study on Vacuum cleaners

Final report

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1. Preface

This Final report for the review study of the Ecodesign Regulation[1] and the annulled Energy Labelling Regulation[2] for vacuum cleaners is the final delivery of the specific contract. As specified in the contract the Final report concerns all tasks of the MEErP methodology and includes recommendations for the revision of these regulations.

Task 1 outlines the scope of the regulations and of the review study as well as the relevant standards and legislation related to vacuum cleaner energy consumption, durability and resource efficiency.

Task 2 gives an overview of the vacuum cleaner market including sales, stock and base data on consumer costs, as well as an overview of market development trends and production structures.

Task 3 regards the user behaviour, especially looking at robot and cordless vacuum cleaners in order to suggest representative testing and energy consumption calculation at later stages of the study. Furthermore, the end-user relevance of the current test standards is discussed.

Task 4 reviews the technical aspects of vacuum cleaners as products, and outlines the current technology levels in terms of average and best available technologies, on both component and product level. Besides the energy consumption effect, the technologies are also reviewed in terms of resource efficiency.

Task 5 defines the base cases and the environmental and economic impact of each of them. The environmental impact is both the energy consumption in the use phase as well as the material consumption and impact categories are given in the EcoReport tool. The environmental impact is calculated as the product life cycle cost for the end-user for each base case.

Task 6 outlines the design options for improving the environmental performance of the base cases without causing excessive costs for the end-users. Design options are outlined for both energy and resource efficiency improvements.

Task 7 defines policy options for each base case based on the viable design options and presents the results on the scenario analyses that estimates the environmental and economic impact of each of the policy options.

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[1] OJ L 192, 13.07.2013, p. 24-34, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R0666
[2] OJ L 192, 13.07.2013, p. 1-23, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R0665

The specific aspects to review according to article 7 of the Ecodesign Regulation and of the annulled Energy Labelling Regulation are:

- The review of the ecodesign regulation in light of technological progress;
- The review of verification tolerances to be used by Member State authorities for market surveillance purposes;
- whether full size battery operated vacuum cleaners should be included in the scope and
- whether it is feasible to use measurement methods for annual energy consumption, dust pick-up and dust re-emission that are based on a partly loaded rather than an empty receptacle.

It should be noted that this review study was begun before the General Court decision to annul the Energy Labelling Regulation 665/2013[3] on November 8, 2018, which took effect on 18 January 2019. The report therefore includes a review of this regulation, including the evaluation of its effect according to the better regulation principles. Furthermore the available market data and development observed in energy efficiency reflects the situation as it has been with the energy label. Even though the Energy Label is now annulled, it was in force from 2014 to January 2019, which is of course reflected in the data. Therefore the text refers to "Regulations" in the plural, because it was in force during the period that was studied.

[3] https://curia.europa.eu/jcms/upload/docs/application/pdf/2018-11/cp180168en.pdf

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5. List of abbreviations

Abbreviation	Full name
ABS	Acrylic Butadiene Styrene
AC/DC	Alternating Current/Direct Current
ACD	Approved for Committee Draft
AE	Annual Energy Consumption (kWh/year)
ANEC	European consumer voice in standardisation
ASE	Average Specific Energy (Wh/m^2)
B2B	Business to Business
BAT	Best Available Technology
BAU	Business as Usual
BC	Base Case
BEP	Best Efficiency Point
BEUC	Bureau Européen des Unions de Consommateurs
BNAT	Best Not Available Technology
GDP	Gross Domestic Product
BOM	Bill-of-Material
Brushless DC (BLDC)	Brushless Direct Current [motor]
CD	Committe Draft
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CLC/TC	Technical Committe
Co	Cobalt
CO_2-eq	Carbon Dioxide Equivalent
CPU	Central Processing Unit
CRM	Critical Raw Material
dB	Decibel
dB(A)	Decibel (Average)
DC	Direct Current
dm^3	Cubic Decimetre
DoD	Depth of Discharge
dpu	Dust Pickup
dpu_c	Dust Pickup (carpet)
dpu_{hf}	Dust Pickup (Hard Floor)
dre	Dust Re-Emission
EC	European Commission
EC	Electronically Communicated [motors]
ECCP	European Climate Change Programme
ECOS	European Environmental Citizens Organisation
EEB	European Environmental Bureau
EEE	Electrical and Electronic Equipment
EI	Energy Index
EMC	Electromagnetic Compatibility Directive
EoL	End of Life
EPA	Efficiency Particulate Air filter

EPS	Expanded Polystyrene
EPS	External Power Supply
ErP	Energy-related Product
EU	European Union
EuP	Energy-using Product
EUR	Euro
Eurostat	European Statistical Office
GfK	Growth from Knowledge
GHG	Greenhouse Gas
gp	General Purpose [50% c + 50% hf]
GPSD	General Product Safety Directive
GWP	Global Warming Potential
HEPA	High Efficiency Particulate Air filter
HPLV	High Pressure Low Volume
HREE	Heavy Rare Earth Elements
HS	Harmonized Commodity Description and Coding Systems
HVAC	Heating, Ventilation, and Air Conditioning
IA	Impact Assessment
IC	Integrated Circuit
ICRT	The Consumer Test Institute
IEC	International Electrotechnical Commission
IR	Infrared
ISO	International Organization for Standardization
JRC-IES	Joint Research Centre - Institute for Environment and Sustainability
kg	Kilogram
kPa	Kilopascal
kt	Kiloton
L/s	Liters per Second
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCI	Labour Cost Index
LD-PE	Low Density Polyethylene
Li-ion	Lithium-ion
LLCC	Least Life Cycle Cost
LREE	Light Rare Earth Elements
LVD	Low Voltage Directive
m	Meter
M	Mandatory
m/s	Meters per Seconnd
m^2	Square Meter
m^3	Cubic Meter
MEErP	Methodology for Ecodesign of Energy-related Products
MJ	Megajoule
mm	Millimeter
MPPS	Most Penetrating Particle Size
Mt	Megaton

N	Newton
NACE	Classification of economic activities issued by the European Commission [Nomenclature statistique des activités économiques dans la Communauté européenne]
NCA	Lithium nickel cobalt aluminum oxide (Li-ion battery)
NiCd	Nickel–Cadmium [battery]
Ni-MH	Nickel Metal Hydride [battery]
NMC	Lithium Nickel Manganese Cobalt Oxide [battery]
OE	Operating Expense
OEM	Original Equipment Manufacturer
PAH	Polycyclic Aromatic Hydrocarbons [battery]
PAS	Publicly Available Specifications
PCB	Printed Circuit Board
PE	Polyethylen
PE-HD	Polyethylen High Density
PET	Polyetylentereftalat
PLF	Part Load Factor
PGM	Platinum Group Metal
PJ	Petajoule
PM	Permanent Magnet [motor]
PO	Power Output
PP	Polypropylene
PP	Purchase Price
PRIME Project	Power-efficient, Reliable, Many-core Embedded systems
PRODCOM	PRODuction COMmunautaire
PS	Polystyren
PWF	Present Worth Factor
Qty	Quantity
RAM	Random Acces Memory
RCF	Room Coverage Factor
REACH	The Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals
RoHS	The Restriction of Hazardous Substances
RPM	Rounds per Minute
RPS	Rounds per Second
RR	Round Robin
RRT	Round Robin Test
SDA	Small Domestic Appliance
SLAM	Simultaneous Localisation and Mapping
SME	Small and Medium-sized Enterprise
SoC	System-On-Chip
SRM	Switched Reluctance Motor
STM32 MCU	32-bit Microcontroller Unit

SVHC	Substances of Very High Concern
TWh	Terawatt Hour
UAP	Unique Acceptance Procedure
ULPA	Ultra Low Penetration Air Filter
UV	Ultraviolet
V	Voluntary
VAT	Value-added Tax
VC	Vacuum Cleaner
VTS	Visual Tracking System
W	Watt
WEEE	Waste Electrical and Electronic Equipment
WIFI	Wireless Fidelity
WOL	Wake-up On LAN
YTD	Year to Date

6. Summary

6.1 Background

The Commission's Regulation[4] (EU) No 666/2013 on Ecodesign requirements for vacuum cleaners and the annulled Regulation[5] (EU) No 665/2013 on Energy Labelling of vacuum cleaners entered into force on 2 August 2013, with the first Ecodesign requirements and energy label classes A to G applicable from 1 September 2014. The second tier of Ecodesign requirements and the energy label classes A+++ to D were applicable from 1 September 2017. The Energy Labelling Regulation (EU) No 665/2013 was annulled with effect from 8 November 2018[6].

The objective of the Regulations is to ensure the placing on the market of technologies that reduce the life-cycle environmental impact, leading to estimated annual electricity savings of 19 TWh by 2020, corresponding to 6 Mt CO_2-eq, according to the Impact Assessment[7].

The Ecodesign Regulation was amended by the horizontal Regulation (EU) 2016/2282 with regard to the use of tolerances in verification procedures, while the annulled Energy Labelling Regulation was amended by two horizontal regulations: Regulation (EU) 518/2014 regarding labelling of energy-related products on the internet and Regulation (EU) 2017/254 regarding the use of tolerances in verification procedures. The horizontal Regulations apply to all products covered at the time by Ecodesign and Energy Labelling Regulations.

Reference to the harmonised standards for the Ecodesign Regulation and the Energy Labelling Regulation was published in the Official Journal of the European Union, C 272, 20 August 2014[8]. In addition to the harmonised standard a standardisation request (M/540[9]) was issued the European standardisation organisations to further develop the test methods. Furthermore Guidelines accompanying the Regulations were published in September 2014[10].

A special review study was performed in 2016 by Van Holstein en Kemna (VHK) regarding the specific Ecodesign requirements on the durability of the hose and the operational motor lifetime, but without changing the content of the Regulation. Therefore, the results from

[4] L 192 of 13.7.2013
[5] OJ L 192 of 13.7.2013
[6] https://curia.europa.eu/jcms/upload/docs/application/pdf/2018-11/cp180168en.pdf
[7] COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT (2013) with regard to Ecodesign requirements for vacuum cleaners and the Energy Labelling of vacuum cleaners. http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2013/swd_2013_0240_en.pdf
[8] OJ 2014/C 272/6, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:C:2014:272:TOC
[9] http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=561
[10] https://ec.europa.eu/energy/sites/ener/files/documents/Manufacturer%20guide%20-%20vacuum%20cleaners.pdf

the special review study will be used in the present study when assessing the need for revising the durability requirements in the Ecodesign Regulation.

The review study of the Ecodesign Regulation EU 666/2013 and the annulled Energy Labelling Regulation EU 665/2913 with regard to vacuum cleaners was started in July 2017. The study follows the MEErP methodology and reviews the scope and Ecodesign requirements as well as the labelling classes, in light of current developments in the market concerning technologies, energy efficiency levels and resource efficiency.

6.2 Scope

The scope of the review study follows the scope of the Ecodesign Regulation and the annulled Energy Labelling Regulation for vacuum cleaners with the addition of cordless and robot vacuum cleaners, as seen in Figure 1. In defining the scope, it was found that there is a need for a redefinition of the current "full size battery operated vacuum cleaner" in order to properly capture the current European market. It is therefore suggested to add a definition for cordless vacuum cleaners and split it into two or three categories based on the size and intended use. The following definitions are suggested:

Cordless vacuum cleaner means a vacuum cleaner powered only by batteries, other than robot vacuum cleaners;

Cordless cleaners not intended for floor cleaning:

Handheld vacuum cleaner means a lightweight cordless vacuum cleaner with cleaning head, dirt storage and vacuum generator integrated in a compact housing, allowing the cleaner to held and operated whilst being held in one hand;

Cordless vacuum cleaners intended for floor cleaning:

Cordless floor vacuum cleaner means a cordless vacuum cleaner that can be used for cleaning floors from an upright standing position, including handhelds fitted with any tubes, aggregates or similar that makes it possible to use them for cleaning floor from an upright standing position;

Some of the vacuum cleaner types shown in Figure 1, particularly upright and cylinder types, can be either bagged or bagless, i.e. using a single-use bag to collect and store the dust (bagged) or a reusable container (bagless). However, it is not suggested to change the definitions of the vacuum cleaner types in the mains-operated group and thus not to include definitions of bagged and bagless cleaners in the regulations, since the same requirements should apply.

Figure 1: main types of vacuum cleaners included in the scope of the review study

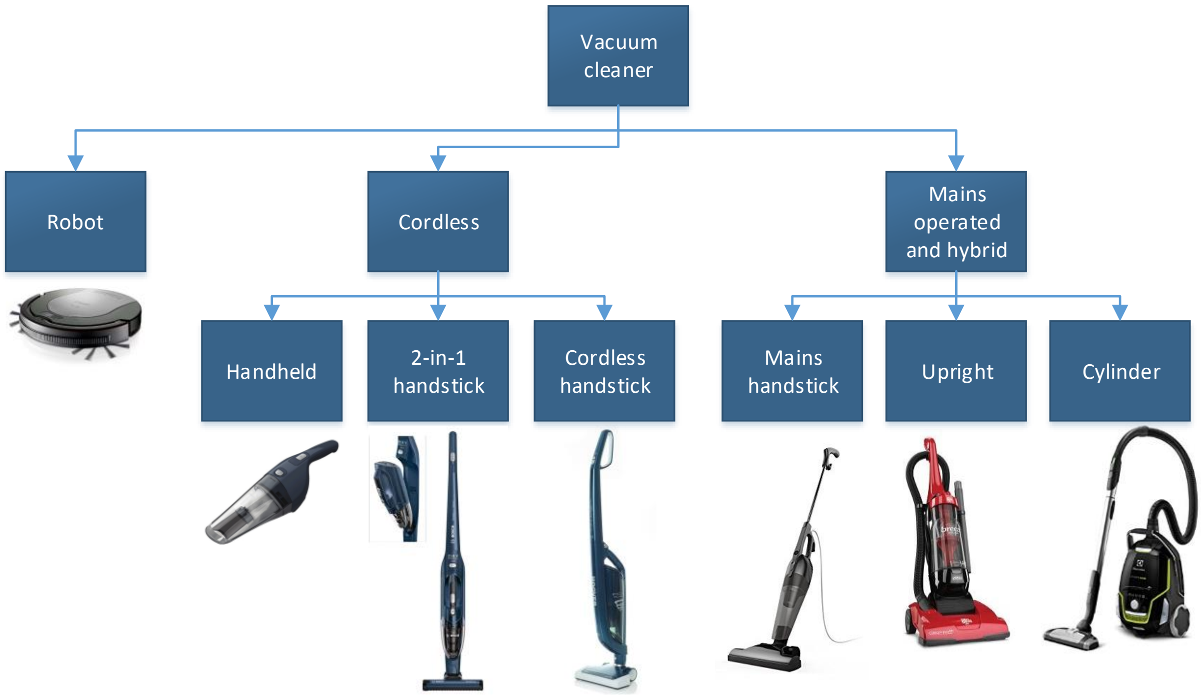
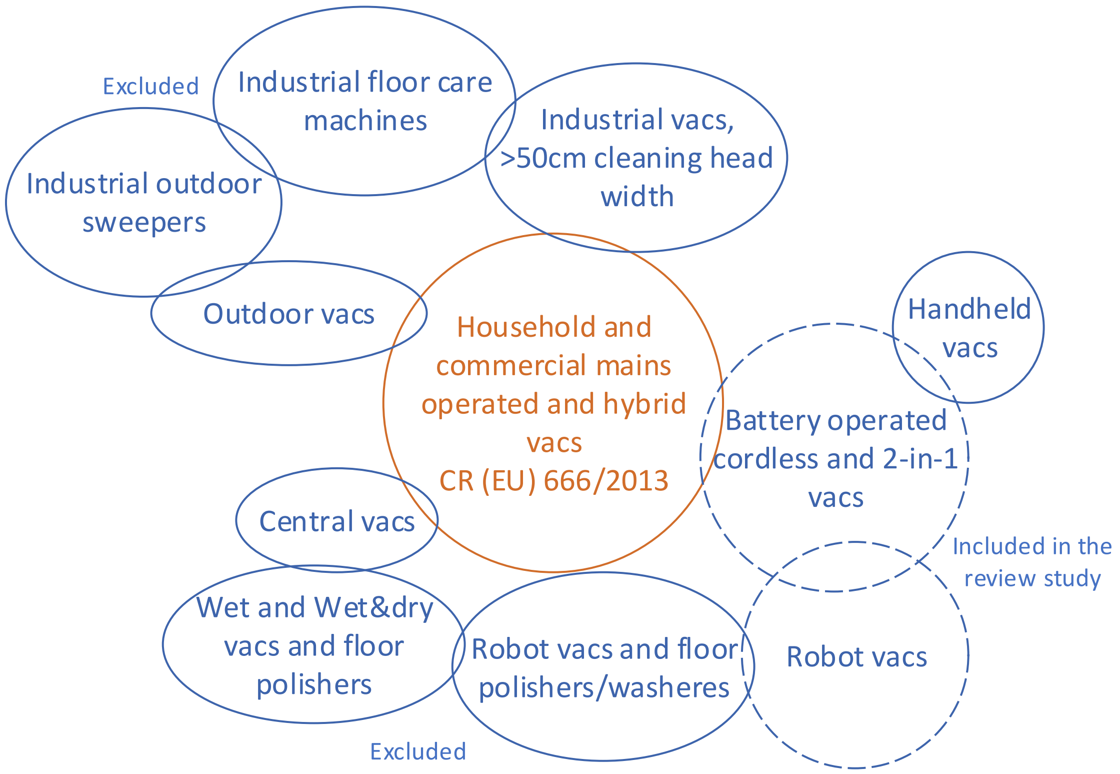


Figure 2: Scope of the Commission Regulation (EU) 666/2013 regarding ecodesign for vacuum cleaners. (Legend: CR=Commission Regulation, Vacs=Vacuum Cleaners)



6.3 Standardisation and legislation

New legislation has entered into force since the 2009 preparatory study for vacuum cleaners, the most important in terms on influence on this study are the WEEE Directive[11] regarding management of electronic and electrical waste and the EPS (External Power Supply)[12] and Standby Regulations[13], which are important for battery operated vacuum cleaners. Furthermore, the 2016 circular economy package[14] entails that an assessment of resource efficiency should be included in Ecodesign and Energy Labelling studies.

Work is also ongoing to improve the standards developed in relation to the Ecodesign and Energy Labelling[15] requirements for vacuum cleaners under standardisation request M/540 of 2015[16]. The improvement of existing standards regarding energy consumption, sound power level and dust pick-up on market-representative hard floors and carpets are carried out in CEN/CENELEC working group 6 (CLC TC59X/WG06).

Furthermore, new standards are under development at both IEC and CEN/CENELEC level for robot and cordless vacuum cleaners. The development of a standard for robot vacuum cleaners was started in 2009 and is handled in IEC SC 59F WG5, and is monitored by the CENELEC working group. The first standard on "Cleaning robots for household use – dry cleaning: methods for measuring performance" was published in July 2014. Work on the next edition of the standard was started in 2015 under IEC 62885-7 with the name "surface cleaning appliances – part 7: dry-cleaning robots for household use – methods for measuring performance", set to be published in July 2020[17]. The new standard will include the following tests:

- Dust pick- up from carpets and hard floor in a straight-line movement;
- Autonomous navigation/coverage test in a test room;
- Obstacle overcome capability in a test room;
- Energy consumption;
- Debris and/or other coarse particles: Straight line;
- Fibre pickup.

In addition, work on a standard for noise measurement of robot vacuum cleaners has begun in IEC 60704-2-17. Tests on corner/edge dust pick-up, multi zone navigation, and dust re-emission have been postponed. A preliminary RRT (Round Robin Test) has been conducted for the tests mentioned above, but the evaluation of the results is still ongoing.

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11 http://ec.europa.eu/environment/waste/weee/legis_en.htm
12 OJ L 93, 7.4.2009, p. 3–10
13 OJ L 225, 23.8.2013, p. 1–12
14 http://www.europarl.europa.eu/EPRS/EPRS-Briefing-573936-Circular-economy-package-FINAL.pdf
15 The previous, annulled Energy Labelling Regulation
16 http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=561#
17 https://www.iec.ch/dyn/www/f?p=103:23:0::::FSP_ORG_ID:1395

For cordless vacuum cleaners the standardisation work is carried out at IEC level by IEC SC 59F WG 7, "IEC 62885-4 ED1: Surface cleaning appliances - Part 4: Cordless dry vacuum cleaners for household or similar use - Methods for measuring the performance"[18]. and results are monitored by the European working group. The test parameters in the new standard include:

- Energy consumption of the batteries; and
- Run time while maintaining reasonable suction power.

6.4 Market data

Vacuum cleaner market data was purchased for the review study from GfK, which included sales data for the years 2006-2016, as well as performance data based on the annulled energy label for the years 2013-2018. From the sales and expected lifespans, the stock was calculated.

Since the market shares of the different vacuum cleaner types are only available for the years 2013 to 2018, the market split was extrapolated to 2030. Assumptions were made for the continued development of the market shares for 2025 and 2030 based on stakeholder inputs, with linear interpolation of market shares in the years between. This yielded the market shares shown in Table 1. The 2005 market split was calculated from the preparatory study data[19], and is assumed unchanged for all years prior to 2005.

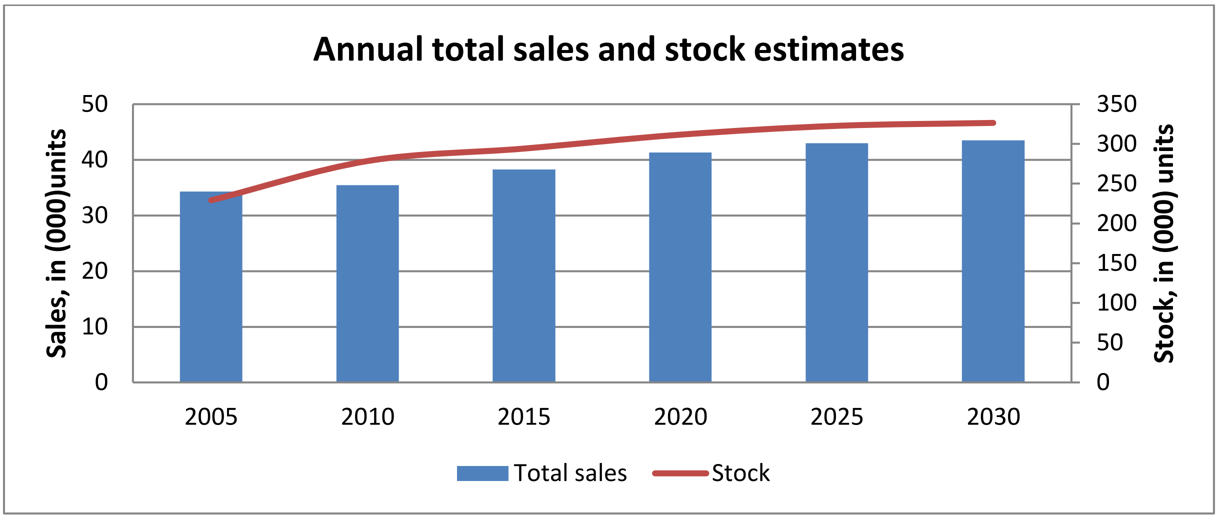
Table 1: Derived sales of each vacuum cleaner type from 1990 to 2030

Sales in millions	1990	2000	2005	2010	2015	2018	2020	2025	2030
Cylinder domestic	14.81	16.92	25.01	25.28	25.07	23.43	22.06	17.88	12.07
Cylinder commercial	1.78	2.03	3.00	3.03	3.01	2.95	2.95	2.95	2.95
Upright Domestic	2.61	2.99	4.41	3.44	2.91	2.60	2.56	2.38	2.01
Upright Commercial	0.31	0.36	0.53	0.41	0.35	0.31	0.31	0.31	0.31
Handstick mains	0.30	0.34	0.50	0.91	1.25	1.66	1.87	2.38	3.22
Handstick cordless	0.51	0.59	0.87	1.56	4.24	7.39	9.11	13.51	18.10
Robot	0.00	0.00	0.00	0.79	1.45	2.00	2.45	3.58	4.83
Total	20.32	23.22	34.33	35.43	38.28	40.35	41.32	43.00	43.49

The sales and stock numbers for the entire vacuum cleaner market in scope of this study, is seen in Figure 3 for the years 2005-2030.

[18] http://www.iec.ch/dyn/www/f?p=103:30:0::::FSP_ORG_ID,FSP_LANG_ID:1395,34q
[19] Preparatory Studies for Eco-Design Requirements of EuPs (II), Lot 17 Vacuum cleaners, TREN/D3/390-2006, Final Report February 2009, carried out by AEA Energy & Environment, Intertek, and Consumer Research Associates between November 2007 and January 2009. https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/vacuum-cleaners/vacuum-cleaners-ecodesign-study-final-report-eup-lot-17-final-report.pdf

Figure 3: Annual sales and stock numbers for the total vacuum cleaner market 2005-2029



The total stock is split between the different vacuum cleaners as shown in Table 2.

Table 2: Stock of different vacuum cleaner types in the EU

Stock, million units	2005	2010	2015	2020	2025	2030
Cylinder domestic	209.97	217.34	213.00	206.71	179.59	140.38
Cylinder commercial	16.72	16.94	16.58	16.38	16.25	16.25
Upright Domestic	34.02	28.54	25.08	23.59	21.45	19.42
Upright Commercial	2.61	2.07	1.85	1.78	1.74	2.14
Handstick mains	5.40	8.36	10.66	12.32	16.77	22.37
Handstick Cordless	7.55	14.19	28.01	39.19	68.58	98.07
Robot	2.21	6.71	9.48	11.69	18.38	27.82
Total	**278.48**	**294.15**	**304.66**	**311.65**	**322.75**	**326.44**

With around 220 million households in EU28 in 2016[20], the penetration rate is 1.3 vacuum cleaners per household, which is lower than in the 2009 preparatory study and 2013 impact assessment due to differences in the scope of the data, but fits with a consumer survey performed by the industry organisation APPLiA[21] in collaboration with InSites Consulting[22] in 2018.

6.4.1 Energy and performance

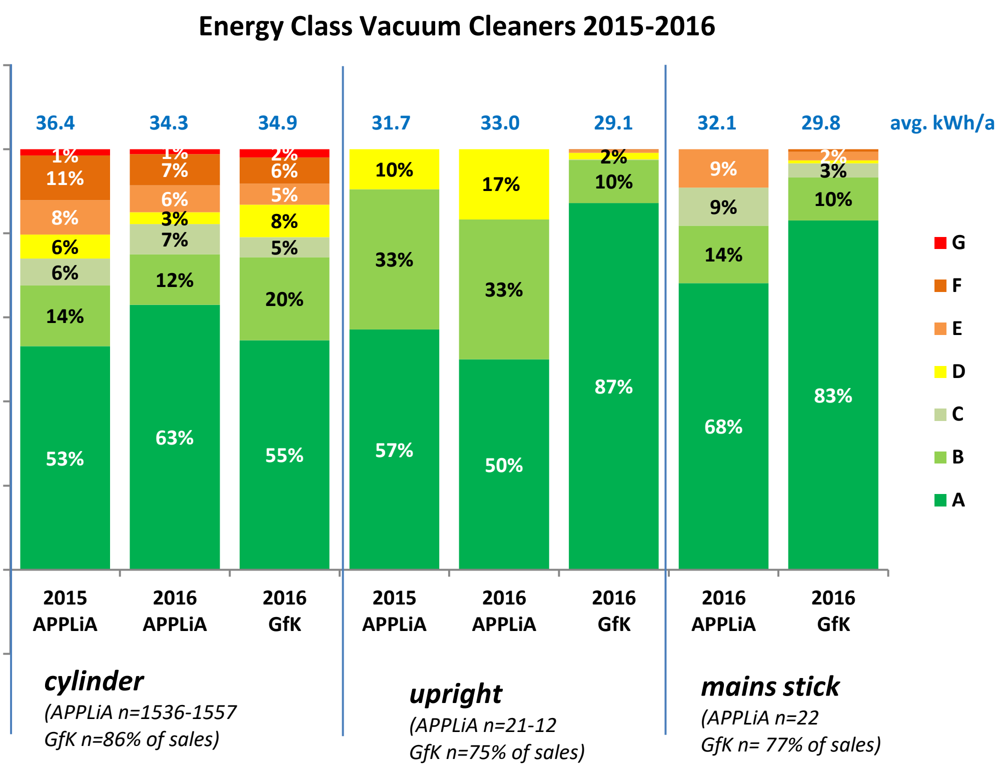
Regarding energy consumption, it is seen from the available market data that the energy consumption of all regulated types of vacuum cleaners have decreased around 40% from introduction of the Ecodesign and the annulled Energy Labelling Regulations in 2013 to 2018. In the same period the performance of vacuum cleaners in terms of dust pick-up

[20] The latest year with data from Eurostat: https://ec.europa.eu/eurostat/statistics-explained/index.php/People_in_the_EU_-_statistics_on_household_and_family_structures
[21] https://www.aplia.com/
[22] https://www.insites-consulting.com/

and dust re-emission improved as well with more than 50% of the vacuum cleaners being in dust pick-up class A on hard floor, corresponding to a dust-pickup of more than 111%[23].

In 2015 there were three cylinder models in the APPLiA database with an energy use of 20 kWh/year and class A. Their max power is 600 W, carpet cleaning performance C, hard-floor cleaning and dust-re-emission are class A. The best upright has an energy use of 27 kWh/year, which just puts it in the energy class A (ranging from 22-28 kWh/year). The best stick model is 23 kWh/year. The class distributions can be seen in Figure 4.

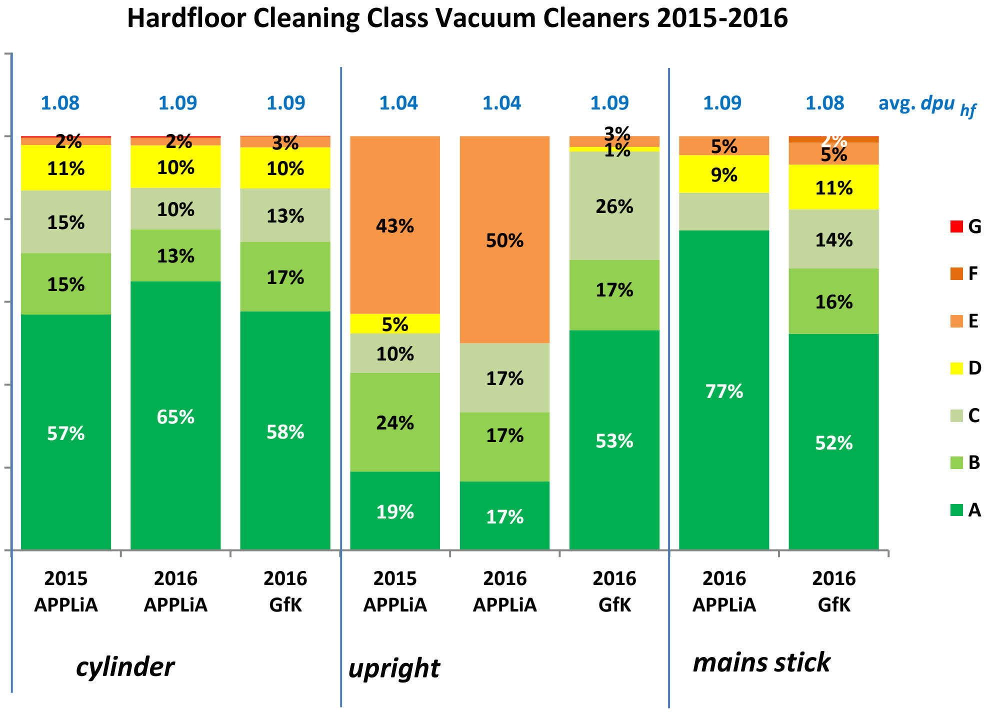
Figure 4: The previous, annulled Energy Label classification energy 2015-2016 (sources: APPLiA and GfK)



The GfK-picture for hard floor cleaning performance is similar to the one for energy: 52-58% of vacuum cleaners scored an A[24], 16-17% a B[24], for the uprights 26% featured a C[24] while for the cylinder it was only 13% with still a significant number in lower classes in 2016. This gives a reasonable match with the APPLiA data as seen in Figure 5. The sales-weighted average dpu_{hf} for mains-operated VCs, all types, is 1.08-1.09.

[23] Dust pick-up results of more than 100% is possible due to the design of the hard floor test as a crevice test, which is one of the test procedures that are under evaluation
[24] According to the previous, annulled Energy Labelling Regulation

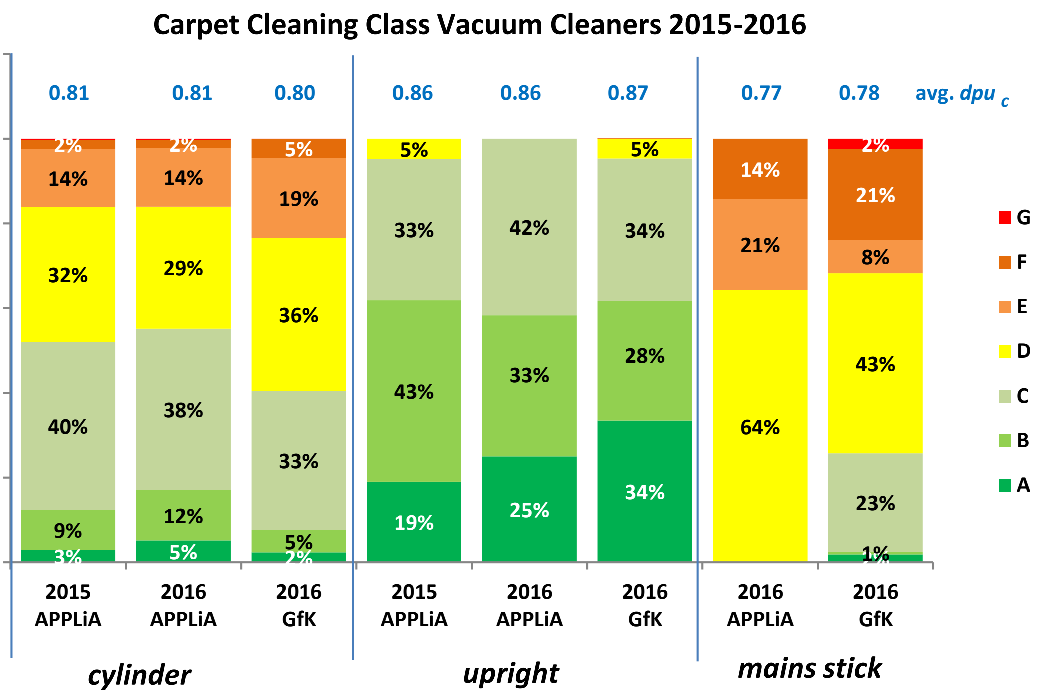
Figure 5: The previous, annulled Energy Label classification hard floor cleaning 2015-2016 (sources: APPLiA and GfK)



For carpet cleaning the situation is different from hard-floor cleaning: According to GfK only 3% of cylinder and mains-powered handstick achieved an A-class[25] rating versus 34% of the uprights in 2016. Especially taking into account the small sample size of uprights these results are similar to those in the APPLiA data-base.

[25] According to the previous, annulled Energy Labelling Regulation

Figure 6: The previous, annulled Energy Label classification carpet cleaning 2015-2016 (sources: APPLiA and GfK)

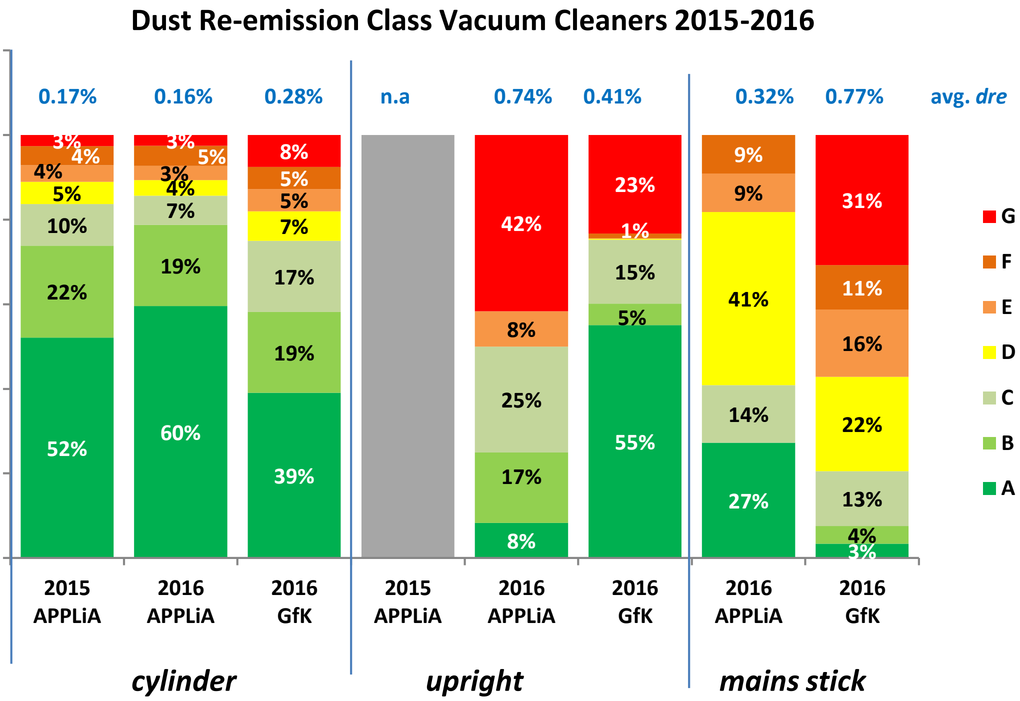


For dust re-emission the classification of cylinders and sticks by APPLiA is similar to that found by GfK, but for uprights it is completely different. In fact, GfK finds that more than 55% of uprights have a class A[26] dust re-emission score, whereas only a few (8%) of upright vacuum cleaners in the APPLiA database have an A[26].

It is difficult from these data to find a convergent value for dust re-emission of all types, but –giving more weight to the more conservative GfK data— a *dre* value of 0.3% for the average mains-operated VC in 2016 is believed to be representative.

[26] According to the previous, annulled Energy Labelling Regulation

Figure 7: The previous, annulled Energy Label classification dust-re-emission 2015-2016 (sources: APPLiA and GfK)



6.4.2 Product prices

The retail prices for household vacuum cleaners were derived from purchased data on sales volume and value, and the data shown in Table 3 is the overall sales weighted average in EU-28. This average, however, covers a large price range as seen from consumer organisation tests, where between 69 € and 350 € are reported for cylinder vacuum cleaners and robot vacuum cleaners are found at prices up to 700 €. Commercial cleaners are often sold business-to-business and as part of larger agreements with an estimated price by manufacturers around 100 € lower than the retail prices. The prices shown in Table 3 are the online retail-prices.

Table 3: Unit retail prices in EUR vacuum cleaners, in 2018-prices for EU28

Unit prices, EUR	2005	2010	2013	2014	2015	2016	2018
Cylinder	133	119	110	112	121	119	120
Upright	210	184	169	177	196	171	168
Handstick mains	114	99	91	89	94	96	90
Sales weighted average of mains-operated vacuum cleaners	145	126	116	118	128	123	123
Commercial[27]	302	269	250	255	274	271	320
Handstick cordless	216	193	180	200	225	220	221
Robot	323	288	268	284	317	344	221

[27] Based on an online survey and prices from 58 different commercial vacuum cleaners.

6.5 Use patterns

In the calculation of annual energy consumption (AE) defined in the regulations, assumptions on cleaning habit are implicitly included. As seen from the current formula the assumptions are on number of strokes over the surface (4 strokes, or 2 double), surface area (87 m^2), and number of cleaning cycles per year (50):

$$AE = 4 * 87 * 50 * 0.001 * ASE * \left(\frac{1 - 0.20}{dpu - 0.20}\right)$$

The cleaning time was assumed in the 2009 preparatory study to be 1 hour, but the actual cleaning time depends on the dust pick-up of the vacuum cleaner. The formula assumes that the annual energy consumption increases as dust pick-up (*dpu*) decreases, because users will spend more time cleaning. The formula has been criticised in two ways. On the one hand, it has been argued that the *dpu* should not be included in the formula at all, but the performance should instead be a separate parameter and the energy class should be based on a direct energy measurement alone as it is for other products, e.g. washing machines. However, for washing machines the cycle time is a fixed parameter for each product, which is not the case for vacuum cleaners, where the time is dependent on the end-user and their perception of when the surface is clean.

Another point of criticism, as opposed to removing the *dpu* from the equation, is that it has too little weight in the equation, which means that improving performance in terms of *dpu* is not a good strategy for improving energy rating, but only choosing smaller motors is. However, the underlying idea of the Ecodesign Regulation and the annulled Energy Labelling Regulation is indeed to save energy, and the *dpu* on both carpet and hard floor are included in the Ecodesign Regulation and on the label itself to ensure that energy is not saved at the expense of good performance.

Based on the arguments and counter-arguments for the formula and the fact that there are still uncertainties related to the test methods, especially for dust pick-up, it is recommended not to change the formula in this revision of the Regulations, but instead focus on improving the test methods.

6.5.1 Commercial vacuum cleaners

Commercial dry vacuum cleaners are typically used for cleaning offices, shops, restaurants and hotels. The AE for commercial vacuum cleaners is calculated using the same formula shown above in the Regulations, even though they are used for many more hours each year than domestic vacuum cleaners. In this study it is assumed that they are used for 300 hours per year in average (compared to 50 hours per year for household cleaners).

During the review study a completely new calculation was suggested for the commercial vacuum cleaners, where instead of the annual energy the requirements and possible future energy label is based on an energy index instead. This would not include arbitrary factors such as the area cleaned or cleaning cycles per year, but instead express the productivity in m^2/min, which is more relevant to commercial users.

6.5.2 Cordless vacuum cleaners

The use pattern for cordless handstick vacuum cleaners is different than that of mains-operated vacuum cleaners, as they are intended to be used for shorter duration. A shorter duration of each cleaning cycle is therefore assumed, however the number of cleaning tasks per year is assumed to be higher. When the cordless cleaner is not cleaning or charging, it is left in 'charged and docked' or 'maintenance mode'. The assumptions regarding the use pattern per year are shown in Table 4. Charging times vs. cleaning times were based on test data from consumer organisations and online data collection.

Table 4: Use pattern for cordless vacuum cleaners

	Average time per week	Average time per year
Cleaning (standby of dock without cordless)	73 minutes[28]	63 hours
Charging	13 hours	671 hours
Charged and docked	158 hours	8026 hours

In order to calculate the energy consumption of cordless vacuum cleaners in a way similar to that of mains-operated vacuum cleaners, the above use hours and the charged and docked consumption is included in the calculation, and the energy used for cleaning is based on the re-charging energy, i.e. including the efficiency of the dock and charger.

6.5.3 Robot vacuum cleaners

As robot vacuum cleaners work autonomously and can be set to start on a timed schedule or via an app, the number of cleaning cycles per year is assumed to be higher than both mains-operated and cordless cleaners, which are both operated by a person. Also, the cleaning time is longer for a robot, both because it often takes a long time to cover a given surface area and because it will often be programmed to clean until the battery is almost discharged. The assumptions for annual use hours for robot cleaners are shown in Table 5 and will be used in the energy calculations, including the charged and docked consumption. Charging times vs. cleaning times were based on test data from consumer organisations and online data collection.

[28] Based on the APPLiA 2018 consumer survey results for mains operated vacuum cleaners, and assumed to be similar for the sake of the calculation.

Table 5: Use pattern for robot vacuum cleaners

	Average time per week	Average time per year
Cleaning (standby of dock without cordless)	120 minutes	104 hours
Charging	4.4 hours	211 hours
Charged and docked	162 hours	8445 hours

Here the dust pick-up effect on cleaning time (and thus energy) cannot be related to the number of double strokes (i.e. the 0.2 factor), but instead the dpu is related to the average market dpu (i.e. the base cases defined in task 4).

6.5.4 End of Life behaviour

The end of life behaviour, in terms of how obsolete vacuum cleaners are handled, is based on average statistics of small household equipment in the EU, as vacuum cleaners identify as such. The average collection rate for the EU was below 40% in 2014[29]. The collection rate should be improved to 65% in 2019 according to the WEEE directive. The low collection rate of vacuum cleaners cannot be addressed exclusively in the Ecodesign Regulation but should be addressed by each EU country who should decide how to fulfil their obligations under the WEEE directive.

The most common failures of both upright vacuum cleaners and cylinder vacuum cleaners are related to suction and blocked filters as shown in Table 6. These problems can be interconnected and also related to the lack of maintenance as filters should be changed regularly.

Table 6: The top fault rates (above 10%) and causes for upright and cylinder vacuum cleaners[30].

Upright vacuum cleaners, Faults experienced	%
Suction deteriorated	24.3%
Blocked filters	21.7%
Belt broken (drive-belt rotating brush)	16.9%
Split hose	13.7%
Motor broken	13.4%
Brush not working properly	12.0%
No suction	10.0%

Cylinder vacuum cleaners, Faults experienced	%
Suction deteriorated	19.5%
Blocked filters	17.8%
Other	15.7%
Broken accessories	12.2%
Brush not working properly	10.8%
Casing cracked/chipped/broken	10.1%

[29] 2014 data is the latest available for Europe: https://www.eea.europa.eu/data-and-maps/indicators/waste-recycling-1/assessment
[30] https://www.vhk.nl/downloads/Reports/2016/VHK%20546%20FINAL%20REPORT%20VC%20Durability%20Test%2020160623.pdf

6.5.5 Consumer relevant testing

In order to give the best information to consumers as possible, it is important that test standards and measurement methods have a high degree of resemblance to the real-life use situation while repeatable and reproducible results are essential for comparability purposes. The former can be described as accuracy, i.e. a measure of how well the test reflects reality, whereas the latter can be described as precision, i.e. a measure of the variance in test results. There will almost always be a trade-off between the two, with more accurate test methods (closer to real life) lead to less precise results (lower repeatability and reproducibility).

There are several initiatives aiming at improving the current test standards for vacuum cleaners to achieve a more consumer relevant (accurate) testing and better repeatability and reproducibility (precision). Recently, a new WG 22 Ad-hoc Group Consumer relevant testing was established at CENELEC TC 59X to support standard makers in assessing standards to reflect 'real-life conditions' while also being suitable for producing measurement protocols with the required repeatability and reproducibility necessary to support legislation. Vacuum cleaners are among the examples mentioned in this draft document. These two parameters are highly co-dependent, as more complex and close-to-real-life tests will inadvertently become more complex and thus result in lower precision. While accuracy is important for the relevance of a regulation, the precision should not be compromised by complicating tests too much. A balance should thus be reached where the tests are as accurate as possible while maintain a high degree of precision.

The working group WG 6 at CENELEC TC 59X are working to improve the test standards and overcome issues with for example carpet type, motion resistance on carpet, debris tests, and receptacle load. These tests are not yet finalised and preliminary results of the round robin tests performed so far still show high uncertainty in measurements, especially between labs, i.e. low reproducibility.

Commercial vacuum cleaner manufacturers have proposed a new test standard for the commercial cleaners with another carpet types and which include debris test on hard floor in addition to the current crevice test.

In order to increases the consumer relevance of the testing, it is suggested to add a debris test to the hard floor crevice test and to the carpet dust pick-up test for both household and commercial vacuum cleaners. Settings/nozzles can be changed between carpet and hard floor test, but it should not be allowed to change the nozzle and nozzle setting for the two tests on the same floor type.

This is to ensure that the nozzle is designed to different types of cleaning on the same floor type (i.e. both dust and debris on carpet as well as dust and debris on hard floor) and is assumed to reduce or completely eliminate the current problems with test-optimised nozzles. The dust and debris pick-up should be reported separately, and only the dpu should be used in the AE calculations, in order to avoid too much focus on debris rather than deep cleaning, since according to technical experts from industry this is much easier to achieve higher values for.

6.5.6 Uncertainties of test methods

In addition to making the tests more consumer relevant, the standardisation groups have also been investigating the expanded uncertainties[31] of the dust pick-up methods, and results point to especially the carpet dust pick-up testing being a problem, because the expanded uncertainties are greater than the class width. This is not a problem for the energy measurements. This is also a problem for the hard floor crevice test and the dust re-emission test, even though it is not as significant.

In order to solve the issue in the short term, before new test methods can be developed and evaluated, a possible solution could be to reduce the number of dust pick-up classes to 4 and increase the class width, i.e. from A to D in a prospective new label regulation. This would make the expanded uncertainty smaller than the class width, and thus making verification easier. Introducing further test parameters to the tests might increase the uncertainty even further as would measuring with partly loaded receptacle.

6.6 Technology overview

Each component of a vacuum cleaner is important for the overall energy consumption and performance. In the report the following components are explained in depth:

- Motor;
- Fan;
- Receptacle;
- Filters;
- Hose;
- Nozzles;
- Batteries;
- Plug and power cord.

Based on this component analysis and data from APPLiA and GfK, the average technology and best available technologies were determined for each of the following vacuum cleaner types:

- Mains-operated household vacuum cleaners;
- Commercial vacuum cleaners;

[31] The expanded uncertainty is based on the standard uncertainty multiplied by 2, providing a level of confidence of approximately 95 %.

- Cordless vacuum cleaners;
- Robot vacuum cleaners.

For each product type, the energy, performance and material consumption in each life cycle phase is presented.

6.6.1 Mains-operated household vacuum cleaners

This category includes mains-operated cylinder, upright and handstick vacuum cleaners, which are all covered by the current Ecodesign regulation and the previous, annulled Energy Labelling Regulation.

Mains-operated household vacuum cleaner models were available in the highest energy label classes for energy efficiency (A+++) and performance classes (A) under the annulled Energy Labelling Regulation, but never for the same model, neither with active nor passive nozzles. This illustrates that there is a clear inverse relationship between carpet cleaning performance dpu_c and energy efficiency. This cannot be said about the hard floor cleaning performance. Rather, every type of vacuum cleaner, even with very low suction power, can get a good hard floor cleaning dpu_{hf} rating with the current crevice test. In the energy efficiency rating of the general purpose vacuum cleaner, the most popular type, both the dpu_c and dpu_{hf} play an equal role and the dpu_{hf} thus tends to 'soften' the inferior carpet cleaning performance of some products, because the AE values for carpet and hard floor are averages, but the hard floor dpu can be above 100%.

Table 7: BAU, BAT and BNAT of household mains-operated vacuum cleaners in terms of energy and performance (2018)

	BAU	BAT	BNAT
Rated power	900	300	300
dpu_c	0.81	0.81	0.91
dpu_{hf}	1.08	1.11	1.11
AE (kWh/year)	33.7	12.7	11.7
Price incl. VAT, €	123	380	430

These values are all for separate products, as no single vacuum cleaner performs as the BAT values on all parameters simultaneously.

Table 8: Household mains-operated vacuum cleaners' materials (product-life 8 years[32])

Life Cycle materials	Production		Use	End of life		
Impacts per product	Virgin + recycled	Only recycled		Disposal	Recycle	Recover
Materials	g	g	g	g	g	g
Bulk Plastics	3,643	911	36	1,129	1,093	1,457
TecPlastics	638	0	6	198	192	255

[32] The average product lifetime of a mains operated vacuum cleaner, as described in task 2, based on preparatory study from 2009

Ferro	863	345	9	52	820	0
Non-ferro	850	340	9	51	808	0
Electronics	55	14	1	28	28	0
Misc.	734	661	7	255	479	7
Auxiliaries	0	0	640	640	0	0
Total weight[33]	**6,784**	**2,271**	**708**	**2,353**	**3,419**	**1,720**

6.6.2 Commercial vacuum cleaners

Commercial dry vacuum cleaners are generally not very different from household vacuum cleaners, except that they generally have a sturdier construction and larger receptacle (8-15 litres) allowing them to operate for 300 hours per year, i.e. 6 times more than household vacuum cleaners. The energy and performance values are therefore very similar, also since the requirements are the same for household and commercial vacuum cleaners.

Table 9: BAU, BAT and BNAT of commercial vacuum cleaners in terms of energy and performance

	BAU	BAT	BNAT
Rated power	900	300	300
dpu_c	0.81	0.81	0.91
dpu_{hf}	1.08	1.11	1.11
AE (kWh/year)	30.73	12.7	11.6
Price incl. VAT, €	331	380	430

The sturdy construction is evident from the bill-of-materials, which is different than for household vacuum cleaners.

Table 10: Commercial vacuum cleaners' materials (product-life 5 years[34])

Life Cycle materials	PRODUCE		USE	END OF LIFE		
impacts per product	Virgin + recycled	only recycled		Disposal	Recycle	Recover
Materials	g	g	g	g	g	g
Bulk Plastics	5,795	1,449	58	1,796	1,739	2,318
TecPlastics	144	0	1	45	43	58
Ferro	1,436	574	14	86	1,364	0
Non-ferro	2,102	841	21	126	1,997	0
Electronics	2	1	0	1	1	0
Misc.	1,631	1,468	16	571	1,060	16
Auxiliaries	0	0	1,000	1,000	0	0
Total weight	**11,110**	**4,332**	**1,111**	**3,625**	**6,204**	**2,392**

[33] Average weight of one appliance
[34] The average product life time of a commercial vacuum cleaner, as described in task 2, based on preparatory study from 2009 and information from manufacturers

6.6.3 Cordless vacuum cleaners

Cordless vacuum cleaners are assumed to follow the same use pattern as mains-operated vacuums. However, most cordless vacuums often would not have sufficient run time, as most can run for 15-40 minutes while only a few can run for up to 60 minutes at the lowest power setting[35]. Hence, the cleaning is assumed to be spread out over more cycles per week.

Also, the capacity of a cordless is smaller than that of a normal vacuum cleaner, i.e. in the range of 0.2-0.8 litres compared with around 2-3 litres for an average-sized standard vacuum cleaner according to Which?[36]. The same source also finds that, while a carpet dust pick-up of 79% is average for a cylinder vacuum cleaner the cordless handstick vacuum cleaner only reaches 47%. In other words, the average cordless would not meet the 2017 Ecodesign requirements for carpet cleaning (minimum dpu_c 75%) and possibly could only enter as a hard-floor only model (minimum dpu_{hf} 98%).

Especially over the last 5 years there has been a lot of progress in performance, battery capacity and life for cordless vacuum cleaners. But there are also typical 'sweepers' and 'electric broom' types, i.e. a rotating brush without filtration and a 10-15 W suction power[37] that is just enough to keep the dust from falling out of the small bin next to the brush. If their performance allows, they could be in scope of a revised regulation as 'hard-floor only'.

Table 11: BAU, BAT and BNAT of cordless vacuum cleaners in terms of energy and performance

	BAU	BAT	BNAT
Maintenance mode consumption; charged and docked [W]	2.6	1.0	0.5
Standby consumption, dock, when cleaning [W]	1.7	0.5	0.5
dpu_c	0.63	0.75	0.80
dpu_{hf}	0.45	0.98	0.98
ASE_c [Wh/m2]	0.59	0.56	0.56
ASE_{hf} [Wh/m2]	0.57	0.56	0.56
AE (kWh/year)	21.88	20.14	19.55
Price incl. VAT, €	221	500	630

Table 12: Cordless vacuum cleaners' materials (product-life 6 years, package 0.05 m³)

Life Cycle materials	PRODUCTION		USE	END OF LIFE		
Impacts per product	Virgin + recycled	Only recycled		Disposal	Recycle	Recover
Materials	g	g	g	g	g	g
Bulk Plastics	1,624	406	16	503	487	649
TecPlastics	287	0	3	89	86	115

[35] http://www.which.co.uk/reviews/cordless-vacuum-cleaners/article/corded-vs-cordless-vacuum-cleaners
[36] https://www.which.co.uk/
[37] E.g. https://www.gtech.co.uk/cordless-vacuum-cleaners/sw20-premium-cordless-floor-sweeper.html, featuring 7.2V battery and a 60 minutes runtime.

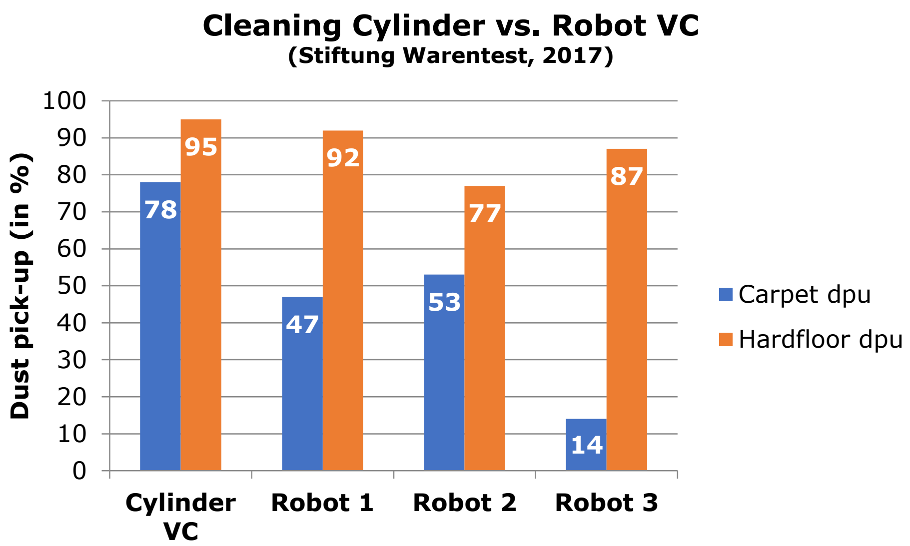
Ferro	400	160	4	24	380	0
Non-ferro	835	334	8	50	793	0
Electronics	295	74	3	148	150	0
Misc.	0	0	0	0	0	0
Total weight	**3,440**	**974**	**34**	**814**	**1,897**	**764**

6.6.4 Robot vacuum cleaners

Robot vacuum cleaners perform cleaning autonomously, i.e. without human intervention. The cleaning algorithm determines the pattern in which the robot moves across the floor and varies from brand to brand and model to model. The pattern can be random or mapped following a zig-zag, crisscross, or spiralling pattern, or it can be controlled by simultaneous localisation and mapping (SLAM) [38].

The top-three robot models in a recent German consumer test reveal a hard floor cleaning performance almost as good as that of an average (150-200 Euro) cylinder vacuum cleaner, while carpet cleaning performance is only half as good in comparison. The dust-retention of a robot cleaners is considerably worse than that of a standard vacuum cleaner. However, it should be noted that there is a difference in the standards used for robot and for a standard cylinder vacuum cleaner, so the performance is not directly comparable.

Figure 8: Dust pick-up for an average cylinder cleaner and the three best robot cleaners (source: Stiftung Warentest 2017).



The high-end robot vacuum cleaners advertise 20 'Airwatts'[39] suction power, which is only 5-18% of that of an average cylinder vacuum cleaner. The relatively limited suction power is a key factor in the relatively low dust retention performance.

[38] https://www.vacuumcleanerbuzz.com/articles/how-does-a-robot-vacuum-cleaner-work/
[39] A measure of efficiency of vacuum cleaners, consisting of the air flow multiplied with the suction, i.e. vacuum.

Cleaning performance not only depends on suction power. Whereas most of the cylinder vacuum cleaners have a 'passive nozzle', robot vacuum cleaners heavily rely on the use of rotating brushes and other 'active' devices to pick up dust and fibres. Consumer association tests show that many robot cleaners have problems cleaning tight corners and that especially low-end models skip parts of the designated floor area. In those cases, secondary (vacuum) cleaning will be needed. In any case, many manufacturers indicate that their robot cleaners are only suitable for hard-floor and low-pile (<1 cm) carpet cleaning.

Table 13: BAU, BAT and BNAT of Robot vacuum cleaners in terms of energy and performance

	BAU	BAT	BNAT
Maintenance mode consumption, charged and docked [W]	3.7	2.0	0.5
Standby consumption, dock, when cleaning [W]	0.99	0.50	0.50
dpu_c first pass*	0.13	0.36	0.50
dpu_{hf} first pass	0.60	0.95	1.00
Cleaning cycle energy, carpet [Wh/cycle]	42.50	26.00	33.00
Cleaning cycle energy, hard floor [Wh/cycle]	42.50	26.00	33.00
Room coverage factor	83%	95%	95%
Average AE (Kwh/y) – Based on test room	42.43	16.94	4.27
Average AE [Kwh/year] – hard floor only	42.43	17.74	5.39

** First pass/single pass of a robot cleaner. Robot cleaners will pass a spot one or more times which results in different dust pick up depending on the number of passes.*

Table 14: Robot vacuum cleaners' materials (product-life 6 years, package 0.05 m³)

Life Cycle materials	PRODUCTION		USE	END OF LIFE		
impacts per product	Virgin + recycled	Only recycled		Disposal	Recycle	Recover
Materials	g	g	g	g	g	g
Bulk Plastics	2,657	664	27	824	797	1,063
TecPlastics	337	0	3	104	101	135
Ferro	823	329	8	49	781	0
Non-ferro	568	227	6	34	539	0
Electronics	607	152	6	304	310	0
Misc.	0	0	0	0	0	0
Total weight	**4,991**	**1,372**	**50**	**1,315**	**2,529**	**1,198**

6.7 Environmental and economic impacts

For vacuum cleaners, the use phase has the highest impacts regarding energy consumption and emission of greenhouse gases. The energy consumption and emission of greenhouse gases during the lifecycle for the different base cases are:

- BC 1: Energy consumption – 3423 MJ, emission of CO_2-eq - 155 kg
- BC 2: Energy consumption – 9611 MJ, emission of CO_2-eq – 419 kg
- BC 3: Energy consumption – 3639 MJ, emission of CO_2-eq - 170 kg
- BC 4: Energy consumption – 4324 MJ, emission of CO_2-eq - 210 kg

The life cycle impacts of the base cases will serve as a baseline or reference for the improvement options and policy scenarios assessment in Task 6 and 7. The comparison between the annual impacts of all vacuum cleaners and the EU total impacts (from all energy-related products) reveals that vacuum cleaners are responsible for 0.79% of the total EU electricity consumption and 0.21% of the total EU emitted greenhouse gases. In total, all EU vacuum cleaners over a lifetime account for 233 PJ of energy consumption, which leads to 10.5 Mt greenhouse gases released to the atmosphere.

The life cycle costs for vacuum cleaners reveal that the highest expenses are related to the purchase of vacuum cleaners. Within the EU, all consumers are spending almost 13 billion euros annually in the purchase and operation of vacuum cleaners. Approximately 20% (2.6 billion euros) are related to electricity expenses.

The critical raw materials consumed during production have limited impacts and constitutes below 1% of the impacts imposed by vacuum cleaners over a lifetime. In the EU stock, the raw materials (gold, copper and cobalt) embedded account for an energy consumption of 7 PJ and an emission of 0.5 million tonnes of greenhouse gases. The combined value of copper, gold and cobalt in the stock amounts to more than 0.87 billion euros.

6.8 Design options

Five different design options are presented in task 6:

- More stringent energy efficiency limits: Setting 750 W power limit for mains-operated and setting energy requirements for cordless and robot vacuum cleaners.
- More realistic performance: including partially loaded receptacle, market-representative floors and debris tests in the performance parameters.
- Recycled content and/or light weighting: increasing the amount of recycled content or decrease the total product weight in order to save materials and reduce environmental impacts of material production.
- Increased product life: different options for increasing the lifetime of products exist, including increasing the technical life, especially of components often experiencing failure, make it easier to repair products and thus increase the re-use of products.

- Recycling: increasing the share of materials from the vacuum cleaners that is recycled at end of life, for example by using materials that are easily recyclable. This is also linked to the option of including more recycled material in new products.

Each of the options are considered for each base case, and the economic impact on the end-user is given. In general, it is not economical to set stricter energy efficiency requirements for the products included in scope of the current regulations, since the price premium is too high compared to the energy savings, especially for household mains-operated vacuum cleaners, due to the relatively low usage hours per year. Efficiency requirements for cordless and robot vacuum cleaners, however, especially related to decreasing the maintenance mode consumption are economically beneficial to end-users. Also, all the resource efficiency options are economically beneficial to end-users, since neither causes high increases in product prices.

6.9 Scenarios

Scenarios are calculated for five different policy options, three for energy and performance requirements, two for resource efficiency. All scenarios include cordless and robot vacuum cleaners, however the impacts are calculated for each of the base cases separately, so it is possible to see the impact of including cordless and robot vacuum cleaners specifically.

6.9.1 Energy efficiency scenarios

The Requirements considered in the policy options are shown in Table 15. PO1 and PO2 includes both Ecodesign and Energy Labelling Regulations, while PO3 is an Ecodesign-only scenario.

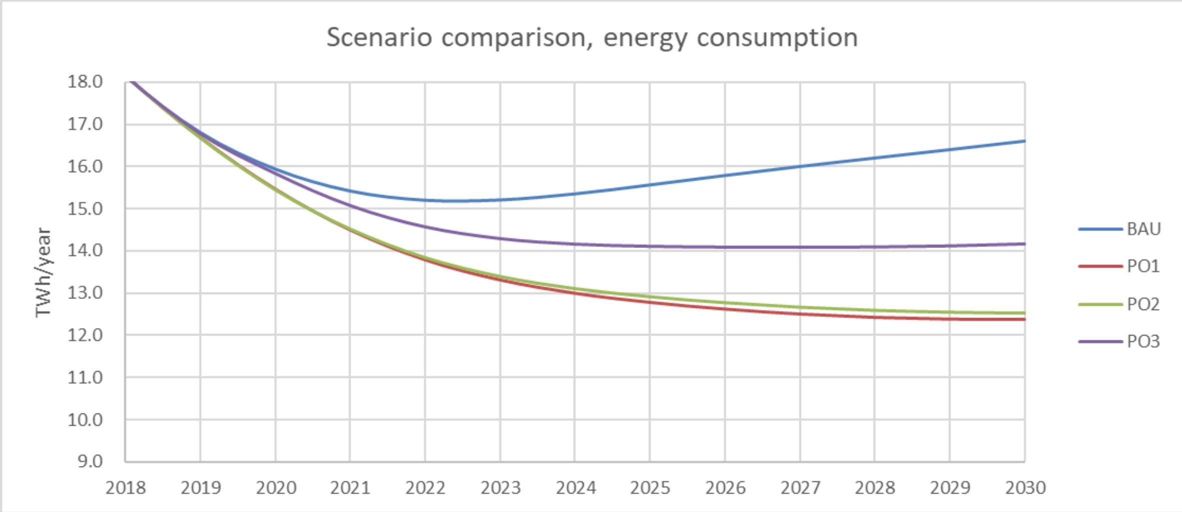
Table 15: Policy Option 1, 2 and 3: Energy and performance related requirements.

Ecodesign Parameter	Commercial	Mains-operated household	Cordless	Robot
Common parameters for Policy Options 1, 2 and 3				
dpu_{hf}	≥0.98	≥0.98		
dpu_{c}	≥0.75	≥0.75		
*Debris hard floor**	≥0.40	≥0.80	≥0.80	
*Debris carpet**		≥0.75	≥0.75	
Dust re-emission	≤0.8%	≤0.8%	Tier 1: ≤3%	
Noise	≤78 dB(A) or ≤80 dB(A) if the product is equipped with a beat and brush nozzle	≤78 dB(A) or ≤80 dB(A) if the product is equipped with a beat and brush nozzle	≤85 dB(A)	≤65 dB(A) Measured from 1.6 m distance

Ecodesign Parameter	Commercial	Mains-operated household	Cordless	Robot
Decrease in air flow with loading	≤15%	≤15%	≤15%	
Motion resistance	40N	40N	40N	
Maintenance power			≤0.5 / 1.0 / 2.0 W	≤0.5 / 1.0 / 2.0 W
Coverage factor				≥80.00%
Policy Option 1				
Annual Energy, AE		≤36 kWh/year		
Energy Index, EI	0,8 m^2/min			
Rated power		≤750 W		
Energy labelling				
Policy Option 2				
Annual Energy, AE		≤43 kWh/year		
Energy Index, EI	0,76 m^2/min			
Rated power		≤900 W		
Energy label				
Policy Option 3				
Annual Energy		≤36 kWh/year		
Energy Index, EI	0,8 m^2/min			
Rated power	≤750 W	≤750 W		
No Energy Labelling				

Based on the data collected in task 1 through 6, the environmental and economic impact of each of the scenarios was calculated until 2030. As seen in the graph below PO1 resulted in that largest energy savings compared to BAU, however, with very similar savings in PO2, while PO3 resulted in only around half of the savings as the other two scenarios.

Figure 9: Annual energy consumption in each of the three policy scenarios compared to BAU



The Energy savings in all scenarios are largely linked to the cordless and robot vacuum cleaners, especially due to the large energy saving potential of setting maintenance mode requirements. As seen in Table 16, around 3.99 TWh/year can be saved in the strictest policy option, PO1, corresponding to 1.3 Mt CO_2-eq/year by 2030. The quite similar savings in PO2, show that setting stricter Ecodesign requirements does not have a significant impact on the energy efficiency, because many products already have a much higher efficiency than the current Ecodesign limit values, due to the market pull of the energy label and the fact that already now, 50% of products are in energy label class A.

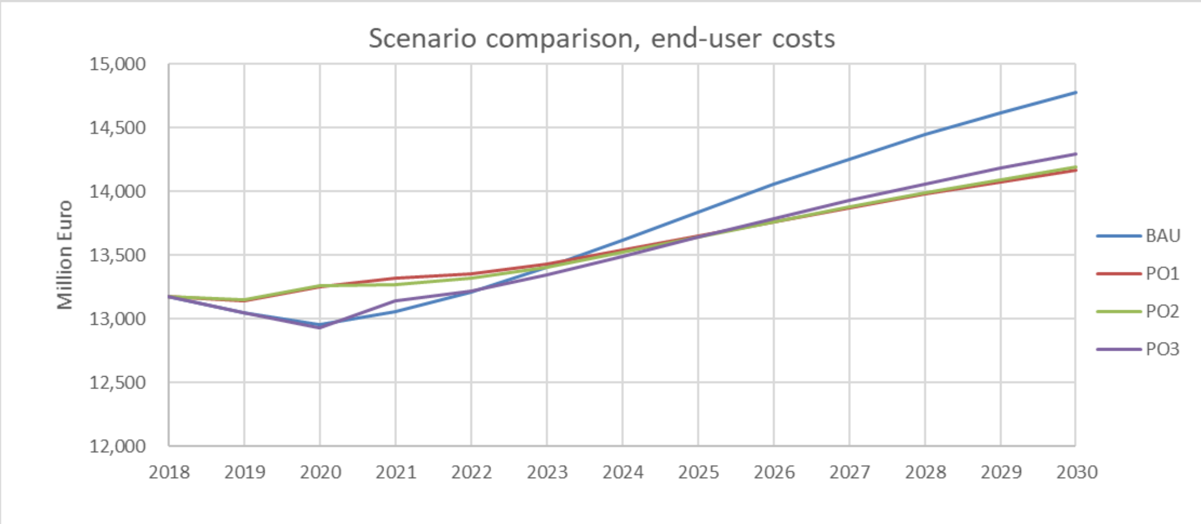
The significantly lower savings in PO3 (around half of PO1 and PO2) shows that removing the energy label would result in higher average AE values for the products that previously were labelled, even when setting stricter Ecodesign requirements (750 W), which decreases the obtainable savings. Hence, even if the savings for cordless and robot vacuum cleaners are similar in PO3 to that in PO1 and PO2, the increase in energy consumption for mains-operated household and commercial cleaners has a negative impact on the savings.

Table 16: 2030 energy consumption and savings in PO1, PO2 and PO3

	2030 energy consumption, TWh				Annual savings in 2030, TWh			Annual savings, %		
	BAU	PO1	PO2	PO3	PO1	PO2	PO3	PO1	PO2	PO3
Household mains	6.71	5.30	5.41	6.28	1.41	1.31	0.44	21%	19%	6%
Commercial	3.88	3.18	3.23	3.78	0.70	0.65	0.10	18%	17%	3%
Cordless	2.15	0.83	0.83	0.83	1.32	1.32	1.32	61%	61%	62%
Robots	1.18	0.62	0.62	0.49	0.56	0.56	0.69	48%	48%	59%
Total	**13.93**	**9.94**	**10.09**	**11.38**	**3.99**	**3.84**	**2.55**	**29%**	**28%**	**18%**

Even though the energy savings are only around half in PO3, the expenditure for end-users is more or less the same in all three policy scenarios, as seen in Figure 10.

Figure 10: Annual consumer costs in each of the three policy scenarios compared to BA



Based on the results obtained in the scenario analysis, it is recommended to continue with the current Ecodesign requirements, but include cordless and robot cleaners in scope of both regulations. This corresponds to PO2. Even though more savings can be obtained in PO1, it is doubly economic for the end-users, as shown in task 6. The specific requirements in PO2 is discussed in more detail in task 7.

6.9.2 Energy label

Besides the changes in the Ecodesign Regulation, it is also recommended to introduce a new Energy Label Regulation. According to the Energy Label Framework Regulation, the energy label should be introduced as an A-G scale and class A should be empty when the label is introduced. Before the annulment of the previous Energy Label Regulation only a few vacuum cleaners were in the A+++ class, and these are not in the top classes for the dust pick-up and dust re-emission parameters. It is therefore recommended to use the same class intervals as demonstrated in Table 17, where the assumed market distribution of vacuum cleaners in the energy label classes after tier 1 of PO2 is also shown.

Table 17: Expected market distribution of energy label classes with the rescaled label

Current label classes	Interval	New label classes	Assumed 2021 market distribution				
			Mains-operated	Commercial	Cordless	Robots tier 1	Robots tier 2
A+++	≤ 10	A	0.0%	0%	2%	0%	0%
A++	10 < AE ≤ 16	B	1.0%	3%	9%	0%	1%
A+	16 < AE ≤ 22	C	2.0%	5%	21%	1%	3%
A	22 < AE ≤ 28	D	61.0%	48%	54%	3%	7%
B	28 < AE ≤ 34	E	22.0%	34%	11%	7%	10%

C	34 < AE ≤ 40	F	7.0%	8%	3%	14%	18%
D	40 < AE	G	7.0%	2%	0%	75%	61%

In order to solve the current issue of test uncertainties for dust pick-up tests in the short term, it is recommended to rescale the performance classes (dust pick-up on hard floor and carpet, and dust re-emission) to only four class-scales from A to D with the intervals shown in Table 18.

Table 18: Suggested performance classes

Performance class	Dust pick up on carpet (dpu_c)	Dust pick up on hard floor (dpu_{hf})	Dust re-emission (*dre*)
A	dpu_c >0.91	dpu_{hf}>1.11	*dre*≤0.02%
B	0.85≤dpu_c<0.91	1.07≤ dpu_{hf} <1.11	0.02%<*dre*≤0.2%
C	0.80≤ dpu_c <0.85	1.02≤ dpu_{hf} <1.07	0.20%<*dre*≤0.60%
D	dpu_c <0.80	dpu_{hf} <1.02	*dre*>0.60%

6.9.3 Resource efficiency scenarios

The resource Requirements considered in the policy options are shown in Table 19. PO4 includes both measures to facilitate increased lifetime and information requirements on the content of recycled plastic in the product. This is intended to promote recycling of plastic and support the 65% recycling goal from the WEEE Directive. Since metals are already recycled at high rates, this requirement is based only on the plastic, which so far has much lower recycling rates.

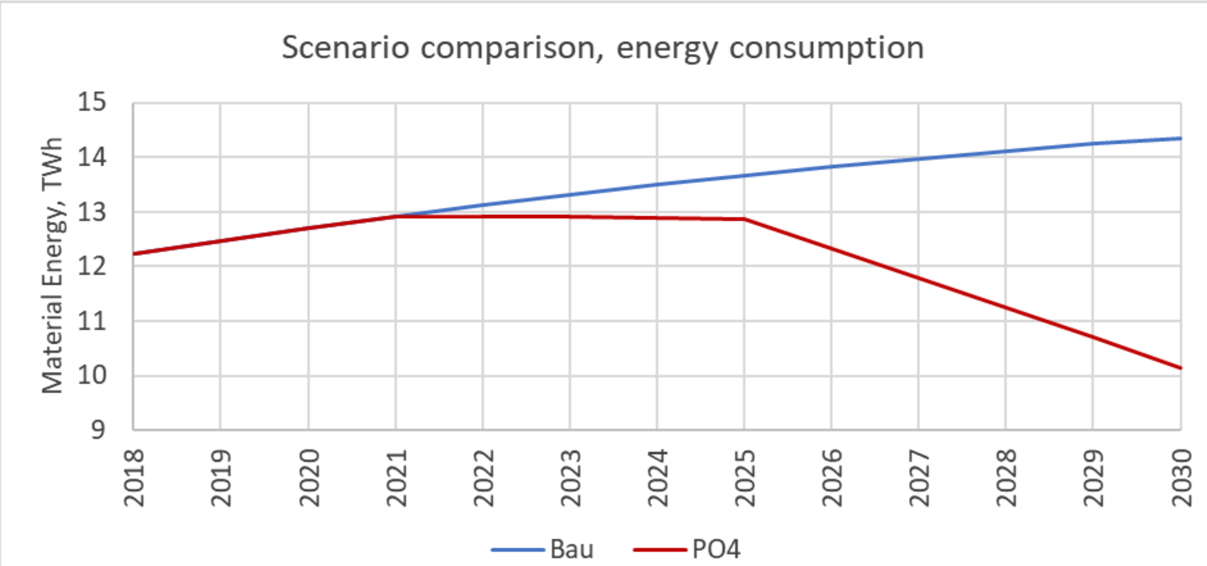
Table 19: Requirements in Policy Options 4

Ecodesign Parameter	Requirements for mains-operated household and commercial	Requirements for cordless	Requirements for Robots
Common parameters for Policy Options 4			
Motor life	500 hours		
Hose oscillation	40,000 oscillations	40,000 oscillations when a hose is present	
Battery lifetime		600 cycles and maintain 70% capacity	600 cycles and maintain 70% capacity
Spare part availability	8 years (household) 5 years (commercial)	6 years	6 years
Easy changeable repair-prone parts	Hose Power cord roll-up Permanent filters Handle Active nozzles	Battery (4 years) Hose Permanent filters Handle Active nozzles	Battery (4 years) Wheels Brushes Permanent filters

Information requirements on repair	How to repair/change repair-prone parts	How to repair/change repair-prone parts and how to best ensure battery longevity	How to repair/ change repair-prone parts and how to best ensure battery longevity
Information requirements on the content of recycled plastic			

Based on the above requirements and the data presented throughout the study, the impact of PO4 has been derived and compared to the BAU scenario. As seen from Figure 11, the material energy in both scenarios is lower than in the BAU scenario from 2022.

Figure 11: GHG emissions in PO4 compared to BAU from 2018 to 2030



The savings in PO4 are caused by an assumed increase in the lifetime of vacuum cleaners of 25%, and an increased use of recycled plastic. This means that more material (spare parts) are used per vacuum cleaner and that the vacuum cleaners will miss out a potential energy improvement according to the longer lifetime. The material energy savings for each base case in 2030 is presented in Table 20.

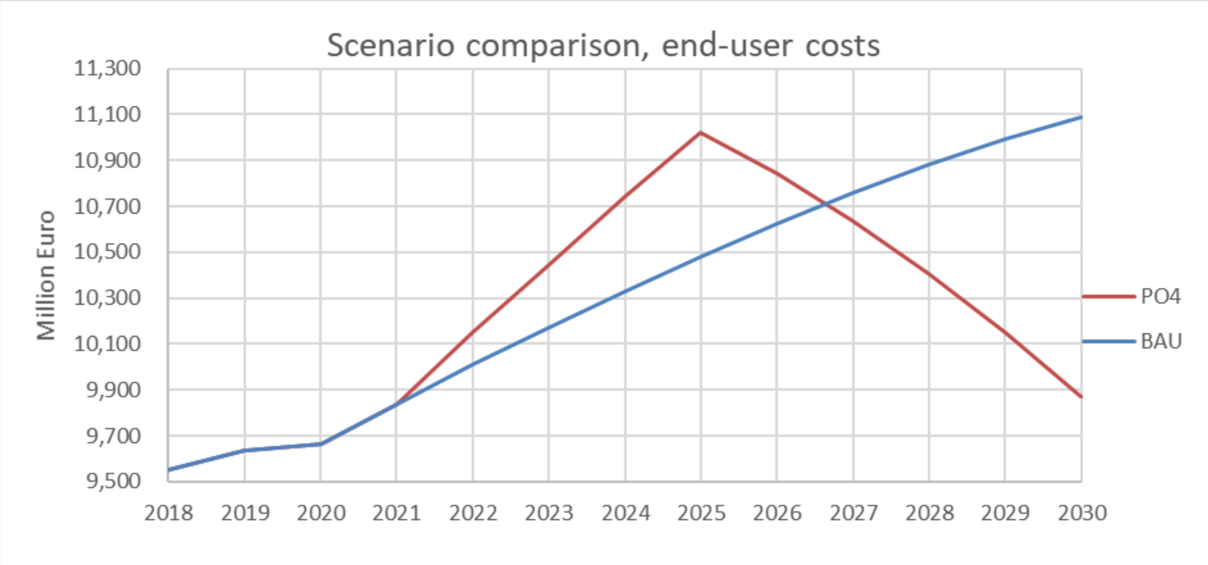
Table 20: Material energy savings for each base case in 2030 for PO4 and PO5

	2030 Material energy, TWh		2030 savings, TWh	2030 savings, %
	BAU	PO4	PO4	PO4
Household mains-operated	4.74	3.11	1.64	35%
Commercial	1.17	0.75	0.42	36%
Cordless	5.73	4.26	1.47	26%
Robots	2.70	2.02	0.68	25%

Total	14.35	10.14	4.21	29%

The energy saving potential in PO4 is also reflected in the monetary savings for the end-users compared to the BAU scenario. For PO4, the consumer expenditure is lower than in the BAU, as seen in Figure 12.

Figure 12: End-user expenditure for all vacuum cleaners in EU each year from 2018-2030.



Based on the results obtained in the scenario analysis, it is recommended to include the resource requirements of PO4 in the Ecodesign Regulation in combination with the energy and performance requirements of PO2 in order to achieve the largest environmental impact improvements and ensure that no excessive costs are placed on end-users or market actors.

7. Task 1: Scope

Task 1 follows the MEErP methodology and includes the following:

- Product scope: Identification and description of relevant product categories and definition of the product scope based on regulations and previous studies, market terms etc, including potential scope extensions.
- Legislation: update of relevant legislation on EU, Member State and third country level.
- Test standards: update and description of relevant test and measurement standards on EU, Member State and third country level.

7.1 Product scope

The review study builds on the scope of the regulations, which is the same for the Ecodesign (666/2013) and the annulled Energy Labelling Regulation (665/2013). The current scope of the regulations covers electric mains-operated and hybrid vacuum cleaners for indoor use for both household and commercial purposes.

Exempted from the scope of the regulation are all types of wet or wet and dry vacuum cleaners, industrial and central vacuum cleaners, as well floor polishers and outdoor vacuum cleaners.

Battery operated and robot vacuum cleaners are also currently exempted from the regulations, but the review clause (article 7) of both regulations state that it should be assessed whether full size battery operated vacuum cleaners should be included in the scope, and robot vacuum cleaners will be considered as well.

7.1.1 Definitions from the regulations

The terms and definitions employed in the Ecodesign regulation and the annulled Energy Labelling Regulation for vacuum cleaners will form the basis of the terminology of the review study. The definitions of products from regulations are listed below:

- Vacuum cleaner means an appliance that removes soil from a surface to be cleaned by means of an airflow created by negative pressure developed within the unit;
- Hybrid vacuum cleaner means a vacuum cleaner that can be powered by both electric mains and batteries;
- Water filter vacuum cleaner means a dry vacuum cleaner that uses more than 0.5 litres of water as the main filter medium, whereby the suction air is forced through the water entrapping the removed dry material as it passes through;
- Household vacuum cleaner means a vacuum cleaner intended for household or household use, declared by the manufacturer as such in the Declaration of Conformity pertaining to Directive 2006/95/EC of the European Parliament and of the Council (2);

- General purpose vacuum cleaner means a vacuum cleaner supplied with a fixed or at least one detachable nozzle designed for cleaning both carpets and hard floors, or supplied with both at least one detachable nozzle designed specifically for cleaning carpets and at least one detachable nozzle for cleaning hard floors;
- Hard floor vacuum cleaner means a vacuum cleaner supplied with a fixed nozzle designed specifically for cleaning hard floors, or supplied solely with one or more detachable nozzles designed specifically for cleaning hard floors;
- Carpet vacuum cleaner means a vacuum cleaner supplied with a fixed nozzle designed specifically for cleaning carpets, or supplied solely with one or more detachable nozzles designed specifically for cleaning carpets;
- Commercial vacuum cleaner means a vacuum cleaner for professional housekeeping purposes and intended to be used by laymen, cleaning staff or contracting cleaners in office, shop, hospital and hotel environments, declared by the manufacturer as such in the Declaration of Conformity pertaining to the Directive 2006/42/EC of the European Parliament and of the Council (1);
- Wet vacuum cleaner means a vacuum cleaner that removes dry and/or wet material (soil) from the surface by applying water-based detergent or steam to the surface to be cleaned, and removing it, and the soil by an airflow created by negative pressure developed within the unit, including types commonly known as spray extraction vacuum cleaners;
- Wet and dry vacuum cleaner means a vacuum cleaner designed to remove a volume of more than 2.5 litres, of liquid, in combination with the functionality of a dry vacuum cleaner;
- Battery operated vacuum cleaner means a vacuum cleaner powered only by batteries;
- Robot vacuum cleaner means a battery-operated vacuum cleaner that is capable of operating without human intervention within a defined perimeter, consisting of a mobile part and a docking station and/or other accessories to assist its operation;
- Industrial vacuum cleaner means a vacuum cleaner designed to be part of a production process, designed for removing hazardous material, designed for removing heavy dust from building, foundry, mining or food industry, part of an industrial machine or tool and/or a commercial vacuum cleaner with a head width exceeding 0.50 m;
- Central vacuum cleaner means a vacuum cleaner with a fixed (not movable) negative pressure source location and the hose connections located at fixed positions in the building;
- Floor polisher means an electrical appliance that is designed to protect, smoothen and/or render shiny certain types of floors, usually operated in combination with a

polishing means to be rubbed on the floor by the appliance and commonly also equipped with the auxiliary functionality of a vacuum cleaner;

- Outdoor vacuum means an appliance that is designed for use outdoors to collect debris such as grass clippings and leaves into a collector by means of an airflow created by negative pressure developed within the unit and which may contain a shredding device and may also be able to perform as a blower;
- Full size battery operated vacuum cleaner means a battery-operated vacuum cleaner which when fully charged, can clean 15 m2 of floor area by applying 2 double strokes to each part of the floor without recharge.

7.1.2 Definitions from preparatory study

Besides the above definitions from the regulations, the preparatory study sets out a number of relevant definitions, which defines vacuum cleaners across the above categories:

- Mains Powered means a vacuum cleaner connected to a mains voltage electrical supply during its operation.
- Cordless means a vacuum cleaner with integrated electrical supply (usually low voltage DC) using rechargeable battery storage of electricity for operational use. It is only connected to the mains electrical supply for the purpose of recharging the batteries.
- Bagged vacuum cleaner means a vacuum cleaner that employs a disposable bag as receptacle, which is disposed of with the soil inside once it is full and replaced by a new, similar receptacle.
- Bagless vacuum cleaner means a vacuum cleaner that employs a reusable container as receptacle, which is sold as part of the vacuum cleaner and is often rigid in form. When the receptacle is full, only the dust inside is disposed of, and the container is used again.
- Upright Cleaner is a vacuum cleaner with the cleaning head forming an integral part of or permanently connected to the cleaner housing, the cleaning head normally being provided with an agitation device (usually a rotating brush or similar) to assist dirt removal and the complete cleaner being moved over the surface to be cleaned by means of an integral handle. It is suited to cleaning carpet and floor areas.
- Canister/ Cylinder/Suction Cleaner is a vacuum cleaner with the cleaning head separated from the vacuum generator (fan) and soil storage facility, usually by means of a flexible hose. The dirt/dust is normally removed using suction power only. This type of cleaner is better suited to cleaning above floor level, e.g. upholstery, stairs etc., but is also used for cleaning carpets and hard floors however.

- Stick Cleaner means a lighter weight vacuum cleaner with dirt storage facility and vacuum generator (fan) mounted centrally on a handle and integrated with a rigid connection to the cleaning head. The dirt is normally removed using suction power only.
- Handheld vacuum cleaner means a lightweight vacuum cleaner with cleaning head, dirt storage and vacuum generator integrated in a compact housing allowing the cleaner to held and operated whilst being held in the hand. It may or may not have an agitation device incorporated.

The definitions of specific vacuum cleaner types such as cylinder, upright and handstick are not defined in the current regulations. For the purpose of energy efficiency requirements this is not necessary, however, when considering resource efficiency requirements, it might be necessary to introduce legal definitions for the different vacuum cleaner types.

7.1.3 Definitions from standards

Even though the regulations do not differentiate between different types of mains-operated dry vacuum cleaners, the harmonised standard EN 60312-1:2017 includes the following definitions:

- Dry vacuum cleaner: Electrically operated appliance that removes dry material (e. g. dust, fibre, threads) from the surface to be cleaned by an airflow created by a vacuum developed within the unit, the removed material being separated in the appliance and the cleaned suction air being returned to the ambient air.
- Upright cleaner: Self-standing and floor-supported vacuum cleaner with the cleaning head forming an integral part of or permanently connected to the cleaner housing, the cleaning head normally being provided with an agitation device to assist dirt removal and the complete cleaner housing being moved over the surface to be cleaned by means of an attached handle.
- Cylinder vacuum cleaner: Portable dry vacuum cleaner having a nozzle separated from the cleaner housing by a hose so that, in use, only the nozzle is guided over the surface area to be cleaned.

7.1.4 Description of products

In the below sections, the four main types of vacuum cleaners identified will be described in more detail to provide explanation of the terms used in the report. The four main types are cylinder, upright, handstick and robot vacuum cleaners. The type, however, is not determining for the power source (mains electricity, batteries or hybrid) or receptacle types of the vacuum cleaners.

Cylinder Vacuum cleaners

Cylinder, sledge, barrel, tub and canister vacuum cleaner are all more or less interchangeable terms used to describe different types of vacuum cleaners. In this study, the term cylinder vacuum cleaners will be used to cover them all. Cylinder vacuum cleaners can be either bagless or bagged and be used in households or commercial surroundings on all indoor flooring types[40]. Common for cylinder vacuum cleaners is that the suction head is connected to the vacuum cleaner housing with a flexible hose, and the vacuum cleaner is pulled around by the user during cleaning.

The two most distinctive types of subcategories within the cylinder vacuum cleaner category are the sledge and barrel, illustrated in Figure 13. Barrel vacuum cleaners are also known as "tub" vacuum cleaners, and are the most popular for non-domestic purposes[41]. As opposed to the barrel vacuum cleaners that stands upright and often have 4 smaller wheels, sledge vacuum cleaners usually have 2 large wheels and one smaller in front, and are horizontally oriented rather than vertically.

Figure 13: Left: Barrel or tub form factor. Right: Sledge form factor

Both the sledge and the barrel form factor fit the definition of Canister/Cylinder/suction cleaner from the preparatory study[42]. A search on Google trend[43] was made on the following six terms to determine the prevalence of the terms searched for on Google:

- Sledge vacuum cleaner
- Barrel vacuum cleaner
- Tub vacuum cleaner
- Canister vacuum cleaner
- Cylinder vacuum cleaner
- Suction cleaner

[40] https://www.godfreys.com.au/upright-vs-barrel-vacuum-cleaners
[41] COMMISSION STAFF WORKING DOCUMENT - IMPACT ASSESSMENT Accompanying the documents "Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for vacuum cleaners" and Commission Delegated Regulation supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to Energy Labelling of vacuum cleaners", Brussels 2013.
[42] Work on Preparatory Studies for Eco-Design Requirements of EuPs (II), Lot 17 Vacuum cleaners, TREN/D3/390-2006, Final Report February 2009
[43] https://trends.google.com/trends/explore?geo=GB&q=Barrel%20vacuum%20cleaner,Cylinder%20vacuum%20cleaner,canister%20vacuum%20cleaner,Sledge%20vacuum%20cleaner,Suction%20cleaner

The results on google trend showed that the terms “barrel”, “tub” and “sledge” were used very little over the last five years, so that there was no data to show. The terms “suction cleaner” was related to other product types such as “pool suction cleaner” and mostly used in the US. The search also showed that the terms “canister” and “cylinder” vacuum cleaners both had a high popularity, but “canister” is prevalently an American term, whereas “Cylinder” is British. It was therefore decided in this study to use the term Cylinder vacuum cleaners for the product type covering all of the above six terms.

Upright vacuum cleaners

Upright vacuum cleaners are also called Beat and Brush vacuum cleaners, because of the roller brush in the head assists dirt removal from the surface, which makes it especially suited for carpet flooring. The upright vacuum cleaner form factor shown in Figure 14 is recognised by the head forming an integral part of the housing and the integrated handle above the housing, which means the entire cleaner is moved over the surface to be cleaned. This type of vacuum cleaner can be either bagless or bagged and be used in households or intended for commercial use, and while they are primarily used for carpet floors, some models can be used on hard floors as well[44].

Figure 14: Upright or Beat & Brush vacuum cleaner form factor (left) and roller brush (right)

Handstick vacuum cleaners

The handstick vacuum cleaner or the stick cleaner is a light weight vacuum cleaner which has a (small) dirt storage facility (receptacle) and a vacuum generator (fan) mounted either

[44] https://www.godfreys.com.au/upright-vs-barrel-vacuum-cleaners

centrally on the handle and integrated with a rigid connection to the cleaning head or located on the stick itself close to the cleaning head, as shown in Figure 15.

Figure 15: Battery operated handstick vacuum cleaners

The handstick vacuum cleaner differs from upright cleaners based on their weight, size and dirt storage capacity and the detachable nozzle. According to the preparatory study, the handstick vacuum cleaners usually remove dust with suction power only (i.e. no movable brush in the cleaning head), however, according to updated information from industry many of the more powerful models on the market today have movable brushes in the cleaning head.

Handstick vacuum cleaners can be either mains-operated[45] or battery operated[46]. Mains-operated and hybrid handstick vacuum cleaners are already covered by the regulations (even though they are not defined specifically), whereas battery operated handstick cleaners are not.

As shown in Figure 18 the battery-operated handstick vacuum cleaners (all battery-operated vacuum cleaners in principle) can fall under the current definition of *full size battery operated* in the regulation, if they are capable of cleaning 15 m^2 floor on one charging. If not, they are not considered "full size" in the current definition in the regulation.

2-in-1 handstick vacuum cleaners

Some handstick vacuum cleaners are operated by a handheld vacuum cleaner (See Figure 16), which is attached to the stick handle itself and provides the suction power, but can

[45] Example of mains operated handstick vacuum cleaner: Shark HV300UK, http://www.argos.co.uk/product/4366269
[46] Example of battery operated handstick vacuum cleaner: Bosch Athlet BCH625KTGB, http://www.trustedreviews.com/reviews/bosch-athlet-bch625ktgb

also be detached and used separately[47]. These 2-in-1 handstick types can also fall under the current definition of *full size battery operated*, but not necessarily.

The 2-in-1 handstick vacuum cleaners are very similar to the cordless handsticks, with the exception that vacuum generator (fan and motor) is a detachable handheld vacuum cleaner, that can be fitted onto the handle/tube and thus be used for cleaning floors, as shown in Figure 16. According to stakeholders from the industry, especially the handstick type shown to the right in the figure, also called an all in one vacuum cleaner, is gaining popularity.

Figure 16: two examples of 2-in-1 handstick vacuum cleaners and the detached handheld vacuum cleaner

Robot vacuum cleaners

The robot vacuum cleaner is a battery-operated vacuum cleaner with a "self-drive" system. The system is using a sensory feedback control to clean surfaces automatically. Depending on the model of the robot vacuum cleaner different capabilities are offered for the consumer. Some vacuum cleaners include both a camera and WIFI allowing the end-user to remotely control the unit while other models are simpler with a more random cleaning pattern. Many robot vacuum cleaners today are equipped with a "dock" where the vacuum cleaner is able to charge itself whenever it is needed. Note that some robot vacuum cleaners come with optional dusting or mopping functions. These functions are secondary functions that, with present technology, have limited consumer value. Also, mopping robots exist but they are not further considered as they are substantially different from

[47] Examples of handstick vacuum cleaner converted to handheld vacuum cleaners: Dyson V6: http://shop.dyson.dk/stovsugere/ledningsfri/dyson-v6-animalpro-exclusive-210672-94 , Nilfisk Handy Stickvac 2 in 1: https://consumer.nilfisk.dk/da/products/Pages/product.aspx?fid=16175

robot vacuums. Robot vacuum cleaners are not included in the scope of the current regulation.

Figure 17: Example of a robot vacuum cleaner

7.1.5 Bagged vs bagless vacuum cleaners

Cylinder and upright vacuum cleaners can either be bagged or bagless, while cordless and robot are almost always bagless. The choice of a bagged or bagless vacuum cleaner depends very much on user preferences. According to a number of consumer and producer websites, the main advantages and disadvantages of each type are the ones shown in Table 21. The two categories are not distinguished in the current regulations, since the consumers should be able to get the same performance of vacuum cleaners irrespective of whether they operate with or without a bag.

Table 21: Advantages and disadvantages for bagged and bagless vacuum cleaners[48]

	Advantages	Disadvantages
Bagged	• Hygienic: No dust exposure when emptying the bag • Low maintenance of filters and less frequent emptying • Higher suction efficiency than bagless vacuums when the bag is new	• Use of bags: costs money and has environmental impact. Also the filters are often disposable • Difficult to see when bag is full, though most have an indicator • Performance deteriorates as bag fills for most models
Bagless	• Performance does not decrease to the same extent as for bagged, when the receptacle fills • Does not need bags • Possible to see the dirt and thus when the vacuum is full	• Decrease in suction power after several fillings due to clogging of motor filter and/or exhaust filter • Requires more regular filter cleaning, often involving washing and drying • Recommended to empty outside

48 https://www.hoover.co.uk/small-appliances/vacuum-cleaners/bag-vs-bagless-vacuum-cleaners/ and https://learn.allergyandair.com/bagged-vs-bagless-vacuum-cleaners/ and https://www.godfreys.co.nz/bagged-vs-bagless-vacuum-cleaners and https://www.thespruce.com/bagless-vs-bagged-vacuum-cleaner-1901195 and http://vacuums.reviewed.com/features/how-to-buy-a-vacuum-bagged-or-bagless and http://www.topten.eu/uploads/File/Deliverables%20ACT/D2_1_Criteria_Paper_Vacuum_cleaners.pdf

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- Exposure to dust when emptying, which is especially a problem for users with allergies

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7.1.6 Alignment of definitions

Aside from the definitions used in the regulations a number of other terms are used to describe various types of vacuum cleaners, which are mostly based on the form factor. For the purpose of this study, especially the definitions used in the regulation and the preparatory study are important for the sake of comparison, and the definitions used by GfK are important because these will determine the segregation of data. The definitions from these three sources and how they relate are shown in Table 22, where the terms under the headline *review study* will be used throughout this study and cover the various definitions also shown in this chapter. Table 22 is not meant as a full coverage of all definitions, and e.g. definitions included in standards are not shown here, but rather as a means of aligning the terminology between various sources[49].

Table 22: Vacuum cleaner product types from different sources

<table>
<tr><th colspan="2">Regulations</th><th colspan="2">Preparatory study</th><th>GfK data</th><th>Review study</th></tr>
<tr><td colspan="2" rowspan="4">Electric-mains-operated, dry vacuum cleaners, including hybrid vacuum cleaners</td><td rowspan="4">Mains-operated</td><td rowspan="2">Canister/ Cylinder/Suction cleaner</td><td>Sledge</td><td rowspan="2">Cylinder</td></tr>
<tr><td>Barrel</td></tr>
<tr><td>Upright cleaner</td><td>Beat & brush</td><td>Upright</td></tr>
<tr><td rowspan="2">Stick cleaner</td><td>Handstick Mains</td><td>Mains handstick</td></tr>
<tr><td rowspan="4">Battery operated</td><td rowspan="2">Full size battery operated</td><td rowspan="4">Cordless</td><td rowspan="2">Handstick Battery</td><td rowspan="2">Cordless</td></tr>
<tr><td>No definition</td></tr>
<tr><td>No definition</td><td>Handheld</td><td>Handheld</td><td>Handheld</td></tr>
<tr><td>Robot</td><td>Robot</td><td>Robot</td><td>Robot</td></tr>
</table>

Based on the above definitions and terms observed in the vacuum cleaner market in general, the correlation between these definitions were developed, as seen in Figure 18. The categories marked in blue are defined in the regulations (chapter 7.1.1), whereas those marked green are only defined in the preparatory study (chapter 7.1.2) and thus not approved politically or by industry. The categories marked orange have not yet been defined, and even though the preparatory study mentions stick vacuum cleaners no distinction is made between battery powered and mains powered. The 2-in-1 handstick

[49] The current Committee Draft (CD) of the cordless standard designated IEC 62885-4, ED1 refers to the IEC 62885-2 mains-connected vacuum standard and defines cordless dry vacuum cleaner as a dry vacuum cleaner that is not mains operated and uses the term "Cordless" equivalent to "Battery-operated".

category refers to the stick-type vacuum cleaners powered by a detachable handheld vacuum cleaner.

The current regulation covers all electric-mains (and hybrid) dry vacuum cleaners as one collective category, whereas the preparatory study mentions for instance canister, cylinder and upright vacuum cleaners. A completely different terminology is used by GfK in their database, which is the data source used for market and stock data in this study. GfK distinguishes between sledge, barrel and beat & brush within the overall category. In the review study, it was decided to distinguish between the product types *Cylinder* and *upright*, according to the definitions set out in the preparatory study. However, there will be no difference in requirements for these two vacuum cleaner types, and thus no further definition is suggested for the regulations.

The mains handstick vacuums are sometimes referred to as "lightweight upright" because they are lighter, smaller and have smaller receptacles and (often) lower suction power than upright vacuum cleaners. The mains handstick will be distinguished from the upright vacuums in this study since they are generally perceived as two distinct product types by consumers and are also marketed as such. However, since they are mains-operated they are already in scope of the regulation with the same requirements as other mains-operated vacuums, no further definition is required in the regulation.

Figure 18: Overview of vacuum cleaner categories and the level to which they are defined

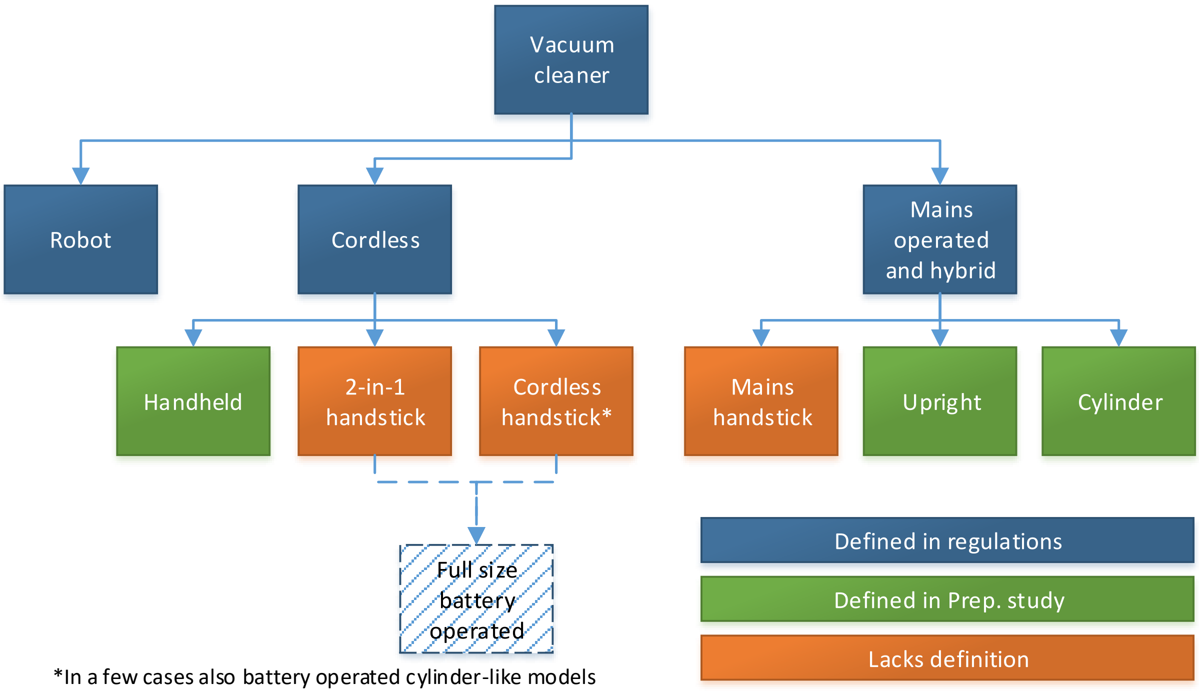
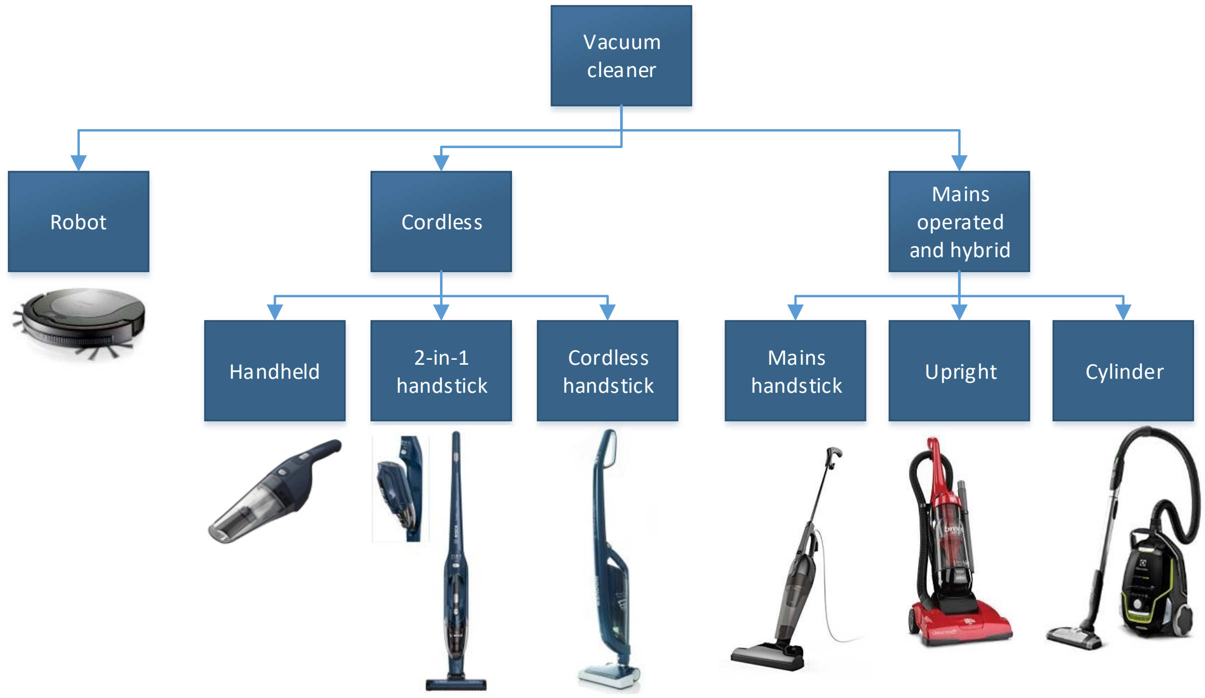


Figure 19: main types of vacuum cleaners included in the scope of the review study



Robot vacuum cleaners have the same definition in all sources, and the regulation's definition of robot vacuum cleaners will therefore be maintained in the review study. Even though robot vacuum cleaners rely on batteries as power source when in operation, they contain completely different technology and have different use patterns than other battery-operated vacuum cleaners, and they are therefore defined as a separate category apart from the cordless vacuum cleaners, which encompasses manually operated battery vacuum cleaners[50].

Handheld vacuum cleaners are defined in the preparatory study, but the wording of that definition would also include many handstick vacuum cleaners. In this review study, it is instead defined as "A small battery-operated vacuum cleaner with cleaning head, dirt storage and vacuum generator integrated in a compact housing allowing it to be operated whilst being held in the hand, but not suitable for cleaning floors". This definition is for comprehension only, and not intended as a legal definition.

The cordless vacuum cleaners are defined in the preparatory study as "A lighter weight battery-operated vacuum cleaner with dirt storage facility and vacuum generator (fan) mounted centrally on a handle and integrated with a rigid connection to the cleaning head". While this definition fits well with cordless handstick cleaners, the cordless category in this

[50] This is predominantly battery operated "handsticks", but according to some stakeholders also some battery operated cylinder vacuum cleaners can be found in the market. It has not, however, been possible for the study team to find examples of any such models.

study encompasses also other form-factors such as cylinder or upright, as long as they are manually operated and powered by batteries.

Cordless vacuum cleaners are intended to be used for vacuuming floors, and some of these will be a *full size battery operated* vacuum cleaner if they are capable of living up to the full size definition (cleaning 15 m^2 floor in one charge). However, this definition exclusively based on the area vacuumed means that many existing cordless handstick vacuum cleaners fall under this definition, even though they are not intended to be *full size*, in the sense that they are intended for lighter duty cleaning tasks. Measurements provided by Bissell show that with the smallest nozzle widths found on the market in 2014, it requires less than 10 minutes run-time to vacuum 15 m^2 of carpet (with 2 double strokes at 0.5 m/s), which is easily achieved by any small, utility, stick vacuum in the market today[51].

Furthermore, some crucial parameters are not taken into account in the current definition, which reduces the usefulness of it. For instance, the following parameters are not considered:

- The setting of the vacuum cleaner while cleaning the 15 m^2, i.e. suction power, which will influence the energy consumption and thus whether one charging of the battery is sufficient
- Whether the flooring is hard floor or carpet, which would also influence power consumption.
- Whether the vacuum cleaner should pick up any dust or debris during this test, and in that case how much.
- Whether the dust receptacle is large enough to clean the 15 m^2, and how the vacuum cleaner should be defined in case it is not
- How it should be measured whether the vacuum cleaner can live up to the *full size battery operated* definition, e.g. by suggesting a standard or measurement method.

7.1.7 Recommendations

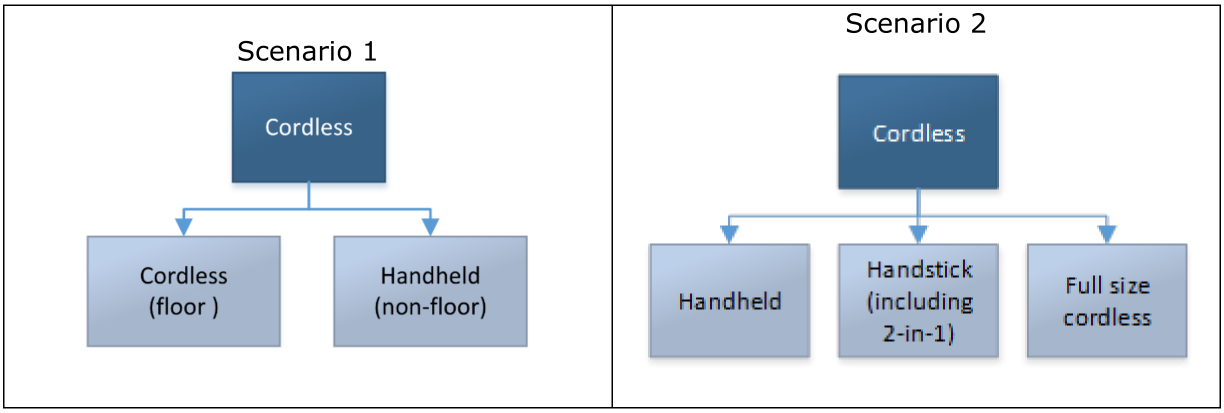
Based on the above it is recommended to change the definitions in the regulations for *battery operated vacuum cleaners* and *full size battery operated vacuum cleaners*.

In order to maintain the robot vacuum cleaners as a separate category, not related to other battery operated cleaners due to the differences in technology, it is suggested to change the current definition: *"Battery operated vacuum cleaner means a vacuum cleaner powered only by batteries",* to: *"Cordless vacuum cleaner means a vacuum cleaner powered only by batteries, other than robot vacuum cleaners"*

[51] Run-time calculations based on the EU 666/2013 definition, according to Bissell;

In order to not complicate the regulations unnecessarily the sub categorisation of the cordless category should be kept to a minimum. Two scenarios for the categorisation of cordless vacuum cleaners have been discussed, which are shown in Figure 20.

Figure 20: scenario for sub-categorisation of the cordless vacuum cleaner category



In the first scenario, the cordless category is split into only two further categories: those intended for floor cleaning and those not (Handheld). The floor cleaner category would include the 2-in-1 stick cleaners (with a detachable handheld cleaner). It is recommended that the two categories in scenario 1 are distinguished based on the ability to vacuum floors, for example something in line with the following:

Cordless floor vacuum cleaner means a cordless vacuum cleaner that can be used for cleaning floors from an upright standing position, including handhelds fitted with any tubes, aggregates or similar that makes it possible to use them for cleaning floor from an upright standing position;

The handheld definition is suggested to be in line with that from the preparatory study:

Handheld vacuum cleaner means a lightweight cordless vacuum cleaner with cleaning head, dirt storage and vacuum generator integrated in a compact housing, allowing the cleaner to held and operated whilst being held in one hand;

Scenario 2 is based on the assumption that the cordless market is split between light duty handsticks, which have significantly poorer performance that mains-operated cleaners, and larger cordless vacuum cleaners with performance similar to a mains-operated cylinder or upright vacuum cleaner. In this scenario it has been suggested to distinguish the cordless floor cleaners into two categories based on their physical characteristics and performance.

Such physical characteristics could include the following:

- Physical size/footprint - (Stick < Full Size)
- Weight - (Stick < Full Size)
- Receptacle size - (Stick < Full Size)

- Performance (air power, cleaning, etc.) - (Stick < Full Size)
- Battery size and energy consumption - (Stick < Full Size)
- Motor power - (Stick < Full Size)
- Design intent - (Stick = quick, convenient, light duty)

The problem with such a distinction is that manufacturers could keep their products just out of scope of the category with the strictest requirements, or which allows for a better energy label class. Another problem is how to define parameters such as e.g. receptacle size and battery size, and in general it is recommended to keep any design intent out of the definitions to prevent loopholes and grey areas.

Overall, it is recommended to use the sub-categorisation scenario 1 for simplicity and to avoid loopholes. This is based on inputs from multiple stakeholders, both from the industry and NGOs, that the market is moving towards cordless being used as primary vacuum cleaners with performances that approaches that of mains-operated vacuum cleaners.

It is recommended to include all floor vacuum cleaners in scope of the regulation, since they all have the same purpose (to remove dust from the floor) and consumers should be able to have this purpose fulfilled with as low energy consumption as possible, no matter which technology they use. According to several stakeholders this will result in a more level playing field in the market.

7.2 Review of relevant regulations

7.2.1 Legislation and agreements at EU level

Vacuum cleaners may be addressed, directly or indirectly, by the following EU legislation (non-exhaustive list):

Ecodesign Directive 2009/125/EC

This Directive is relevant for vacuum cleaners as its implementing measures address vacuum cleaners directly (666/2013)[52], which is the background for this review study.

The tier 1 Ecodesign requirements were applicable from 1 September 2014, and included requirements on annual energy consumption, rated input power, and cleaning performance. In tier 2, applicable from 1 September 2017, requirements on dust re-emission, noise, and lifetime of hose and motor were added. These are the same parameters shown on the the previous, annulled energy label. The specific requirements and values are shown in Table 23.

Table 23: Outline of Ecodesign requirements

Parameters	Tier 1, 2014	Tier 2, 2017

[52] OJ L 192, 13.07.2013, p. 24

Annual energy consumption *AE*	< 62 kWh/year	< 43 kWh/year
Rated input power in *W*	< 1600 W	< 900 W
Dust pick up on carpet dpu_c	≥ 0.70	≥ 0.75
Dust pick up on hard floor dpu_{hf}	≥ 0.95	≥ 0.98
Dust re-emission d_{re}		≤ 1%
Sound power level in dB(A)		≤ 80 dB(A)
Hose oscillations in #		> 40 000
Operational motor life time in *h*		> 500 hours

Energy labelling regulation (EU) 2017/1369

Regulation 2017/1369[53] sets a framework for Energy Labelling and repeals Directive 2010/30/EU. The annulled Commission delegated Regulation (EU) No 665/2013[54] established requirements for the labelling and the provision of supplementary product information for electric mains-operated vacuum cleaners, including hybrid vacuum cleaners. This regulation is also the background for this review study. Any new energy labelling regulation for vacuum cleaners would be made under Regulation 2017/1369.

As with the Ecodesign requirements, the annulled energy label was also introduced in two tiers, Label 1 with energy efficiency classes A to G applicable from 1 September 2014, and label 2 with energy efficiency classes A+++ to D applicable from 1 September 2017. The two labels are shown in Figure 21.

[53] OJ L 198, 28.7.2017, p.1
[54] OJ L 192, 13.07.2013, p. 1

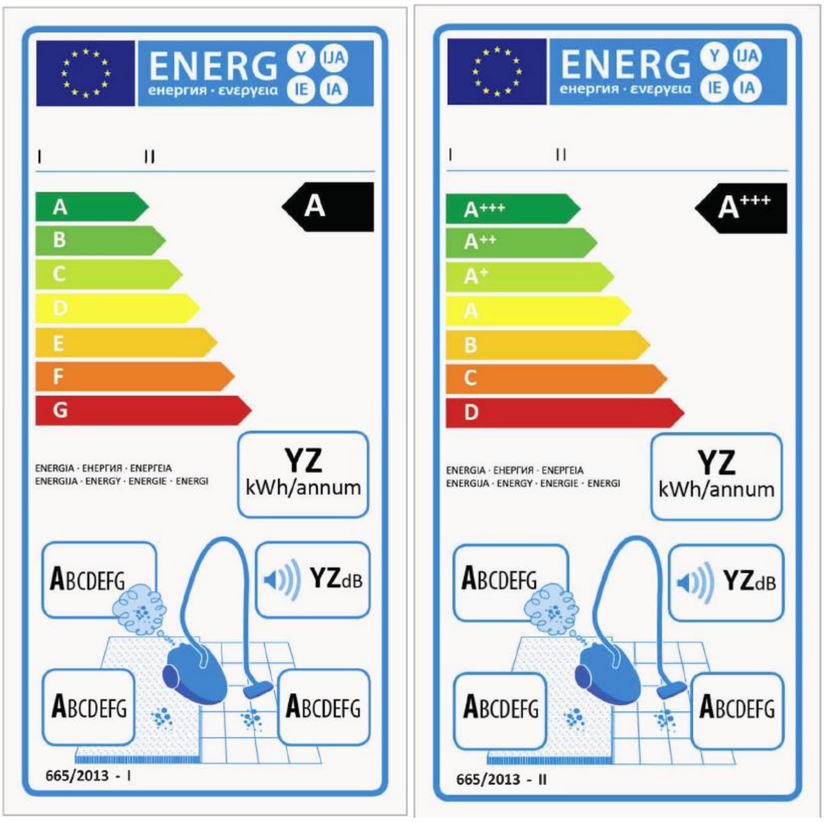


Figure 21: The previous, annulled Energy Label 1 (left) and label 2 (right) for vacuum cleaners

The energy efficiency class shown in the annulled energy label is based directly on the annual energy consumption, AE, which is also shown as a value on the label (kWh/annum). The cleaning performance class is based on the dust pick up on carpet and/or hard floor, and the dust re-emission class is based on the percentage of dust that is emitted from the vacuum cleaners to the surroundings. The classification according to the different performance parameters can be seen in Table 24.

Table 24: Vacuum cleaner - the previous, annulled energy label classifications

Energy Class	Annual energy (*AE*)	Perfor-mance class	dust pick up on carpet (dpu_c)	dust pick up on hard floor (dpu_{hf})	Dust re-emission (*dre*)
A+++	$AE \leq 10.0$	A	$dpu_c > 0.91$	$dpu_{hf} > 1.11$	$dre \leq 0.02\%$
A++	$10.0 < AE \leq 16.0$	B	$0.87 \leq dpu_c < 0.91$	$1.08 \leq dpu_{hf} < 1.11$	$0.02\% < dre \leq 0.08\%$
A+	$16.0 < AE \leq 22.0$	C	$0.83 \leq dpu_c < 0.87$	$1.05 \leq dpu_{hf} < 1.08$	$0.08\% < dre \leq 0.20\%$
A	$22.0 < AE \leq 28.0$	D	$0.79 \leq dpu_c < 0.83$	$1.02 \leq dpu_{hf} < 1.05$	$0.20\% < dre \leq 0.35\%$
B	$28.0 < AE \leq 34.0$	E	$0.75 \leq dpu_c < 0.79$	$0.99 \leq dpu_{hf} < 1.02$	$0.35\% < dre \leq 0.60\%$
C	$34.0 < AE \leq 40.0$	F	$0.71 \leq dpu_c < 0.75$	$0.96 \leq dpu_{hf} < 0.99$	$0.60\% < dre \leq 1.00\%$
D	$AE > 40.0$	G	$dpu_c < 0.71$	$dpu_{hf} < 0.96$	$dre > 1.00\%$

The dust pick-up cleaning performances for carpet (dpu_c, measured with standard test dust applied to a test carpet according to harmonised test standard) and hard floor (dpu_{hf}) are measured after 5 double strokes[55]. The annual energy consumption *AE* (in kWh/a) assumes specific energy use per m² (*ASE*, in Wh/m²) at two double strokes (4 passes) for an apartment of 87 m² once every week, at 50 weeks per year (2 weeks holiday/year), with Wh converted to kWh (factor 0.001) per unit of cleaning performance (dpu_c or dpu_{hf} or 50% of both) corrected with a term 0.2 to account for the fact that only 2 strokes and not 5 strokes are used in practice.

$$AE = 4 * 87 * 50 * 0.001 * ASE * \left(\frac{1 - 0.20}{dpu - 0.20}\right)$$

The parameters ASE and *dpu* have the suffix *c* when relating to carpet cleaning, *hf* when relating to hard floor cleaning and *gp* (50% *c* + 50% *hf*) when relating to general purpose.

The Average Specific Energy *ASE* (in Wh/m²) is the average power consumption *P* (in W) measured during the 5 double stroke cleaning test, increased with the average power consumption *NP* of an active nozzle battery calculated as the energy consumption *E* (in Wh) to restore a fully charged battery before the test to its original state after the test, divided by the time t_{bat} (in h) that the nozzle is active during the test, according to the manufacturer's instructions. This total power is then multiplied by the total test time *t* (in h) and divided by the test area *A* (in m²) covered in the test[56].

$$ASE = (P + NP) * \frac{t}{A}$$

LVD - Low Voltage Directive [57]

The Low Voltage Directive 2014/35/EU[58], covers electrical equipment with a voltage between 50 and 1000 V for alternating current and between 75 and 1500 V for direct current. For electrical equipment within its scope, the Directive covers all health and safety risks, thus ensuring that electrical equipment is safe in its intended use. Consumer goods with a voltage below 50 for alternating current or 75 for direct current are covered by the General Product Safety Directive as amended (GPSD) (2001/95/EC).

Machinery Directive

The Machinery Directive 2006/42/EC[59] (amended by Directive 2009/127/EC 60 and Regulation (EU) No 167/2013) has the dual aim of harmonising the health and safety requirements applicable to machinery on the basis of a high level of protection of health

[55] At nozzle-width on a test area at speed 0.50 m/s ±0.02 m/s, according to EN IEC 60312-1.
[56] According to EN 60312-1 the length of the test area is (700 ± 5) mm and the width is the nozzle-width. This area should be multiplied by 10 (euqals 5 double strokes).
[57] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:374:0010:0019:en:PDF
[58] OJ L 96, 29.03.2014, p.357
[59] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006L0042-20160420&from=EN
[60] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0127 (with regard to machinery for pesticide application)

and safety, while ensuring the free circulation of machinery on the EU market. The revised Machinery Directive does not introduce radical changes compared with the previous versions. It clarifies and consolidates the provisions of the Directive with the aim of improving its practical application. This directive applies to non-domestic products, such as commercial vacuum cleaners.

RoHS Directive

The Restriction of Hazardous Substances (RoHS) Directive 2011/65/EU[61] (amended by Directive (EU) 2017/2102[62]) aims to reduce hazardous substances from electrical and electronic equipment (EEE), including vacuum cleaners, that is placed on the EU market. A number of hazardous substances are listed in the Directive along with maximum concentration values that must be met, contributing to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE.

REACH Regulation

The Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) [63] Regulation 1907/2006/EC, addresses chemicals and their safe use, and aims to improve the protection of human health and the environment through a system of Registration, Evaluation, Authorisation and Restriction of Chemicals. The REACH Regulation places greater responsibility on industry to manage the risks from the chemicals they manufacture, import and market in the EU. Companies are required to demonstrate how substances can be used safely and risk management measures must be reported to users. The REACH Regulation also establishes procedures for collecting and assessing information on the properties and hazards of substances and requires that companies register their substances in a central database. The entries in the database are then assessed to determine whether the risks of the substances can be managed. The REACH Regulation allows for some chemicals to be classified as "substances of very high concern (SVHC)" due to their large potential negative impacts on human health or the environment. The European Chemicals Agency must be notified of the presence of SVHCs in certain products and the use of SVHCs may then be subject to prior authorisation. Substances can also be banned were risks are deemed to be unmanageable. As such, REACH encourages substitution of the most dangerous chemicals when suitable alternatives have been identified.

EMC – Electromagnetic Compatibility Directive

The Electromagnetic Compatibility (EMC) Directive 2014/30/EU[64] has the primary aim of protecting the electromagnetic spectrum. The Directive requires products to not emit

[61] OJ L 174, 01.07.2011, p.88
[62] OJ L 305, 21.11.2017, p.8
[63] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006R1907-20140410&from=EN
[64] http://ec.europa.eu/growth/sectors/electrical-engineering/directives/index_en.htm

unwanted electromagnetic interference and to be protected against a normal level of interference. The vast majority of complete electrical products must comply no matter of whether they are mains or battery powered. The EMC Directive does contain exemptions for a range of components with no intrinsic function and some products that are already covered by other directives such as medical, military and communications equipment.

Packaging 94/62/EC65

The packaging directive[66] was amended by Directives 2004/12/EC[67], 2005/20/EC[68], Regulations No 219/2009[69] and 2013/2/EU[70]), and covers all packaging placed on the market in EU and all packaging waste, whether it is used or released at industrial, commercial, office, shop, service, household or any other level, regardless of the material used.

The WEEE Directive

The WEEE Directive 2012/19/EU[71],[72] sets selective treatment requirements for Electronic and Electrical Equipment waste and its components. Vacuum cleaners fall into the scope of the WEEE Directive under category 2 "Small household appliances" of Annex I in the transitional period (from 13 August 2012 to 14 August 2018), and is specifically mentioned in the indicative list of EEE in Annex II[73]. After the transitional period (from 15 August 2018), vacuum cleaners fall under the category "Small equipment (no external dimension more than 50 cm)" set out in Annex III, and are specifically mentioned under the "small equipment" category in Annex IV that contains a non-exhaustive list of EEE covered by the Directive. Commercial vacuum cleaners are also covered by WEEE as noted in the FAQ[74], which notes that recital 9 to the Directive makes it clear that it covers all EEE used by consumers and EEE intended for professional use.

The WEEE Directive obliges 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. Furthermore, Member States shall encourage cooperation between producers and recyclers and ensure that producers provide information free of charge in

[65] OJ L 365, 31.12.1994, p.10
[66] http://eur-lex.europa.eu/legal-content/en/TXT/?uri=celex%3A31994L0062
[67] OJ L 47, 18.2.2004, p.26
[68] OJ L 70, 16.3.2005, p.17
[69] OJ L 87, 31.3.2009, p.109
[70] OJ L 37, 8.2.2013, p.10
[71] OJ L 197, 24.7.2012, p. 38
[72] Directive 2012/19/EU of the European Parliament And of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE)
[73] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012L0019
[74] http://ec.europa.eu/environment/waste/weee/pdf/faq.pdf

order to promote design that facilitates re-use, dismantling and recycling of WEEE, its components and materials[75].

The Battery Directive

The Batteries Directive 2006/66/EC[76] 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 January 1 2017 it was no longer possible to place on the market battery-operated vacuum cleaners with Nickel-Cadmium batteries. Furthermore, it sets rules for collection, treatment, recycling and disposal of waste batteries.

Directive 1999/44/EC on sale of consumer goods and associated guarantees and Directive 2011/83/EU on consumer rights

Directive 1999/44/EC[77] and its national transposition laws provide protection to consumers in cases of defects in or non-conformity of goods which they purchase. However, there is a lot of variation in the legal guarantee within the EU depending on the national transposition of the Directive. Below is a list with the variation in the legal guarantee across EU.

- 2 years in the majority of EU-countries, which is the minimum EU requirement (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Romania, Slovenia, Slovakia and Spain) as well as in Iceland and Norway,
- 3 years in Sweden,
- 5 years in Iceland and Norway for goods with a longer expected lifespan[78],
- 6 years in Ireland.
- United Kingdom has two different limitation periods: 6 years in England, Wales and Northern Ireland, 5 years in Scotland.
- In the Netherlands and Finland, the duration is based on the expected lifespan of the item.

Directive 2011/83/EU[79] gives consumers the same strong rights across the EU. It aligns and harmonises national consumer rules, for example on the information consumers need

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[75] Article 4 and 15 of the WEEE Directive, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012L0019
[76] OJ L 266, 26.9.2006, p. 1
[77] OJ L 171, 7.7.1999, p. 12–16
[78] Even though Iceland and Norway are not EU member states they have adopted the Ecodesign Directive and implementing Regulations through the EEA agreement.
[79] OJ L 304, 22.11.2011, p. 64–88

to be given before they purchase something, and their right to cancel online purchases. This directive also includes specific rules related to commercial warranties.

EPS Regulation

The External Power Supply (EPS) Regulation 278/2009[80] is relevant to all battery-operated vacuum cleaners, including cordless handstick and robot vacuum cleaners, as they require an EPS for charging the batteries[81]. The power supply is covered by the EPS regulation, as long as it is not defined as a "low voltage external power supply", having a voltage below 6 V and above or equal to 550 mA. The regulation sets requirements for EPS no-load condition electric power consumption and average active efficiency.

Standby Regulation

The Standby Regulation 1275/2008[82] covers household vacuum cleaners since they fall under Annex I, point 1 "Other appliances for cooking and other processing of food, cleaning, and maintenance of clothes"[83]. However, in the FAQ related to the Standby Regulation, it is stated that "The maintenance mode of the battery load in portable appliances (e.g. portable vacuum cleaners) is one of the key functions of the system (battery charge and portable appliance) to avoid discharge of the battery. This is a function beyond reactivation function and information display, and therefore not considered to be standby-mode"[84]. This statement is intended to be affirmed when implementing the changes from the latest review of the regulation. It can therefore be assumed that neither cordless nor robot vacuum cleaners are covered by the Standby Regulation, which requires products to switch into a low power mode after a reasonable amount of time after use and not consume more than 0.5 Watts in standby mode.

7.2.2 Voluntary agreements at Member State level

The German Blue Angel ecolabel is at the moment the only label active in the EU dealing with vacuum cleaners[85]. This eco-label is awarded to vacuum cleaners that have the following environmental attributes:

- limit values for input power,
- high dust pick-up and low dust re-emissions,
- low noise emissions,
- avoidance of polluting materials, durable and recyclable design

[80] OJ L 093, 7.4.2009, p.3
[81] http://ec.europa.eu/DocsRoom/documents/4701/attachments/1/translations/en/renditions/native
[82] OJ L 339, 18.12.2008, p. 45
[83] Commission Regulation (EUC) No 1275/2008, Annex 1: List of energy-using products covered by this Regulation
[84] https://ec.europa.eu/energy/sites/ener/files/documents/guidelines%20for%20SMEs%201275_2008_oct_09.pdf
[85] https://www.blauer-engel.de/en/products/home-living/staubsauger/staubsauger

These Basic Criteria apply to vacuum cleaners for both commercial and household use in line with the Ecodesign Regulation and the annulled Energy Labelling Regulation. Excluded from the scope are:

- wet, wet and dry, battery-operated vacuum cleaners,
- robot, industrial and central vacuum cleaners.
- floor polishers, outdoor vacuum cleaners.

The Blue Angel eco-label requires a motor service life of at least 600 hours, the suction nozzle must survive 1200 falls from as high as 80 cm, the appliance must withstand a threshold and doorpost impact test of at least 500 cycles and the suction hose must survive at least 40,000 deformations. Thereby, the Blue Angel also points the way to an extended service life of products and the corresponding avoidance of waste.

7.2.3 Legislation and agreements at third country level

Mandatory measures

An analysis of the Clasp online database[86] on measures shows that Iran, Korea, Switzerland and Turkey have introduced mandatory measures for electric vacuum cleaners.

Voluntary initiatives

In Russia a voluntary endorsement label scheme exists for electric vacuum cleaners.

[86] http://www.clasponline.org/ResourcesTools/Tools/SL_Search/SL_SearchResults?p=compressors

Economy	Product Type	Scope	Policy Name	Policy Type	Mandatory / Voluntary	Most Recent Effective Date	Test Procedures
Iran	Vacuum cleaner	Household Vacuum cleaner (electric)	ISIRI 10672 Household Vacuum cleaner-Technical Specifications and Test Methods for Energy Consumption and Energy Labeling Instructions	Minimum Energy Performance Standard	M	7/22/2012	NS 5635 (2001)
			ISIRI 10672 Household Vacuum cleaner-Technical Specifications and Test Methods for Energy Consumption and Energy Labeling Instructions	Label Comparative	M	7/22/2012	NS 5635 (2001)
			ISIRI 10672, Amendment No.1, Household Vacuum cleaner-Technical Specifications and Test Methods for Energy Consumption and Energy Labeling Instructions	Minimum Energy Performance Standard	M	1/1/2014	-
Korea (ROK)	Electric	Vacuum cleaner of rated power consumption of 800W ~ 2,500W, and shall be moveable (dry only) Energy Efficiency (Suction power efficiency) shall be measured by the test method in KS C IEC 60312 which is obtained from maximum suction power rate divided by power consumption.	Energy Efficiency Grade Label for Vacuum cleaners	Label Comparative	M	1/1/2009	KS C IEC 60312
			MEPS for Vaccum Cleaners	Minimum Energy Performance Standard	M	1/1/2009	KS C IEC 60312
Russia	Electric	Household vacuum cleaners with dry filters, intended for cleaning of premises, clothes, carpets and furniture	GOST 10280-83	Minimum Energy Performance Standard	V	1/1/1985	GOST 27570.6-87, art. 6.13

							GOST 10280-83
Switzer-land	Electric	Applies to vacuum cleaners powered by electricity, including hybrid-type vacuum cleaners. Does not apply to: - wet vacuum cleaners, battery-type vacuum cleaners, robot vacuum cleaners, industrial vacuum cleaners and central vacuum; - floor polishers; - vacuum cleaners for outdoor use.	The previous, annulled regulation EU 665/2013	Label Comparative	M	1/8/2014	Art 4 e and Append. II and III of (UE) n. 666/2013
	Electric	This Regulation establishes eco-design requirements for the placing on the market of electric mains-operated vacuum cleaners, including hybrid vacuum cleaners. This Regulation shall not apply to: (a) wet, wet and dry, battery operated, robot, industrial, or central vacuum cleaners; (b) floor polishers; (c) outdoor vacuums.	EU 666/2013	Minimum Energy Performance Standard	M	1/9/2014	Art 4 e and Append. II and III of (UE) n. 666/2013
Turkey	Electric	This Regulation establishes eco-design requirements for the placing on the market of electric mains-operated vacuum cleaners, including hybrid vacuum cleaners. This Regulation shall not apply to: (a) wet, wet and dry, battery operated, robot, industrial, or central vacuum cleaners; (b) floor polishers; (c) outdoor vacuums.	Turkish Official Gazette No. 29236 (transposition of EC 666/2013)	Minimum Energy Performance Standard	M	1/14/2015	
	Electric	This Regulation establishes requirements for the labelling and the provision of supplementary product information for electric mains-operated vacuum cleaners, including hybrid vacuum cleaners. This Regulation shall not apply to: (a) wet, wet and dry, battery operated, robot, industrial, or central vacuum cleaners; (b) floor polishers; (c) outdoor vacuums.	Turkish Official Gazette No. 29236 (transposition of EC 665/2013)	Label Comparative	M	1/14/2015	-
							-

7.3 Review of relevant standards

This section presents an overview of the test standards relevant for vacuum cleaners. Further details are shown in Annex A. These are also set out in the Commission Guidelines for the Ecodesign Regulation of vacuum cleaners[87].

7.3.1 Mandate 540

The Commission published on 11 December 2015 the standardisation request for vacuum cleaners M/540[88], which aims to create a harmonized standard (or standards) which cover(s) the requirements of Regulations 666/2013 and the previous, annulled regulation 665/2013.

The requested new harmonised standards shall be established, in particular, by revising existing harmonised standards for vacuum cleaners making them fit for purpose in the context of Ecodesign and the annulled Energy Labelling in relation to the following aspects related to the scope and requirements of the regulations:

- durability of the hose and operational lifetime of the motor;
- water filter vacuum cleaners;

as well as the following aspects related to potential future scope and requirements for Ecodesign and Energy Labelling Regulation for vacuum cleaners:

- full size battery operated vacuum cleaners; new draft standard "IEC 62885-4 Surface cleaning appliances – Part 4: Cordless dry vacuum cleaners for household or similar use – Methods for measuring the performance" based on the EN 60312-1 for dry vacuum cleaners. The new draft standard IEC 62885-4 is currently at CD stage. It is subject to parallel voting on CENELEC level.
- robot vacuum cleaners; new standard "IEC 62885-7 Surface cleaning appliance – Part 7: Dry-cleaning cleaning robots for household use – Methods of measuring performance" amending the existing test standard IEC (EN) 62929:2014
- measurement of energy consumption, dust pick-up and dust re-emission with a partly loaded instead of an empty receptacle; A Round Robin Test (RRT)[89] is being carried out (started November 2017)
- measurement of energy consumption, dust pick-up and sound power level with sufficiently market-representative carpet(s) and hard floor(s).

[87] https://ec.europa.eu/info/sites/info/files/commission_guidelines_ecodesign_requirements_for_vacuum_cleaners.pdf
[88] http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=561#
[89] Seven test labs are involved

7.3.2 Safety standards

EN 60335-2-2:2010+A1:2013+A11:2012 Household and similar electrical appliances - Safety - Part 2-2: Particular requirements for vacuum cleaners and water-suction cleaning appliances

The A11 amendment was prepared by CLC/TC 61: Safety of household and similar electrical appliances. This European Standard deals with the safety under the Low Voltage Directive[90] of electric vacuum cleaners and water suction cleaning appliances for household and similar purposes, including vacuum cleaners for animal grooming, their rated voltage being not more than 250 V. It also applies to centrally-sited vacuum cleaners and automatic battery-powered cleaners, to motorized cleaning heads and current-carrying hoses associated with a particular vacuum cleaner.

This European Standard EN 60335-2-2+A1:2013+A11:2012 is also the designated harmonised standard for 'rated power input' for residential vacuum cleaners in the Regulations 666/2013 and the previous, annulled regulation 665/2013[91], but the Annex ZZ linking the paragraphs of the standard with the regulation is missing.[92] Furthermore, although the study team did not receive specific comments from stakeholders on the issue, there is a possible loophole in the standard regarding the definition of 'booster setting', which allows (temporary) operation at a wattage higher than the rated power input. Also there is an ambiguity regarding the admissible deviation on 'rated power input' value in the standard vis-à-vis the verification tolerances in the regulations. In paragraph 3.11 there is a proposal to improve the robustness of the definition of 'rated power input' in the context of Ecodesign and Energy Label regulations for vacuum cleaners.

IEC / EN 60335-2-69:2012 Household and similar electrical appliances - Safety - Part 2-69: Particular requirements for wet and dry vacuum cleaners, including power brush for commercial use

International Standard IEC 60335-2-69 was prepared by subcommittee 61J: Electrical motor-operated cleaning appliances for commercial use, of IEC technical committee 61: Safety of household and similar electrical appliances. The EN version has been harmonised under the Machinery Directive, which is applicable to commercial vacuum cleaners.

This International Standard deals with the safety of electrical motor-operated vacuum cleaners, including back-pack vacuum cleaners, and dust extractors, for wet suction, dry suction, or wet and dry suction, intended for commercial indoor or outdoor use with or without attachments. This standard contains also the test procedure for the determination

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[90] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/low-voltage_en

[91] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/ecodesign/vacuumcleaners_en and see also Guidelines accompanying the vacuum cleaner regulations 666/2013 and 665/2013, European Commission, 2014.

[92] The Commission remarks in the publication that "This standard needs to be completed to clearly indicate those legal requirements aimed to be covered".

of acoustical noise for the appliances within the scope. It also deals with the safety of centrally-sited vacuum cleaners[93], excluding the installation of the system. Furthermore, the standard includes vibration and noise test codes, which are safety related items for commercial vacuum cleaners rather than performance criteria.

7.3.3 Material efficiency standards

In December 2015 the Commission issued a standardisation request to the European Standardization organisations regarding Ecodesign requirements on material aspects for energy-related products. The standardisation work is performed in CEN-CLC/J WG 10 under M/543[94]. The set of standards should be ready by March 2019[95], but most standards have received a 9 month tolerance in order to meet the CEN-CENELEC procedures. Publication is to be expected in end 2019/ early 2020.

prEN 45557 General method for assessing the proportion of recycled material content in energy related products

This European Standard is currently under development. The aim is to ensure a general method for assessing the proportion of recycled material content in energy related products. This standard relates to the physical characteristic of the materials and manufacturing history of all the parts in the product. The standard includes:

- Methods for calculating the recycled material content
- Specific guidelines per material type
- Traceability
- Reporting

Guidelines for accounting and reporting recycled content will contribute to avoid potentially unsubstantiated and misleading claims on recycled content for which it is not clear how they are determined. This standard enables requirements of recycled content in products as these claims can be controlled by market surveillance authorities

prEN 45555 General methods for assessing the recyclability and recoverability of energy-related products

This European Standard is currently under development and deals with methods for the assessment of the ability to repair, reuse and upgrade energy related products. This standard suggests a horizontal approach for all energy related products. The standard is described as generic and general in nature which means that it is not intended to be applied directly but may be cited in relation with product specific or product group harmonised standards.

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[93] Vacuum cleaner that is connected to a ducting system installed in the building
[94] http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=564
[95] http://ecostandard.org/work-on-material-efficiency-standards-for-ecodesign-finally-kicks-off/, https://docs.wixstatic.com/ugd/39a2f0_75eb06c438494c8ea0bb578f5b2f6ef0.pdf

The standard provides a general methodology for:

- the ability to repair products
- the ability to reuse products, or parts thereof,
- the ability to upgrade products, excluding remanufacturing.

Furthermore, this standard provides a common framework for future vertical/product specific standards.

7.3.4 WEEE and RoHS standards

ISO 11469:2016 - Plastics - Generic identification and marking of plastics products

The EN ISO 11469 standard identifies specifies a system of uniform plastic material marking system. The standard does not cover every aspect of marking (e.g. the marking process, the minimum size of the item to be marked, the size of the lettering or the appropriate location of the marking) but the marking system described is intended to help identify plastics products for subsequent decisions concerning handling, waste recovery or disposal. The standard refers to ISO 1043-1 for generic identification of the plastics.

EN ISO 1043-2:2011 - Plastics. Symbols and abbreviated terms. Fillers and reinforcing materials

The EN ISO 1043 standard defines abbreviated terms for the basic polymers used in plastics, symbols for components of these terms, and symbols for special characteristics of plastics.

IEC TR 62635:2012 - Guidelines for end of life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment

IEC/TR 62635:2012(E) provides a methodology for information exchange involving electronic and electrical equipment manufacturers and recyclers. The standard also provides a methodology enabling calculation of the recyclability and recoverability rates of to facilitate optimized end of life treatment operations.

EN 50419:2006 - Marking of electrical and electronic equipment in accordance with Article 11(2) of Directive 2002/96/EC (WEEE)

EN 50419 contains the product marking requirements needed to ensure compliance with the WEEE Directive. EN 50419 also contains additional information relating to the marking requirements, including positioning, visibility, dimensions, location and referenced documents. The marking requirements are applicable to all manufacturers and producers of electrical and electronic equipment placing products on the EU market.

EN 50625-1:2014 Collection, logistics & treatment requirements for WEEE - Part 1: General treatment requirements

EN 50625 was prepared as part of a series of standards requested in Commission mandate 518 which aim to support implementation and effectiveness of Directive 2012/19/EU

(WEEE). The standard contains requirements applicable to the treatment of all types of WEEE and addresses all operators involved in the treatment (including related handling, sorting, and storage) of WEEE. In particular, the standard addresses the following issue areas:

- Management principles
    - Technical and infrastructural pre-conditions
    - Training
    - Monitoring
    - Shipments
- Technical requirements
    - General
    - Receiving of WEEE at treatment facility
    - Handling of WEEE
    - Storage of WEEE prior to treatment
    - De-pollution (including Annex A normative requirements)
    - De-pollution monitoring (including Annex B normative requirements)
    - Treatment of non-de-polluted WEEE and fractions
    - Storage of different fractions of waste (e.g. plastics, metals etc.)
    - Recycling and recovery targets (including Annex C & D normative requirements)
    - Recovery and disposal of fractions
- Documentation

The standard applies to the treatment of WEEE until end-of-waste status is fulfilled, or until the WEEE is prepared for re-use, recycled, recovered, or final disposal.

EN 50574 on the collection, logistics & treatment requirements

EN 50574 on the collection, logistics & treatment requirements for end of life household appliances containing volatile fluorocarbons or volatile hydrocarbons.

EN 62321 series - Determination of certain substances in electrotechnical products

The purpose of the harmonized EN 62321/IEC 62321 series of standards is to provide test methods that will allow determination of the levels of certain substances of concern in electrotechnical products on a consistent global basis.

EN 50581:2012 - Technical documentation for the evaluation of electrical and electronic products with respect to restriction of hazardous substances

The EN 50581 standard specifies the technical documentation a producer of EEE has to collect for applicable substance restrictions in order to demonstrate compliance with Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS). The technical documentation required to meet the standard includes:

- A general product description

- Documentation of materials, parts and/or sub-assemblies
- Information showing the relationship between the technical documents and respective materials, parts and/or sub-assemblies

A list of harmonized standards and/or technical specifications used to prepare the technical documents.

7.3.5 Other relevant standards

This paragraph is intended to give an overview of other standards used to test vacuum cleaners. These can standards for dry, wet or commercial vacuum cleaners, it is a non-exhaustive list that is included to show the big diversity in test standards related to vacuum cleaners.

IEC 62885-8 ED1: Surface cleaning appliances - Part 8: Dry vacuum cleaners for commercial use - Methods for measuring the performance

This standard was developed particularly for commercial vacuum cleaners to better simulate the use hereof. The standard includes measurement of vacuum cleaner performance in terms of debris pickup on hard floor simulated by vacuuming M3 brass nuts laid out in a specific pattern. Furthermore, the standard includes measurement of the push/pull forces, or motion resistance, on carpet, which is a safety criterion under the machinery directive. The standard applies to commercial vacuum cleaners, meaning vacuum cleaners compliant with the Machinery Directive rather than the Low Voltage Directive.

EN 60704-2-1:2015 "Household and similar electrical appliances. Test code for the determination of airborne acoustical noise. Particular requirements for vacuum cleaners".

Note that this standard does not apply to commercial vacuum cleaners, for which noise is measured according to EN 60335-2-69 as a safety criterion under the machinery directive.

This standard applies to electrical vacuum cleaners (including their accessories and their component parts) for household use, or under conditions similar to those in households. This part of IEC 60704 applies as it is to electrical vacuum cleaners operating in dry conditions.

IEC 60704-2-17 "Household and similar electrical appliances - Test code for the determination of airborne acoustical noise - Part 2-17: Particular requirements for dry cleaning robots for household use".

This standard is being developed by IEC SC 59F WG 2 to test airborne acoustical noise for dry cleaning robots and is currently in the ACD stage[96].

[96] Approved for Committee draft. http://www.iec.ch/dyn/www/f?p=103:38:4477692311473::::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:1395,20,23534

EN 60704-3:2006 "Household and similar electrical appliances - Test code for the determination of airborne acoustical noise - Part 3: Procedure for determining and verifying declared noise emission values".

This part of IEC 60704 describes procedures for determining and verifying the declared values of the noise emitted by household and similar appliances. It applies to all categories of household and similar electrical appliances covered by IEC 60704-1 and IEC 60704-2 dealing with particular requirements for special categories of appliances. It applies to appliances being produced in quantity (in series, batches, lots) manufactured to the same technical specification and characterized by the same labelled value of noise emission.

EN 62826:2014 "Surface cleaning appliances - Floor treatment machines with or without traction drive, for commercial use - Methods of measuring the performance".

This International Standard lists the characteristic performance parameters for walk-behind and ride-on floor scrubbers and sweepers and other floor cleaning machines according to IEC 60335-2-72[97]. This standard does not apply to IEC 60312 series.

The intent is to serve the manufacturers in describing parameters that fit in their manuals, and in their literature. This may include all or some of the parameters listed in this definition document. When any of the parameters listed in this document are used, they are noted as being measurements made in accordance with this document.

EN 62929:2014 "Cleaning robots for household use - Dry cleaning: Methods of measuring performance".

This International Standard is applicable to dry cleaning robots for household use in or under conditions similar to those in households. The purpose of this standard is to specify the essential performance characteristics of dry cleaning robots and to describe methods for measuring these characteristics. The standard describes several tests:

- Measuring the dust removal in a box (hard floor and carpets):
- Measuring dust removal in a straight line (hard floor and carpets):
- Autonomous navigation/coverage test
- Average robot speed

EN 61960-3:2017 "Secondary cells and batteries containing alkaline or other non-acid electrolytes.

Secondary lithium cells and batteries for portable applications. Prismatic and cylindrical lithium secondary cells, and batteries made from them". Includes measurement methods

[97] *Household and similar electrical appliances – Safety – Part 2-72: Particular requirements for floor treatment machines with or without traction drive, for commercial use*

for battery performance, including electrical measurements, charge measurements and endurance testing in terms of cycle times the battery can withstand.

IEC 62885-2:2016 "Surface cleaning appliances - Part 2: Dry vacuum cleaners for household or similar use - Methods for measuring the performance".

IEC 62885-2:2016 is applicable for measurements of the performance of dry vacuum cleaners for household use in or under conditions similar to those in households. The purpose of this standard is to specify essential performance characteristics of dry vacuum cleaners which are of interest to users and to describe methods for measuring these characteristics. This standard is not intended for cordless vacuum cleaners.

A new edition is currently under preparation which will incorporate the new content of EN 60312-1:2017 (like amended durability tests, water filter vacuum cleaners etc.). It should be highlighted that the draft new edition also adopts new tests reflecting better real life and being more consumer relevant. As an example the debris pick-up test from hard floor can be mentioned, this is without a predecessor test.

IEC 62885-4:2016 "Surface cleaning appliances - Part 4: Cordless dry vacuum cleaners for household or similar use - Methods for measuring the performance".

A standard for cordless (= battery operated) vacuum cleaners is currently under development at IEC SC 59F WG 7. The designation of this new standard will be IEC 62885-4 ED1 Surface cleaning appliances - Part 7: Cordless dry vacuum cleaners for household or similar use - Methods for measuring the performance which is at CD (Committee Draft) level. Publication is expected for 2019-09[98].

The purpose of this standard is to specify the essential performance characteristics of cordless dry vacuum cleaners which are of interest to users and to describe methods for measuring these characteristics. This standard is not intended for mains-operated vacuum cleaners or cleaning robots. For safety requirements, reference is made to IEC 60335-1 and IEC 60335-2-2. This is still a draft standard and the expected date of publication is July 2020[99]. The IEC standard will be submitted for parallel voting at CENELEC.

This standard will be a fragmented standard based on the standard for mains-operated vacuum cleaners IEC 62885-2. That means that the standard for cordless vacuum cleaners only contains the deviations from the standard for mains-operated vacuum cleaners. Most of the tests remain unchanged.

Important changes are:

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98 https://www.iec.ch/dyn/www/f?p=103:23:23463396680231::::FSP_ORG_ID,FSP_LANG_ID:1395,25

99 https://www.iec.ch/dyn/www/f?p=103:38:1857809424266::::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:1395,23,23200

- All tests were checked and amended where applicable regarding the duration of a test with respect to the limited runtime of a cordless vacuum cleaner (e.g. time for conditioning, running-in procedures, waiting time and alike).
- As a new test the (effective) runtime of a cordless VC introduced which is the time it takes to go from an original vacuum (negative pressure versus ambient) realised by a fully charged cordless VC, operating in accordance with the manufacturer's instructions for the cleaning performance, to a vacuum that is 40% of the original vacuum. The test shall be performed on both hard floor and carpet. This is presumed to reflect real-life runtime.
- The test cycle for measurement of the energy consumption is adapted to cordless vacuum cleaners. The outcome of this test gives the energy used to clean an area of 10 m^2.

IEC 62885-4 ED1 also contains a first tentative definition of a 'Non-full size battery operated vacuum cleaner', i.e. a 'handheld' that is not typically used for floor cleaning, as 'a battery operated vacuum cleaner which when fully charged, cannot clean 15 m2 of floor area by applying 2 double strokes to each part of the floor without recharge'. It is mentioned that this definition is not clear enough. Thus it should be extended/amended.

EN 62929:2014 Cleaning robots for household use - Dry cleaning: Methods of measuring performance

The purpose of this standard is to specify the essential performance characteristics of robot vacuum cleaners which are of interest to users and to describe methods for measuring these characteristics.

The standard describes several tests:

- Measuring the dust removal in a box (hard floor and carpets):
  Section 5 describes a test with a rectangular dust area of 1300 mm x 500 mm in the middle of a rectangular box of 2000 mm x 1150 mm where the robot has to find its own way in picking up the dust during a test run of 15 minutes. There are two test runs, each with a different starting position of the robot.
  This test is designed to give indicative data on the dust removal capability of a robotic cleaner, while allowing it to function and move in an autonomous way in an open area with no obstacles. Navigation strategies differ, so the dust removal result shall always be reported with time taken to deliver that score, to allow for relative comparison between different products.

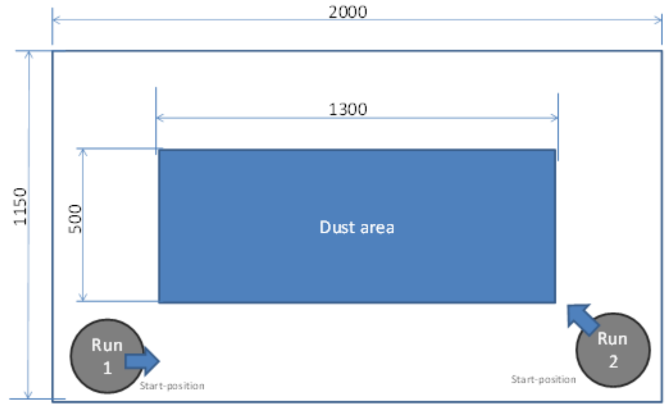


Figure 22: Floor plan of test-box for cleaning, according to section 5

- Measuring dust removal in a straight line (hard floor and carpets):
  Section 6 describes a straight-line cleaning test, similar to that of a mains-operated vacuum cleaner, using a dust area of 700 mm x (Nozzle width -20 mm) and appropriate acceleration and deceleration zones before and after the 700 mm long test area to ensure a constant speed.
  This test is designed to isolate the dust removal system of the robot from the autonomous movement, in order to assess only the ability to remove dust. This facilitates direct comparison between robotic cleaners.

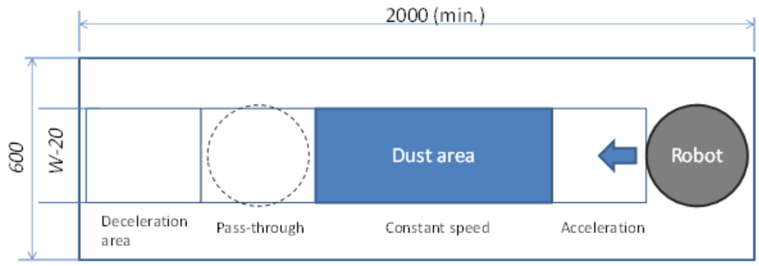
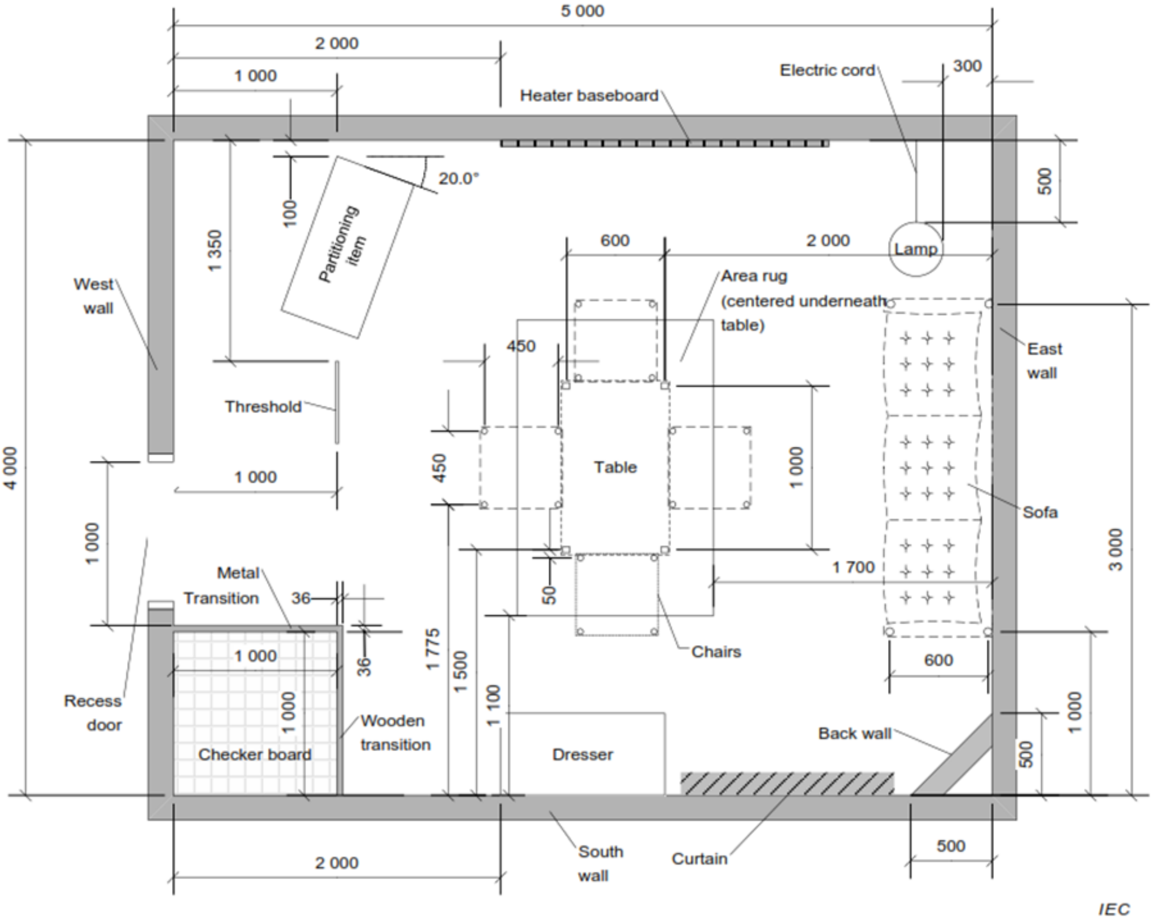


Figure 23: Floor plan of straight-line cleaning test according to section 6

- Autonomous navigation/coverage test
  Section 7 describes the determination of how well the robot covers a typical room area (in cumulative percentage floor area traversed), also measuring multiple floor area passes. The standardised test room configuration has a floor plan of 4 m x 5 m with full height walls, furniture and other obstacles, carpet-areas, etc, described in great detail. In three test runs (each with a different starting position) the robot will get typically half an hour from each starting position to cover the area efficiently and effectively. The robot's movements are measured with a Visual Tracking System (VTS).
  The purpose of the autonomous navigation/coverage test is to measure the ability of floor cleaning robots, as defined within this standard, to cover the available floor space against a standardised room configuration. The measure of performance for

this test is the cumulative percent floor space traversed during a period of time. Multiple passes of the robot over the same floor space is also measured in this test.

Figure 24: Floor plan for testing autonomous coverage



This standard is neither concerned with safety nor with performance requirements.

A new edition of this standard is currently under development at IEC SC 59F WG 5. The designation of this new edition will be IEC 62885-7 ED1 Surface cleaning appliances - Part 7: Dry-cleaning robots for household use - Methods of measuring performance, which is at CD (Committee Draft) level. Publication is expected for 2019-09[100].

This draft standard contains new tests like mobility, debris pick-up, fibre removal from carpet and energy consumption while the box test will be removed. Tests like corner/edge cleaning and emissions will be considered for a future edition.

The draft standard describes these new tests:

- Mobility

[100] https://www.iec.ch/dyn/www/f?p=103:23:23463396680231::::FSP_ORG_ID,FSP_LANG_ID:1395,25

Section 9 describes a variety of obstacles which can be found in a real environment at home. These include a minimum gap to go through or to go under, a maximum transition (floor height offset) and a maximum threshold to go over.

The purpose of these tests is to quantify the capability of a cleaning robot to overcome various standardised obstacles in defined configurations.

- Debris pick-up

  Sections 10 to 12 describe the determination of the capability of the cleaning robot to pick up debris of various size. Debris that can be found in households is often organic material. For the sake of repeatability and reproducibility this organic material is represented by synthetic material of similar size and weight which is available in defined dimensions. In addition a pre-defined amount of set screws[101], screws and nuts are proposed which are distributed on the carpet[102].

- Fibre removal

  Section 13 describes the determination of the capability of the cleaning robot to remove fibre from carpets. Fibres are distributed and embedded on a certain area of the carpet. Fibre removal performance is evaluated based on visual inspection

Illustrative picture of fibre distribution before and after the test

[101] A set screw is a type of screw generally used to secure an object within or against another object, normally not using a nut

[102] The plastic (PA6.6) nuts and screws according to ISO 4032 (nuts, M3, weight approx. 0.5 g/piece) and ISO 4766 (screws, M3 x 6, approx. 0.35 g/piece) are roughly similar in shape as rice and lentils. They are distributed on the test carpet at a density of 15 g/m² each.

- Energy consumption of a cleaning robot

  Section 14 describes the energy consumption of a cleaning robot in different states. These states are:

  1.) Docking station without the cleaning robot
  Considers the energy consumption of the docking station in "stand-by".
  2.) Cleaning robot is charged after operating in the navigation test room
  Determines the energy consumption for one operation in the navigation room which is typically half an hour.
  3.) Fully charged robot at docking station
  Determines the energy consumption of a cleaning robot waiting for the next cleaning task.

  State 3.) is an important part of the robot use but details about this state are not yet agreed and are under further consideration.

  This test is a general method for measuring and calculating the energy consumption of cleaning robots. This method should be the basis for further definitions of annual energy consumption for cleaning robots and also mobile household robots.

Note that the CD for IEC 62885-7 ED1 is a preliminary draft that still has to go through several stages of comments and approvals and thus can be changed considerably before publication.

IEC/PAS 62611:2009 "Vacuum cleaners for commercial use - Methods for measuring performance"

These test methods are applicable to vacuum cleaners for commercial use. The purpose of this PAS is to specify essential performance characteristics of vacuum cleaners being of interest to the users and to describe methods for measuring these characteristics. For safety requirements, refer to IEC 60335-1, IEC 60335-2-2 and IEC 60335-2-69.

Work recently started to replace this PAS by a new performance standard for commercial vacuum cleaners: IEC 62885-8 ED1 Surface cleaning appliances - Part 8: Dry vacuum cleaners for commercial use - Methods for measuring the performance.

7.3.6 Consumer organizations

Besides industry or Market surveillance testing, consumer organisations also do product testing. The harmonised standard EN 60312-1 has been used for many years but they also deviate sometimes and test different aspects. A detailed overview of test performed by consumer organizations is given in Annex A.

Consumentenbond is a Dutch independent consumer organization who have tested cylinder vacuum cleaners[103]. Which? is an independent consumer organization based in the UK. Every year they test over 3600 products and cover the essential features of a product. They perform tests performed on cylindrical and upright vacuum cleaners[104], robot vacuum cleaners[105] and Cordless vacuum cleaners[106]. Stiftung Warentest is an independent German consumer organization who tests products and services according to scientific methods in independent institutes and publishes the results in their publications. The Stiftung Warentest tested corded vacuum cleaners, battery and robot vacuum cleaners. The Belgian consumer association Test Achats tested cylinder vacuum cleaners in 2017.[107]

[103] https://www.consumentenbond.nl/stofzuiger/hoe-wij-testen
[104] http://www.which.co.uk/reviews/vacuum-cleaners/article/how-we-test-vacuum-cleaners
[105] http://www.which.co.uk/reviews/robot-vacuum-cleaners/article/how-we-test-robot-vacuum-cleaners
[106] http://www.which.co.uk/reviews/cordless-vacuum-cleaners/article/how-we-test-cordless-vacuums
[107] Test Achats, Test d'aspirateurs, juin 2017 - No. 620. www.test-achats.be

8. Task 2: Market data: sales and stock

In the following sections the market for vacuum cleaners is analysed in terms of sales, stock and prices. The analyses are based on data purchased from GfK on household vacuum cleaners, supplemented with data from stakeholders. Furthermore, assumptions from the preparatory study and the impact assessment are applied where necessary and appropriate.

8.1 Production and trade

The official source of market and stock data is the Eurostat PRODCOM database[108], in which data is collected from Member States each year. There are a number of PRODCOM codes that relate to vacuum cleaners and associated products and are relevant for the study. However, these product categories, shown in Table 25, group the vacuum cleaner market in a different way than the regulations. This poses an issue, since the PRODCOM data encompasses more products than the scope of the regulations, for instance battery operated vacuum cleaners or wet and dry vacuum cleaners are included in the scope of the PRODCOM data, but not in that of the regulations.

Table 25: PRODCOM and HS6 product codes and nomenclature

PRODCOM code	PRODCOM Nomenclature (NACE Rev. 1.1, until 2006)
29.71.21.13	Domestic vacuum cleaners with self-contained electric motor for a voltage >= 110V
29.71.21.15	Domestic vacuum cleaners with self-contained electric motor for a voltage < 110V
	PRODCOM Nomenclature – (NACE Rev 2, from 2007)
29.71.21.23	Vacuum cleaners with a self-contained motor of a power <= 1500 watt and having a dust bag or receptacle <=20 litres
29.71.21.25	Other vacuum cleaners
29.71.30.10	Parts for vacuum cleaners

New categories were introduced in the PRODCOM database 2007, changing the grouping of the market data, but not the total number of vacuum cleaners included in the database. One of the most important changes in light of this study, is that in revision 1.1 the categories specified that they covered only domestic vacuum cleaners, whereas after 2007 this distinction is not made. For both revisions, however, it is not possible to exclude vacuum cleaners that are not covered by the scope of the regulation, and thus difficult to use these categories or the data directly for this study. PRODCOM data will therefore in this study mainly be used for comparison with data from other sources, and not used for estimating sales in specific product categories.

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

The production and extra-EU trade data for the total of the two NACE Rev 2 categories is given in Table 26. Note that the values and prices relate to the manufacturer selling price.

Table 26: Eurostat, PRODCOM, Total vacuum cleaners with self-contained motor - codes 27512123+27512125. Trade data relates to extra-EU only

	Exports			Imports			Production			Apparent consumption		
	Qty	value	price	Qty	value	price	Qty	value	price	Qty	value	price
	mill#	Mill €	€	mill#	Mill €	€	mill#	mill €	€	mill#	mill €	€
2010	9	770	86	68.8	1910	28	12.9	1034	80	72.7	2175	30
2011	9.7	820	85	67.5	2044	30	13.9	1135	82	71.7	2360	33
2012	9.6	864	90	64.6	2259	35	13.1	1098	84	68.1	2493	37
2013	10.2	933	91	67.4	2330	35	13.8	1193	87	71.0	2590	36
2014	9.9	892	90	70.6	2434	34	14.0	1200	86	74.7	2742	37
2015	8.8	862	98	74.6	3113	42	14.1	1151	82	79.9	3401	43
2016	10.3	954	93	77.3	3070	40	14.4	1158	80	81.4	3275	40
2017	6.4	591	92	43.9	1773	40	15.9	1263	80	53.4	2445	46

The table shows an apparent EU consumption of around 70 million units in the period 2010 to 2014. In 2015 and 2016, the apparent consumption jumps to approximately 80 million units, possibly because wholesalers and retailers are stocking up before the second tier of the Ecodesign measure in 2017. Then in 2017, the apparent consumption drops to 53 million units, possibly because retailers selling their stock from the previous two years. Based on this, it is concluded that 70 million units constitutes a plausible long term average apparent consumption for the relevant PRODCOM categories.

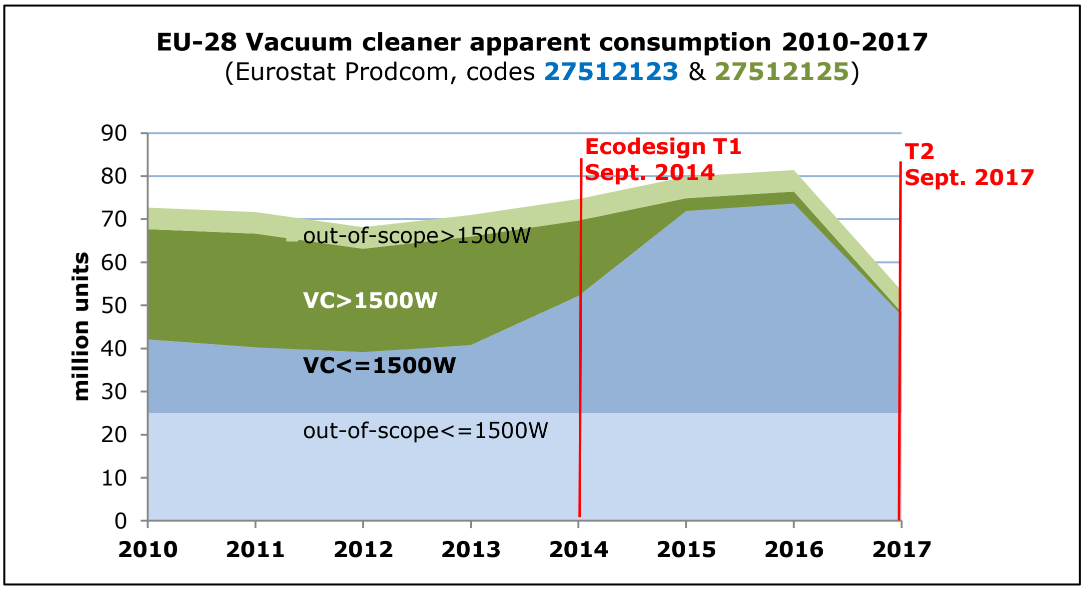
Only around half of the quantities in the table relate to vacuum cleaners in scope of the current regulation. The other half includes vacuum cleaners that are explicitly out of scope, such as wet, wet & dry, industrial and central vacuum cleaners. Based on the apparent consumption of vacuum cleaners >1500W in 2017 [109] this fraction is estimated at 5.7 million units. Also out-of-scope, by definition, are small handhelds not for floors (see Chapter 1), USB- or car-battery driven gadgets with a small suction motor, etc. Based on the GfK figures of approximately 40 million products in scope[110] in recent years and the 5 million out-of-scope products mentioned above, it is estimated that the fraction of small out-of-scope items is in the order of 25 million units.

Based on these estimates the graph in Figure 25 gives a split of the apparent consumption for both categories over the period 2010-2017. Despite the large uncertainty in the

[109] the year in which the regulation certainly has eliminated all products >1500W in scope
[110] This is 35 million units in the current scope and 5 million for cordless and robot products that could possibly be in the new scope

numbers, it is reassuring that the impact of the Ecodesign Regulation and the annulled Energy Labelling Regulation is clearly visible even from the Eurostat numbers.

Figure 25: Apparent VC consumption 2010-2017 according to Eurostat PRODCOM, with estimated fractions of products out of scope of the regulation



Regarding production per country the PRODCOM country-specific data show many gaps, probably for reasons of confidentiality. For vacuum cleaners ≤1500W the EU28 production in 2016 was 11.7 million units, of which Germany 3.2 million, Hungary 3.5 million, Italy 0.7 million. The production data for FR, NL, UK, SV, PL, RO and SI were withheld. For vacuum cleaners >1500W production of 2.7 million units is reported for 2016, of which Italy 0.48 million, Hungary 0.31 and the UK 0.06 million. Other data is zero or withheld.

Imports, not only of these out-of-scope items, play an important role. PRODCOM statistics for EU trade (according to HS6) are the only source to estimate the origin of EU imports and the destination of EU exports. The table and graphs below give the most important EU trade partners for vacuum cleaners in that respect.

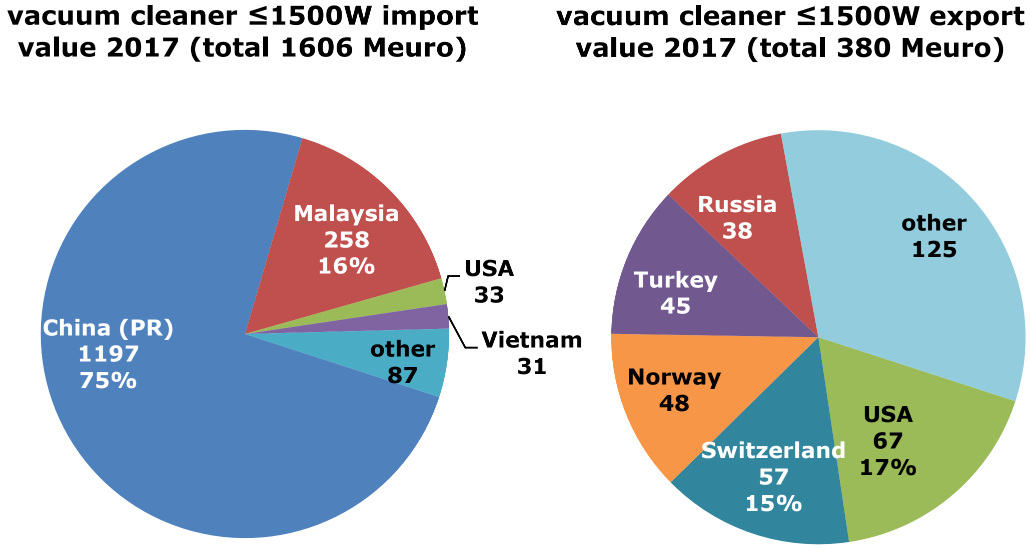
Table 27: Value of EU production and selected Extra-EU trade data 2011-2017 in million euros[111]

Year	Production	Extra-EU import				Extra-EU Export		*Apparent consumption
	EU28	Total	China	Malaysia	USA	Total	USA	EU
2011	669	561	346	148	35	147	20	1083
2012	636	673	408	194	43	189	24	1120
2013	710	697	392	231	51	222	24	1185
2014	808	867	569	189	59	240	28	1435

[111] Eurostat, production data: Prodcom, code 27512123 –vacuum cleaners ≤1500W, ≤20 L receptacle; trade data: EU trade since 1988 by HS6, code 850811; extracted Sept. 2018

2015	811	1395	937	298	59	274	32	1932
2016	799	1370	953	267	60	309	33	1860
2017	849	1605	1197	258	67	381	33	2073
**= There are deviations between different Eurostat codes, which may lead to deviations max. ±5%*								

Figure 26: Vacuum cleaner ≤1500W and <20L receptacle, EU 2017 imports by origin and EU 2017 exports by destination



8.2 Sales data

As mentioned, around half of quantities in the PRODCOM totals table relate to vacuum cleaner products that are not in the scope of the regulations. It was thus imperative to find a more robust source for the EU market. For that reason the sales volumes used for models and calculations in this study are based on market data purchased from GfK. The GfK data is based point of sales data on household vacuum cleaners for 22 countries (see Annex B) with an average market coverage of 87% in these countries.

The GfK data has a high coverage of the European market and only six[112] of the EU-28 countries, representing a total of 3% of the EU population and 1.1% of the GDP[113], are not included. Considering the coverage in each of the countries included in the dataset, the GfK vacuum cleaner data coverage on EU-level is 84% based on population and 85% based on BNP. This makes the GfK data highly reliable in the sense that it is both precise (collecting specific data from retailers) and accurate (covers a large number of retailers in each country).

[112] Bulgaria, Cyprus, Latvia, Lithuania, Estonia, and Malta
[113] https://europa.eu/european-union/about-eu/countries_en

The remaining 15% of sales in the EU, not included in the GfK data, was scaled based on the coverage % for each country. This means that for each country with tracked data and e.g. 87% coverage, the remaining 13% was scaled based on the average values for that specific country. For the six Member States not included in the data (i.e. the remaining 3% of the population), the average data for all other countries was used to scale to 100% coverage based on population.

The GfK product categories are very much in line with those in the regulations and include the mains-operated *'Cylinder', 'Upright'* and *'Handstick mains'* dry vacuum cleaners as well as the battery operated categories that are considered in the study ('*Robot'* and *'Cordless'*). Aggregated EU sales are provided by GfK for the period 2006-2016[114]. For the years 2013-2016 GfK gives a split per product category. GfK does not give figures on commercial vacuum cleaners, but based on corrected data from the 2009 preparatory study and inputs from manufacturers, a share of 12% commercial compared to domestic vacuum cleaners for cylinder and upright types is assumed[115].

Future sales are based on the yearly sales growth rates calculated from the GfK data from 2006 to 2016, which was 1.6% per year for the entire market including both commercial and domestic products. To make a conservative estimate of future sales, it is estimated that the 1.6% growth in total sales per year, moved toward 0% per year in 2030. However, the growth will be different for different product types.

The data shows that cylinder vacuum cleaners are the prevalent type in the EU with a market share of 68% in 2016, and upright vacuum cleaners are only sold to a lesser extent (7%). The increase in total sales primarily results from the increased sales of handstick vacuum cleaners and to a lesser extent the robot vacuum cleaners, which still make up the smallest market share (4%) despite the increasing sales trend of this category.

Since the market shares of the different vacuum cleaner types are only available for the years 2013 to 2016, the market split was extrapolated to 2030. Assumptions were made for the continued development of the market shares for 2025 and 2030 based on stakeholder inputs, with linear interpolation of market shares in the years between. This yielded the market shares shown in Table 28. The 2005 market split was calculated from the preparatory study data, and is assumed unchanged for all years prior to 2005.

Table 28: Market shares of household vacuum cleaners

	2005	2010	2015	2018	2020	2025	2030
Cylinder	82%	80%	73%	65%	61%	48%	35%
Upright	14%	11%	9%	7%	7%	6%	5%

[114] In the scenario calculations in Task 7 a scaled down version of PRODCOM data will be used, for lack of better data
[115] The preparatory study assumed a 6% share of PRODCOM data. Because PRODCOM data are too high, it is now assumed that this translates into 11% of the GfK data.

Robot	0%	2%	4%	5%	6%	8%	11%
Handstick mains	1%	3%	3%	4%	5%	6%	7%
Handstick cordless	3%	4%	11%	18%	22%	31%	42%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

According to vacuum cleaner manufacturers more and more people buy cordless vacuum cleaners. According to industry most users buy them with the intention of using them for small cleaning jobs, but end up using them as their main vacuum cleaner. This is also reflected in the sales, where the market for cordless cleaners is expected to pick up speed as it becomes more accepted by users. The newest GfK data (YTD April 2017-2018) shows an accelerating trend with an 11% decrease in cylinder cleaners and a simultaneous increase in of 24% in cordless sales. Based on these data, it is expected that sales of cordless cleaners will exceed that of cylinders in around 2028.

The robot market is not increasing as fast as the cordless market, but is expected to pick up speed as well. This is, however, more uncertain, and a more conservative forecast has been made for robot sales. Based on the above, the following assessments and projections were made for household vacuum cleaners.

Since robot vacuum cleaners were not included in the preparatory study because it was a new technology at the time, the market share was assumed to be 0% for robot vacuum cleaners in 2005. This is consistent with the fact that the first robot vacuum cleaner was introduced to the market first in 1996 and then in 2001, but phased out each time due to poor functionality and high cost, respectively[116]. The first robot vacuum cleaner with commercial success was the Roomba, introduced in 2002[117]. It is thus assumed that the market share of robot vacuum cleaners remained in the sub-1% range for approximately five years. The market split shown in Table 28 together with the total market size result in the sales figures (shown as million units) in Table 29. Sales for all years can be seen in Annex C.

Table 29: Derived vacuum cleaner sales from 1990 to 2030

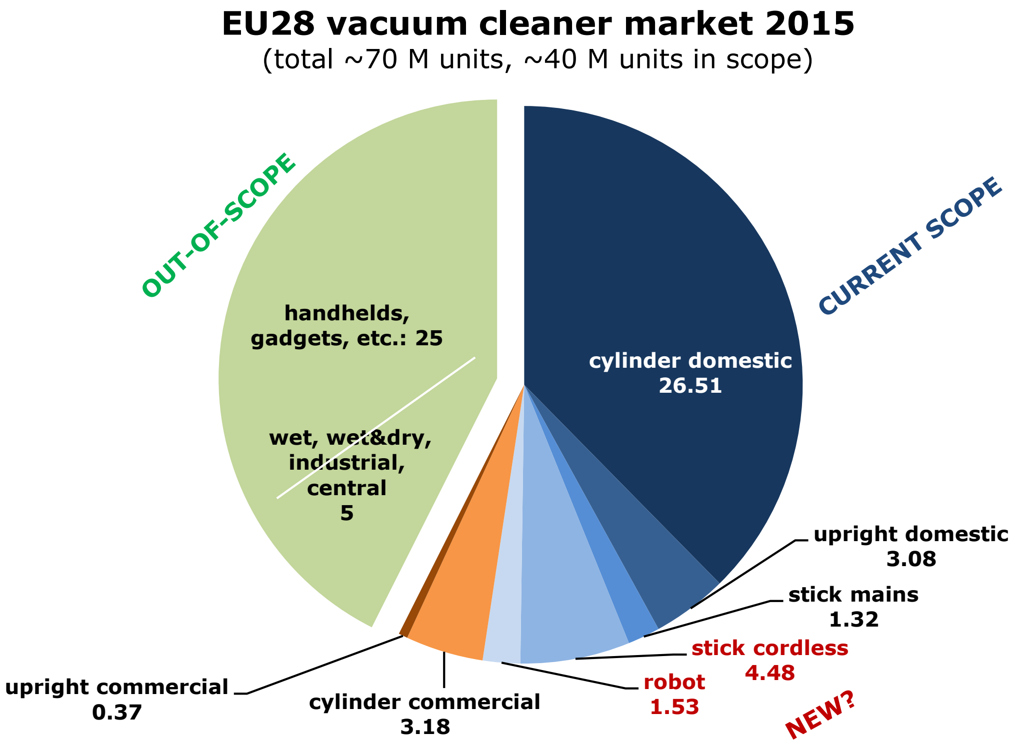
Sales in millions	1990	2000	2005	2010	2015	2018	2020	2025	2030
Cylinder household	14.81	16.92	25.01	25.28	25.07	23.43	22.06	17.88	12.07
Cylinder commercial	1.78	2.03	3.00	3.03	3.01	2.95	2.95	2.95	2.95
Upright Household	2.61	2.99	4.41	3.44	2.91	2.60	2.56	2.38	2.01
Upright Commercial	0.31	0.36	0.53	0.41	0.35	0.31	0.31	0.31	0.31
Handstick mains	0.30	0.34	0.50	0.91	1.25	1.66	1.87	2.38	3.22
Handstick cordless	0.51	0.59	0.87	1.56	4.24	7.39	9.11	13.51	18.10

[116] The Electrolux Trilobite in 1996 and the Dyson DC06 in 2001: http://www.vacuumcleanerhistory.com/vacuum-cleaner-development/history-of-robotic-vacuum-cleaner/
[117] http://www.irobot.dk/About-iRobot/About-iRobot

Robot	0.00	0.00	0.00	0.79	1.45	2.00	2.45	3.58	4.83
Total	**20.32**	**23.22**	**34.33**	**35.43**	**38.28**	**40.35**	**41.32**	**43.00**	**43.49**

The graph below combines the PRODCOM data for vacuum cleaners out of scope with the GfK sales data.

Figure 27: Vacuum cleaner ≤1500W and <20L receptacle, EU 2017 imports by origin and EU 2017 exports by destination



No split of sales per VC type is available per EU country. Based on anecdotal data it is known that some of the product types, for example stick vacuum cleaners and upright vacuum cleaners, are sold to specific countries. The upright cleaners are primarily sold in the UK, while the handsticks are primarily sold in Italy. According to Euromonitor[118], 54% of the handsticks sold in 2016, where sold on the Italian market, followed by 12% in France and 11% in Germany.

8.2.1 Market values

The purchased data from GfK provides data on value of the EU vacuum cleaner market, based on point of sales data, i.e. the end-user prices. The data is shown in Table 30.

Table 30: Vacuum cleaner market values

Market values, million EUR	2006	2007	2010	2015	2016	2018*

[118] Bissell, presentation by Ken Lee

GfK market value	2 735	2 894	2 865	4 200	4 367	5 018

**Projected data from first half of 2018*

PRODOM collects production data and thus corresponds to manufacturer selling price, import and export prices, whereas GfK collects point of sales data, i.e. the end-user prices. The difference in data collection point means that the calculated average unit price is available for both production and point-of-sales, leading to an estimation of the average mark-up factor, as seen in Table 31. The mark-up factor is defined as the difference in manufacturer selling price and the end-user purchase price, and are used in economic calculations.

Table 31: Average unit price for vacuum cleaner in EU according to GfK and Prodcom

Unit prices, EUR	2006	2007	2010	2015	2016	2018*
GfK unit price	109	109	112	147	148	139
PRODCOM unit price	42	49	30	43	40	n/a
Mark-up factor	2.57	2.24	3.73	3.4	3.7	-

** Projected data from first half of 2018*

8.3 Lifespan

The lifespan of the different product categories is used to determine how long they are in use after purchase, and thus for how long they are a part of the energy-consuming stock.

In the preparatory study, it was determined that the lifetime of household vacuum cleaners ranged between 6.3 and 10 years according to various sources and an average lifetime of 8 years was used in that study[119]. A lifetime of 8 years on average is backed up by a 2016-survey made by consumer reports, but with emphasis on the variation in lifetime between brands[120]. According to an Austrian study from AK Wien in 2015 the average expected lifetime of vacuum cleaners by consumers is 10.3 years[121]. This does not reflect the actual lifetime, but shows that consumer might expect products to last longer than they actually do. Based on these sources an average of 8 years lifetime with a standard deviation of 2 years is used for mains-operated household vacuum cleaners in this study.

For commercial vacuum cleaners no sources were found that reported the lifespan. It is therefore assumed that the three times higher amount of use hours per year compared to household vacuum cleaners[122] will decrease the lifespan in years. One third of the lifespan would be 2.7 years, however it is also assumed that the cleaners are built more robustly

[119] Preparatory Studies for Eco-Design Requirements of EuPs (II), Lot 17 Vacuum cleaners, TREN/D3/390-2006, Final Report February 2009, carried out by AEA Energy & Environment, Intertek, and Consumer Research Associates between November 2007 and January 2009. https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/vacuum-cleaners/vacuum-cleaners-ecodesign-study-final-report-eup-lot-17-final-report.pdf
[120] https://www.consumerreports.org/vacuum-cleaners/how-long-do-vacuum-cleaners-last/
[121] https://www.arbeiterkammer.at/infopool/wien/Bericht_Produktnutzungsdauer.pdf (https://wien.arbeiterkammer.at/service/studien/Konsument/index.html)
[122] Preparatory Studies for Eco-Design Requirements of EuPs (II), Lot 17 Vacuum cleaners, TREN/D3/390-2006, Final Report February 2009, carried out by AEA Energy & Environment, Intertek, and Consumer Research Associates between November 2007 and January 2009. table 13, page 43. https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/vacuum-cleaners/vacuum-cleaners-ecodesign-study-final-report-eup-lot-17-final-report.pdf

than household cleaners and thus that they can withstand a larger number of use hours over their lifetime. As no specific sources could be found, a rough estimate is that commercial vacuum cleaners can withstand around double the use hours of household cleaners (on average), thus leading to a lifespan of around 5 years. Since this number is based on uncertain assumptions, a standard variation of 2 years will still be used.

The lifetime for robot and cordless vacuum cleaners was more difficult to determine because these categories are relatively new in the market. The preparatory study suggested a 5-year lifetime for cordless vacuum cleaners but none for robots. A shorter life expectancy is very likely for both vacuum cleaner types, as they are dependent on a battery as power source, which will not last for a full 8 years. Depending on the battery type, they will last between 300-1000 charging cycles, which again depends on the use frequency and general maintenance. Furthermore, especially robot vacuum cleaners are complex and use many small parts and advanced technologies (sensors, cameras, etc.), which might decrease the life expectancy.

The predominant battery type in cordless and robot vacuum cleaners are NiMH (Nickel metal hydride) and Li-ion (Lithium-ion) batteries[123]. NiMH batteries usually last between 300-500 charging cycles[124], which might limit the vacuum cleaner lifetime, but on the other hand replacement batteries are readily available for almost all robot and most cordless vacuum cleaners. Searching the internet for user experience on robot vacuum cleaners, 4-7 years' service life is not unusual, even without replacing batteries. It is assumed that the technology has been improved since the preparatory study, also in terms of lifespans, and a 6-year lifetime is therefore used for cordless and robot vacuum cleaners in this study, but with a standard deviation of 3 years, as this is a quite uncertain approximation.

The lifespans and standard deviations (with presumed normal distribution of lifespans) used in this study shown in Table 32.

Table 32: Average expected lifetimes and assumed variations used in the stock model, in years

Vacuum cleaner type	Average lifespan (Years)	Standard variation (Years)
Cylinder Household	8	2
Upright Household		
Cylinder Commercial	5	2
Upright Commercial		
Cordless	6	3
Robot		

123 http://www.pickvacuumcleaner.com/vacuum-cleaner-battery-types.html
124 https://www.canstarblue.com.au/appliances/cleaning/vacuum-cleaners/robot-vacuum-cleaners-buying-guide/ , https://www.batteribyen.dk/batterityper-og-teknologier

8.4 Stock

The stock of vacuum cleaners in the EU-28 is calculated based on the sales figures described in section 8.2, and the expected lifespans described in section 8.3. Normal distribution of the lifetime was applied to the sales volume for each vacuum cleaner type each year, which yielded the total EU stock shown in Table 33. Stock for all years can be seen in Annex C.

Table 33: Stock of vacuum cleaners in EU 28 from 2005 to 2030

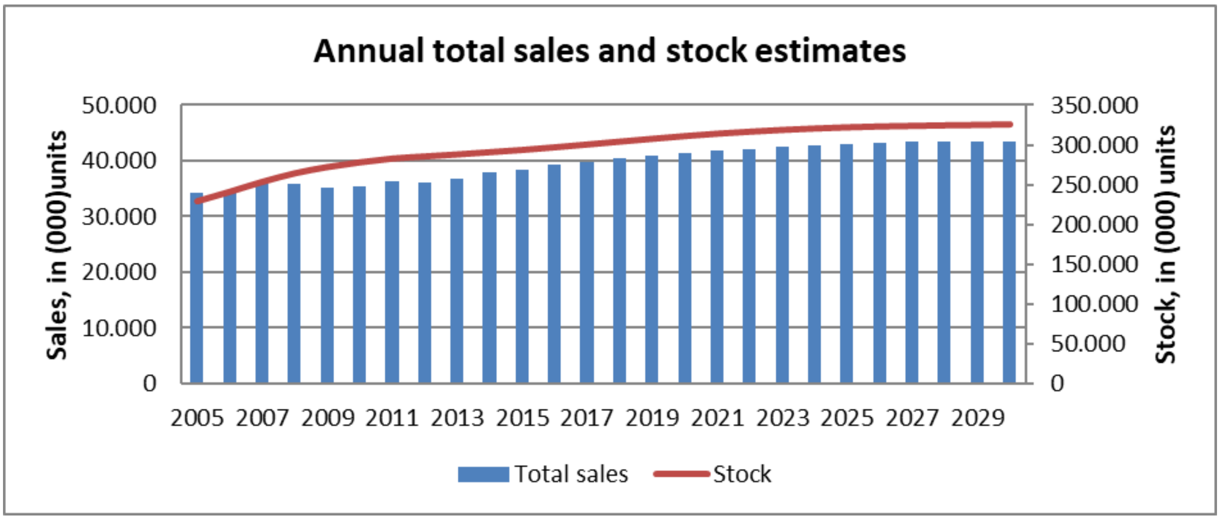
Stock, million units	2005	2010	2015	2020	2025	2030
Cylinder household	209.97	217.34	213.00	206.71	179.59	140.38
Cylinder commercial	16.72	16.94	16.58	16.38	16.25	16.25
Upright Household	34.02	28.54	25.08	23.59	21.45	19.42
Upright Commercial	2.61	2.07	1.85	1.78	1.74	2.14
Handstick mains	5.40	8.36	10.66	12.32	16.77	22.37
Handstick Cordless	7.55	14.19	28.01	39.19	68.58	98.07
Robot	2.21	6.71	9.48	11.69	18.38	27.82
Total	**278.48**	**294.15**	**304.66**	**311.65**	**322.75**	**326.44**

When looking at the sales and the stock in a compiled graph (Figure 28), it is seen that the sales (and thus the stock) increases over time, resulting in a total stock of 325 million vacuum cleaners by 2030. The stock based on collected data is thus a little lower than calculated in the preparatory study[125] and Impact assessment[126]. The sales and stock figures will be used in subsequent tasks to estimate annual energy consumption.

Assuming a total of 220 million households in EU in 2016, the penetration rate of all types of household vacuum cleaners in 2018 was on average 1.4 vacuum cleaners per household[127]. The second vacuum cleaners of most households with more than one is expected to mostly be robot vacuum cleaners or cordless handstick vacuum cleaners. This fits partly with the specified stock numbers in Table 33, which shows that cordless handstick and robot vacuum cleaners make up approximately 14% of the stock in 2016.

[125] Preparatory study: 342 million in 2005 (Table 15, Page 44)
[126] Impact Assessment: 288 million units in 2005, 355 million in 2010 (domestic only), (Table 2 Page 19) COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT (2013) with regard to Ecodesign requirements for vacuum cleaners and the Energy Labelling of vacuum cleaners. http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2013/swd_2013_0240_en.pdf
[127] Total 220 million house holds, http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Private_households_by_household_composition,_2006-2016_(number_of_households_in_1_000_and_%25_of_household_types)_new.png

Figure 28: Total annual sales and stock of all vacuum cleaner types in EU-28



8.5 Energy and performance

For energy and performance data the study can draw on surveys by GfK 2013-2016 and the new APPLiA-database with models from 2015 and 2016. Furthermore, a confirmation of these data can be found in test-results from consumer associations like Stiftung Warentest (DE), Consumentenbond (NL) and Test Achats (BE) presented in Annex E. As far as energy is concerned, also the PRODCOM (Eurostat) findings in section 8.1 give an order of magnitude of the impact.

The GfK data is sales weighted and gives a good coverage of 80-85% of sales for 2016, but for the first year of the previous, annulled energy labelling (2013) less than 10% of sales is covered and thus strongly biased. GfK covers cylinders ('barrel' and 'sledge' form factor), uprights and mains handsticks. The APPLIA data is based on model count, with a representative population of almost 1600 models for cylinders, but a clear underrepresentation of upright and stick models with only a few dozen models. Main characteristics of the APPLIA database are given in Table 34. In the following sections the label classifications of APPLiA for 2015-2016 and GfK 2016 are presented side by side.

Table 34: APPLIA Database 2015-2016, Model count, average energy, power and sound power

	Cylinders		Upright		Stick		Others
	2015	2016	2015	2016	2015	2016	2016
Model count	1536	1557	21	12	44	35	22
Energy kWh/yr	35.3	33.4	29.6	30.9	32.7	29.5	29.9
Power W	812	774	754	767	868	730	789
Sound Power dB	77.1	76.5	88.3	86.0	81.3	80.0	83.1

8.5.1 Energy

In 2015 there were three cylinder models in the APPLiA database with an energy use of 20 kWh/year and that, starting from September 2017, would be in the A+ class (ranging from 16-22 kWh/year). Their max power is 600 W, carpet cleaning performance C, hard-floor cleaning and dust-re-emission are class A. The best upright has an energy use of 27 kWh/year, which just puts it in the energy class A (ranging from 22-28 kWh/year). The best stick model is 23 kWh/year.

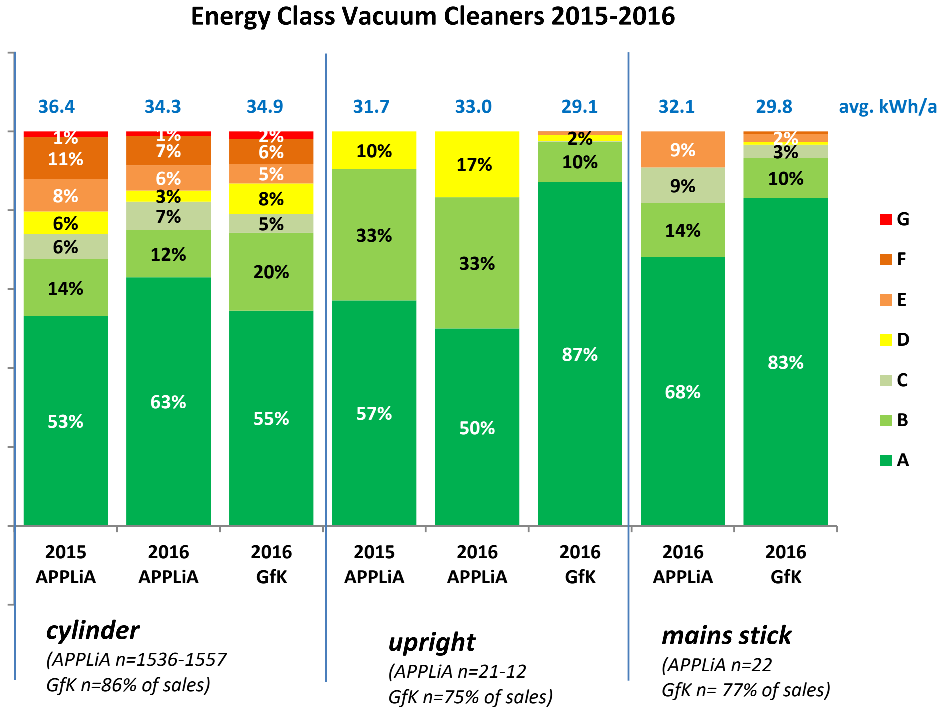


Figure 29: The annulled Energy Label classification energy 2015-2016 (sources: APPLiA and GfK)

In 2016 the most energy efficient vacuum cleaner was a 485 W hard-floor-only model with annual energy use of 15.8 kWh/year, available in cylinder and in stick version. After 1.9.2017 such a model would be classified as energy label class "A++"[128], with hard-floor cleaning and dust re-emission classes both A[128]. The most efficient general-purpose vacuum cleaner is a 550 W model with AE of 19.5 kWh/year (A+[128]) with carpet cleaning performance class B[128] and with hard-floor cleaning and dust re-emission classes both class A[128]. The most efficient upright vacuum cleaner is a 700 W universal model using 23.3 kWh/year, with carpet cleaning performance class C[129], hard-floor cleaning performance class A[129], and dust re-emission class F[129].

[128] According to the previous, annulled Energy Labelling Regulation
[129] According to the previous, annulled Energy Labelling Regulation

Comparing the APPLIA database figures with the outcomes of the GfK research database it has to be remembered that GfK reported the residential canister/cylinder type to be dominant with 68% of 2016 unit sales (17.5 million units). Uprights held an 8% share (2 million units), robots 4% (1.1 million units), handstick mains 4% (1 million units) and the fast growing handstick cordless 16% (4.1 million units). In the APPLIA database the cylinder types represent 96% of all models. Sticks and uprights are clearly underrepresented at each 2% and have a very small sample size.

According to GfK, 55% of cylinder types sold in 2016 scored an A[129] in energy efficiency (APPLIA 63%), 18% had a B[129] (APPLIA 12%) and over 25% were in the lower classes (APPLIA 23%). In other words, possibly with a delay of one year, there is a fair compatibility between GfK and APPLIA data for cylinder vacuum cleaners. For uprights and sticks, where e.g. GfK reports 87% A's[129] for energy efficiency of uprights and 83% A's[129] for sticks, the data do not match in any plausible way. This is probably due to the small sample size of the APPLIA database for these types.

According to GfK, calculated by multiplying sales with the lower energy label class limits[129], the average annual energy consumption of cylinders in 2016 was 34 kWh/a, of uprights 29 kWh/a and of handstick mains 29 kWh/a. According to APPLIA the cylinders in the 2016 model database scored 34 kWh/a, uprights 33 kWh/a and sticks 32 kWh/a.

Both data-sources are incomplete. E.g. the GfK data covers 86% of sales and for the APPLiA database that fraction will not be different. Assuming instead that the missing 14-15% represents the least efficient models (rather than following the distribution of the 85% that is covered), the average for the total sales of mains-operated vacuum cleaners would be 10% higher, i.e. a value of 38 kWh/year.

GfK and APPLiA also give an assessment of the electric power input, as is shown in

Table 35. Here the two data sources are further apart, with an overall sales weighted average for all three types of 909 W according to GfK and a model count average of 771 W for APPLiA. In this case also the consistency with the energy consumption average of 38 kWh/year has to be taken into account and thus, as will be demonstrated in section 10.3.1 the GfK figure of 909 W makes more sense. The sales weighted average price of mains-operated vacuum cleaners is 122 € (see section 8.7.2 hereafter).

Table 35: Average power (in W) of mains-operated household VCs EU in the year 2016

GfK power class (assumed avg. W)		Cylinder	Upright	Mains handstick	Average
> 0 <= 600W	(550)	3%	3%	35%	
> 600 <= 700W	(650)	25%	22%	19%	

> 700 <= 800W	(750)	28%	19%	28%	
> 800 <= 899W	(850)	3%	22%	0%	
> 899 <= 1400W	(1150)	30%	31%	16%	
> 1400 <= 1600W	(1500)	8%	1%	3%	
> 1600W	(1700)	4%	1%	0%	
GFK average		936	718	721	909
APPLiA average		774	767	730	771
Unit sales covered GfK, in mln.		19.59	2.09	1.16	22.84

Based on the 2016 distribution of power it is possible to estimate the average power after Ecodesign Tier 2 comes into application (Sept. 2017). It is assumed that the models>899W will disappear from the population and will return according to the distribution of the remaining classes. The table below shows the results, which gives an average power of 704, i.e. 23% lower than in 2016. Comparing this e.g. to the 2018 consumer tests in Annex E (693W in NL, 709W in DE) this seems reliable.

Table 36: Average power (in W) of mains-operated household VCs EU in the year 2018, after tier 2 Ecodesign

GfK power class (assumed avg. W)		Cylinder	Upright	Stick	Average
> 0 <= 600W	550	4.6%	4.4%	43.0%	6.5%
> 600 <= 700W	650	42.6%	33.5%	22.9%	40.7%
> 700 <= 800W	750	47.7%	28.7%	34.2%	45.3%
> 800 <= 899W	850	5.2%	33.4%	0.0%	7.5%
GFK average in W		*703*	*741*	*641*	*704*
Unit sales covered GfK, in mln.		19.59	2.09	1.16	22.84

8.5.2 Cleaning performance

The GfK-picture for hard floor cleaning performance is similar to the one for energy: 52-56% of vacuum cleaners scored an A[130], 15-18% a B[24], for the uprights 28% featured a C[24] while for the canister it was only 14-15% with still a significant number in lower classes in 2016. This gives a reasonable match with the APPLIA data as seen in Figure 30. The sales-weighted average dpu_{hf} for mains-operated VCs, all types, is 1.08-1.09.

[130] According to the previous, annulled Energy Labelling Regulation

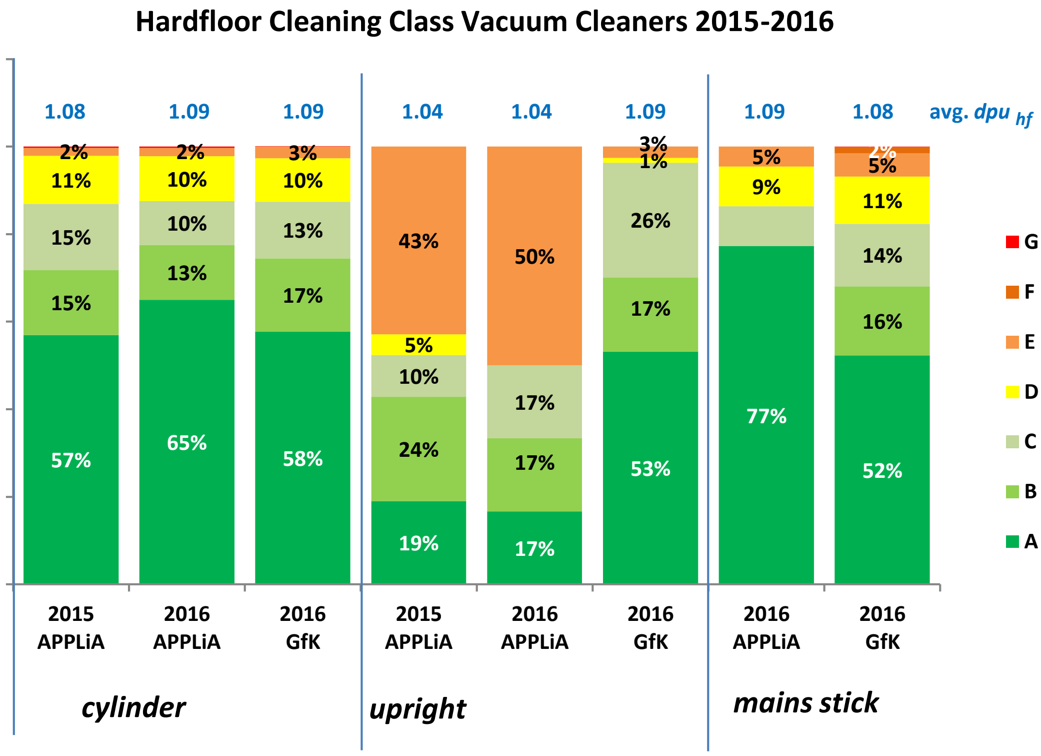


Figure 30: The previous, annulled Energy Label classification hard floor cleaning 2015-2016 (sources: APPLiA and GfK)

For carpet cleaning the situation is different from hard-floor cleaning: According to GfK only 3% of cylinder and mains-powered handstick achieved an A-class[131] rating versus 33% of the uprights in 2016. Especially taking into account the small sample size of uprights these results are similar to those in the APPLIA data-base

Overall, according to GfK the uprights did better in carpet cleaning, with 27% in B^{25} and 33% in C^{25}. The canister and mains-powered handsticks scored respectively 2 or 5% in B^{25}, 32 or 25% in C^{25} and the most populated class was D^{25} with 37% and 47%, respectively.

Nonetheless, given that 85-90% of mains-operated VC sales are cylinder types, the overall average dpu_c for all types is 0.81 in 2016.

Having said that, the 2016 APPLIA database features 56 'AAAA' cylinder models (A^{25} in energy and in all performance classes) and only 1 upright vacuum cleaner and 1 handstick vacuum cleaner with 'AAAA'.

[131] According to the previous, annulled Energy Labelling Regulation

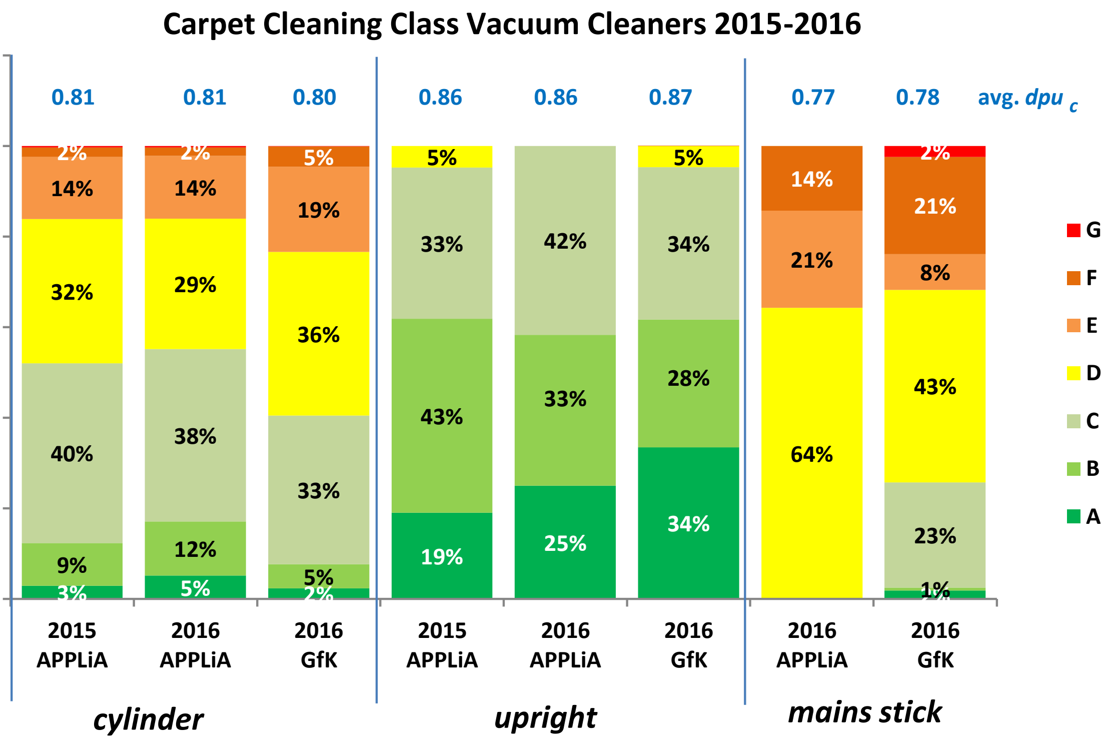


Figure 31: The previous, annulled Energy Label classification carpet cleaning 2015-2016 (sources: APPLiA and GfK)

8.5.3 Dust re-emission

For dust re-emission the classification of cylinders and sticks by APPLiA is similar to that found by GfK, but for uprights it is completely different. In fact, GfK finds that more than 70% of uprights have a class A[132] dust re-emission score, whereas only a few (8%) of upright vacuum cleaners in the APPLIA database have an A[26].

It is difficult from these data to find a convergent value for dust re-emission of all types, but –giving more weight to the more conservative GfK data— a *dre* value of 0.3% for the average mains-operated VC in 2016 is believed to be representative.

[132] According to the previous, annulled Energy Labelling Regulation

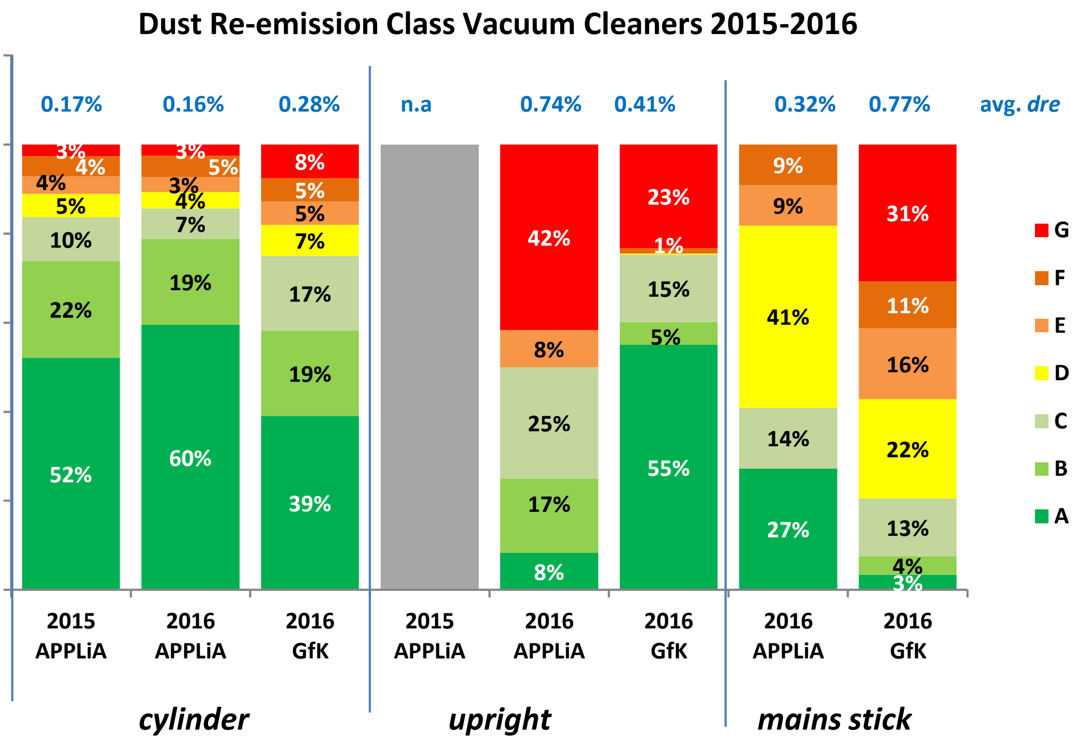


Figure 32: The previous, annulled Energy Label classification dust-re-emission 2015-2016 (sources: APPLiA and GfK)

8.5.4 Sound power

The following table gives the sound power data for the EU 2016 from GfK and APPLiA. The values between the data sources converge, with the cylinder type the most silent and the uprights the noisiest. Taking the more conservative data from GfK as a yardstick it is estimated that the overall sales-weighted average for the EU 2016 is 79 dB(A).

Table 37: Sound power mains-operated household vacuum cleaners EU 2016

Noise power classes GfK	Cylinder	Upright	Mains handstick
< 70 db	7%	0%	0%
70-75 db	10%	0%	3%
75-80 db	40%	3%	21%
>=80 db	42%	96%	76%
Coverage (% of the whole population)	92%	75%	81%
GfK Linear average*	79	83	82
APPLiA linear average	77	86	81
*= at class values of assumed 67, 73, 78, 83 dB(A)			

8.5.5 Cordless vacuum cleaners

Since cordless vacuum cleaners are not included in scope of the current regulations, there is no available data about the energy label. While Market data was available from GfK (sales volume and value), the performance data is not available, other than from separate sources, such as consumer test organisations and products for sale online, where some information is gathered.

In order to obtain data for cordless vacuum cleaners in accordance with the current daft test standards, GTT Laboratories133 located in Suzhou China, offered to perform testing of 13 cordless vacuum cleaner models. The cordless cleaners were tested according to the IEC Cordless Draft Standard (IEC 62885-4 CDV). Vacuum settings to be based on manufacturers recommendations for each floor surface, and these settings to be employed for all relevant tests on the specified floor surface.

- Dust pickup on carpet (all samples)
- Dust pickup on hard floor crevice (all samples)
- Dust re-emissions (all samples)
- Noise level on hard floor (all samples)
- Runtime on hard floor surface (all samples)
- Max air data (all samples)
- Energy consumption – (1 representative sample from each price segment)
- Max motor power (all samples - based on motor name plate. Note: units will probably need to be disassembled to obtain this information.)

In total 13 cordless cleaners were tested from different price segments, the models were chosen based on sales reported by Amazon in Germany, Italy, Spain and France in 2018. The total list of vacuum cleaners and results of the tests can be seen in Annex H. In Table 38 the results (currently only 5 models) are presented:

Table 38: Performance of cordless vacuum cleaners. Test results from GTT Laboratories[134]

	Average	Highest	Lowest
Motor Rated Power (W)	212.50	525.00	95.00
Motor Power measured carpet (W)	244.28	590.88	126.36
Motor Power measured hard floor (W)	223.05	520.24	114.47
Annual Energy carpet (kWh)	15.92	25.46	7.70
Annual Energy hard floor (kWh)	10.01	18.53	3.47
Air data at the end of nozzle (W)	19.35	81.50	4.90
Dust pick up carpet (%)	65.72	91.50	43.50
Dust pick up hard floor (%)	58.13	106.50	3.40

[133] An accredited Laboratory founded in 2013, which performs test for several vacuum cleaner manufacturers, including SEB (France), Vax (UK), Dirt devil (Germany), Hoover (Italy), Arcelik(Turkey), Euro-Pro (USA) and Panasonic (Japan).

[134] An accredited Laboratory founded in 2013, which performs test for several vacuum cleaner manufacturers, including SEB (France), Vax (UK), Dirt devil (Germany), Hoover (Italy), Arcelik(Turkey), Euro-Pro (USA) and Panasonic (Japan).

Dust re-emissions (%)	3.98	8.65	0.001
Noise carpet dB(A) Brush ON	81.68	86.30	77.20
Noise hard floor dB(A) Brush ON	82.81	86.30	78.50
Runtime on carpet t90%rt (min:s)	11:28	22:53	04:47
Runtime on carpet t40%rt (min:s)	16:34	23:24	07:58
Runtime on hard floor t90%rt (min:s)	12:43	23:51	05:08
Runtime on hard floor t40%rt (min:s)	16:51	23:51	08:43

t90%rt : time until vacuum is fully discharged or the vacuum has dropped to 90% of the original.
T40%rt : time until vacuum is fully discharged or the vacuum has dropped to 40% of the original.

This shows that the average cordless cleaner has lower performance than the standard mains-operated vacuum cleaner. However, the best performing cordless vacuum cleaner (also one of the most expensive cordless vacuum cleaner) has a performance on par or close to a cylinder vacuum cleaner. It should be noted that the corded vacuum cleaners have a higher noise level (all of the tested appliances) than the current requirement of maximum 80 dB(A) for mains-operated vacuum cleaners. Also, the dust reemission seems very high for some of the tested cordless vacuum cleaners and the worst performing vacuum cleaner has a dust reemission of more than 8%.

8.5.6 Robot vacuum cleaners

Since robot vacuum cleaners are not included in the scope of the current regulations, there is no available data from the energy label. While Market data was available from GfK (sales volume and value), the performance data is not available, other than from separate sources, such as consumer test organisations and products for sale online, where some information is gathered. In Table 39 the results (currently only 5 models) are presented.

Table 39: Performance of robot vacuum cleaners than from separate sources, such as consumer test organisations and products for sale online,

	Average	Highest	Lowest
Standby, dock only (W)	0.99	3.51	0.18
Standby, robot in charger (W)	3.70	8.10	0.40
Fully recharging (0% to 100%) (Wh)	68.18	125.00	30.00
Noise dB - 1.6 m (A)	60.75	70.10	52.60
Battery size (mAh)	2,810	5,800	1,800
Coverage (%)	83%	95%	58%
Runtime (min)	83.03	240.00	25.00
Charging time (min)	168.13	390.00	54.50
DPU Hard Floor (first pass)	0.63	0.95	0.07
DPU Hard Floor (fifth pass)	0.79	0.96	0.23
DPU Carpet (first pass)	0.16	0.53	0.01
DPU Carpet (fifth pass)	0.27	0.57	0.04

The current average robot vacuum cleaner has a high energy consumption in standby, a battery size of a mobile phone (mAh), and a cleaning performance below mains-operated and cordless vacuum cleaners. However, robots clean with a high degree of autonomy, and cleans more often and at a lower noise level. The best robot vacuum cleaners have a high dust pickup on hard floor, but the performance is lower on carpet in general.

8.6 Market structure and -actors

8.6.1 Industry

The household vacuum cleaner market is characterised by a large number of manufacturers, with the main players being Dyson, TTI group (VAX, Hoover and more), Electrolux (including AEG), Miele, Bosch/Siemens, and Philips as well as far east brands such as LG, Panasonic, and Samsung[135]. The cordless vacuum cleaner market is largely dominated by the same brands.

The robot vacuum cleaner market is to a larger extend dominated by specialised manufacturers such as iRobot, Neato and Eufy RoboVac, even though many of the above-mentioned brands today have a robot model.

The European industry association for household vacuum cleaners is APPLiA[136]. Consumers associations are represented at EU-level by ANEC/BEUC. Other NGOs include ECOS, EEB, TopTen and CLASP.

The commercial vacuum cleaner market is characterised by fewer large manufacturers. The main players are Nilfisk, Kärcher and Numatic, but Hako, Tennant and FIMAP also produce commercial vacuum cleaners, even though most are wet/dry cleaners, which are not covered by the regulations. The European industry association for commercial cleaning is EUnited cleaning.[137]

As mentioned in the preparatory study[138], the majority of vacuum cleaners are manufactured in China or other far east countries, and this has not changed. Many of the large manufacturers have their own Chinese-based production facilities, while others purchase from OEM (Original Equipment Manufacturer) companies. The most significant production companies located in Western Europe is Numatic[139], who continues to produce

[135] Preparatory Studies for Eco-Design Requirements of EuPs (II), Lot 17 Vacuum cleaners, TREN/D3/390-2006, Final Report February 2009, carried out by AEA Energy & Environment, Intertek, and Consumer Research Associates between November 2007 and January 2009. https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/vacuum-cleaners/vacuum-cleaners-ecodesign-study-final-report-eup-lot-17-final-report.pdf + http://www.grandviewresearch.com/industry-analysis/household-vacuum-cleaners-market
[136] www.applia-europe.eu
[137] https://www.eu-nited.net/cleaning/
[138] Preparatory Studies for Eco-Design Requirements of EuPs (II), Lot 17 Vacuum cleaners, TREN/D3/390-2006, Final Report February 2009, carried out by AEA Energy & Environment, Intertek, and Consumer Research Associates between November 2007 and January 2009. https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/vacuum-cleaners/vacuum-cleaners-ecodesign-study-final-report-eup-lot-17-final-report.pdf
[139] https://www.numatic.co.uk/about.aspx

in the UK, and Miele who has a large automatized vacuum cleaner production site in Germany. Some brands including VAX, Electrolux and Nilfisk also have production in the US and Mexico.

There are no SMEs making domestic vacuum cleaners. There are two smaller companies, SEBO and Fimap, that have some commercial dry cleaning vacuum cleaner models in their catalogue, probably as a distributor and not a manufacturer

The following gives an (incomplete) overview of vacuum cleaner companies, headquarters (HQ), most recently published revenue and number of employees as well as brand-names where they differ from the company name:

- TTI (Hong Kong HQ, 6 bn turnover, 22,000 staff, power tools & floor care, VC brands Hoover, Dirt Devil, Oreck, etc.; power tools brands Ryobi, AEG)
- Midea group (China HQ, home appliances & lighting, 100,000 employees, VC brand Eureka since 2016)
- Nilfisk (Denmark HQ, 5,800 employees, >1 bn euros)
- Electrolux (Sweden HQ, 82,000 employees, VC production in Hungary; residential and commercial VC brands AEG, Electrolux, Sanitaire; industrial VC brand Husqvarna)
- Bissel (US, 2,500 employees, $800 million, market leader US)
- Kärcher (Germany HQ, 12,304 employees, >turnover? 2.5 bn euros)
- Miele (Germany HQ, turnover 3.9 bn euros, 19,500 employees)
- Dyson (UK HQ, turnover £3.5bn (US$4.82bn), >8500 employees)
- BSHG (Germany HQ, turnover 13.8 bn, 60,000 employees, vacuum cleaners brands Bosch, Siemens)
- SEB (France HQ, turnover 6.5 bn euros, 33,600 employees, vacuum cleaners brands: Rowenta,
- Fakir (Turkey HQ, site in Germany, vacuum cleaners brands: Fakir, Nilco)
- SEBO (Germany HQ, commercial VCs, small)
- Arçelik (Turkey HQ, 30,000 employees, turnover 4.57 bn euros, vacuum cleaners brand: Grundig)
- Vorwerk (Germany HQ, 12,000 employees, turnover 2,9 bn euros, vacuum cleaners brands: Kobold, Neato Robotics)
- Philips (Netherlands HQ, 74,000 employees, turnover 17,8 bn euros)
- LGE (S-Korea HQ, turnover 56 bn euros, 77,000 employees)
- Samsung (S-Korea HQ, turnover ca. 180 bn euros, 320,000 employees)
- Numatic (UK HQ, 885 employees, turnover 124 million GBP (2013), vacuum cleaners brand: Henry)
- Hako (Germany HQ, only one commercial dry cleaner model in scope)

- Tennant (US HQ, turnover 1 bn $, 4297 employees, some commercial dry cleaning vacuum cleaners s in scope)
- Fimap (Italy HQ, 100-250 employees, some commercial VC models)
- ECOVACS (China HQ, 5,000 employees, turnover? $270 mln)
- iRobot (US HQ, 920 employees, revenue $883.9 mln)
- Distributor brands, amongst others: Clatronic (DE), Inventum (NL), Princess (NL), Bestron (NL)

8.6.2 Distribution structure

Vacuum cleaners are sold through traditional retail channels, the internet and door-to-door. In the traditional retail sector the position of larger retail chains such as Metro (Media Markt), Carrefour, etc. is increasing. The European trade sector is represented by Eurocommerce. According to GfK the internet sales of 'small domestic appliances' (SDA), including (robot) vacuum cleaners, is increasing rapidly. In 2015 the SDA-internet sales value rose 22.8% compared to 2014, whereas traditional retail sales value increased only 2.8% [140]. Vorwerk employs the services of 633,000 independent (door-to-door) advisors to sell its products.

8.6.3 Other actors

Consumers associations are represented at EU-level by ANEC/BEUC. Other NGOs include ECOS, EEB, TopTen and CLASP.

8.7 Consumer expenditure base data

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

- Purchase price
- Repair and maintenance costs
- Electricity costs
- End of life cost

As there are no installation costs for the types of vacuum cleaners included in the study scope, this was not be included. Each of the other costs are explained in the following sub-sections. The costs are shown as unit prices for each product, maintenance event, kWh electricity and so on. The total life cycle costs, which also depend on use patterns and frequency of events, is discussed in task 5.

[140] GfK, ONLINE VS. TRADITIONAL SALES: KEY FACTS FOR TECHNICAL CONSUMER GOODS (TCG) IN EUROPE, Infographic, 2016.

8.7.1 Interest and inflation rates

All economic calculations was made with 2016 as base year, as this is the latest whole year for which data is available. HICP inflation rates from Eurostat[141] will be used to scale purchase price, electricity prices etc. to 2016-prices. Furthermore, a discount rate of 4% will be used in accordance with the MEErP methodology.

8.7.2 Consumer purchase price

The consumer price including VAT was calculated from the data on unit sales and total market value collected by GfK. The data was available for the years 2013-2016 and was extrapolated back to 2005 based on the total average. The unit prices reported in the preparatory study were 110 € for all household vacuum cleaner types in 2005 (excluding robots. The average unit price for each vacuum cleaner type, corrected for inflation[142] to be in 2016-prices, are shown in Table 40.

Table 40: Unit retail prices in EUR for household vacuum cleaners, in 2016-prices for EU28

Unit prices, EUR	2005	2010	2013	2014	2015	2016	2018
Cylinder	133	119	110	112	121	119	120
Upright	210	184	169	177	196	171	168
Handstick mains	114	99	91	89	94	96	90
Sales weighted average of mains-operated vacuum cleaners	145	126	116	118	128	123	123
Commercial[143]	302	269	250	255	274	271	320
Handstick cordless	216	193	180	200	225	220	221
Robot	323	288	268	284	317	344	221

**Projected data*

As seen from the table, prices decreased from 2005 to 2010 (actually the decrease happened from 2006 to 2009), which is assumed to be due to the economic crisis. From 2013 to 2015 the price increased, however in 2016 the prices actually decreased for cylinder, upright and handstick vacuum cleaners.

The increase in price from 2013 to 2015 is likely to be a result of implementing the Ecodesign Regulation and the annulled Energy Labelling Regulation, which caused a shift in design criteria from high wattage to low wattage and high dust pickup[144]. Such a shift is likely to cause a price increase due to increases in R&D costs, using higher efficiency electric motors and other parts. The small decrease in prices from 2015 to 2016 could be

[141] http://ec.europa.eu/eurostat/statistics-explained/index.php/File:HICP_all-items,_annual_average_inflation_rates,_2006-2016_(%25)_YB17.png
[142] Using the HICP index from Eurostat
[143] Based on an online survey and prices from 58 different commercial vacuum cleaners.
[144] According to the preparatory study, "manufacturers have developed products with higher and higher input wattage. These have been marketed to consumers on the basis that the higher the wattage the better the product cleans to the point that consumers now associate power rating with cleaning efficiency."

the result of saturation of the market with high-efficiency products and maturation of technologies allowing for lower manufacturing costs and thus increased competition on price in the market.

It should be noted that the prices in Table 40 are the sales weighted averages of the entire EU, but that the average price covers a larger price variety. An example of this price variation is seen from the prices of the vacuum cleaners tested by the consumer organisations Consumentenbond, Test Achat and Stiftung Warentest, which are listed in Annex E, and range from 69 € to 335 €[145]. It is thus reasonable to assume that the average price for each country differs significantly, and that on average, the cheaper vacuum cleaners are often chosen by end-users.

For the commercial cleaners, the numbers are more uncertain, as there are only 3 major players in Europe, and no sales numbers directly available. Furthermore, most of the far majority of the products are sold as B2B and a fair share with a service/maintenance package, which reduces the sales price of commercial vacuum cleaners significantly. According to the chairman of EUnited cleaning[146] an average unit sales price of 100 EUR for commercial cleaners is consistent with the reported annual sales and total annual turnover in the commercial vacuum cleaner industry. However, based on an online survey the average price of commercial vacuum cleaners is assumed to be 331 euro, based on 58 different models, from different countries.

8.7.3 Electricity cost

The annual electricity prices from the PRIME Project[147] was used for the economic calculations in this study. The electricity prices were reported as €/toe (ton of oil equivalent) in fixed 2015-prices. They were then converted to €/kWh and corrected for inflation to fixed 2016-prices as shown in Table 41. The electricity prices were given for every fifth year and linear interpolation was used in between.

Table 41: Electricity prices with 2016 as base year will be used[148]

	Price in €/kWh (2016-prices)	
Year	Households	Services
2005	0.159	0.127
2010	0.175	0.151
2015	0.194	0.160
2020	0.207	0.174
2025	0.213	0.179
2030	0.216	0.183

145 Note that price can be much higher, especially for robot vacuum cleaners
146 http://www.eu-nited.net/cleaning/association/technical-committee/index.html (Chairman: Charalambos Freed, Nilfisk A/S)
147 https://ec.europa.eu/eurostat/cros/content/prime_en
148 The data from primes suggests an annual increase of approximately 1% in electricity prices

8.7.4 Repair & maintenance costs

Regarding repairs, few repair shops exist for vacuum cleaners expect those who handle warranty repairs. Also, according to various forums and websites, most vacuum cleaner repairs (exchanging hose, suction head or other external parts) can be performed by the end-users themselves[149]. However, some internal repairs (e.g. motor and wiring) require professional expertise. Therefore, the cost of repair can vary greatly depending on the type of repair.

An internet search was made for various vacuum cleaner spare part providers, to find the retail prices of various spare parts, which are shown in Table 42.

In addition to repairs when the vacuum cleaner is broken, a general maintenance is also needed. This consists primarily in changing bags and filters and cleaning the brushes. The price for bags and filters included in the table are thus considered as maintenance rather than repair costs. The bags are often sold in packs of different sizes, and according to the data found, the most common is five bags per pack, with a new filter in approximately half of them.

For bagless vacuum cleaners there is no need to purchase new bags, but the receptacle should be emptied regularly, and for upright vacuum cleaners also the belts should be checked. Furthermore, inspection of the vacuum tube or hose and power cord is recommended. The cost of the regular maintenance is the bags and filters, which vary depending on the vacuum cleaner type. Furthermore, the upright and robot vacuum cleaners especially, would need new brushes and belts as part of the maintenance.

Table 42: Vacuum cleaner spare part retail prices

Spare part type	Price		
	Min	Max	Average
Wheels	2.3	50.9	18.8
Switch	3.7	46.9	14.6
Cable/rewind	9.5	96.7	31.1
Motor	20.0	147.7	54.8
Carbon brush	5.4	53.5	12.6
Heads	9.3	137.0	48.9
Bag frame	4.0	36.2	17.5
Hose and grips	18.1	107.4	48.2
Belts (upright)	2.3	18.9	6.7
Brush (uprights)	6.8	35.7	18.1
Batteries (robot)	17.1	120.8	59.0

[149] https://www.nettoparts.dk/shop/svaerhedsgrad-stoevsuger-14550c1.html

Brush (robot)	13.3	45.9	27.6
Filters (Robot)	18.7	26.7	24.1
Battery charger	5.0	88.9	23.8
Bags 5-pack			8.6

If vacuum cleaners need to be repaired by a professional, the average EU average labour cost in the category "*Industry, construction and services (except public administration, defence, compulsory social security)*" is used, as shown in Table 43. 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[150].

Table 43: Average total labour costs for repair services in euro per hour, in fixed 2016-prices

	2005	2010	2011	2012	2013	2014	2015	2016
EU-28 countries, EUR/h	24.5	24.6	24.5	24.5	24.4	24.6	25.1	25.3

For bags and filters, it is assumed that bagged vacuum cleaners use two bags per year[151], while bagless cleaners use two filters in their lifetime, assuming that the filters can be cleaned instead of exchanged, in most cases.

The overall lifetime expenses connected with repair and maintenance are assumed to be 20 euro per year for household mains-operated vacuum cleaners and 31 euro for commercial cleaners. These prices do not include the price of bags and filters, which is expected to be 25 € and 40 €, respectively. The repair and maintenance cost can be difficult to quantify as some products are never repaired and others may be repaired more than once.

8.7.5 End of life costs

Since vacuum cleaners 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 is therefore be set to zero.

[150] http://ec.europa.eu/eurostat/cache/metadata/en/lc_lci_lev_esms.htm#unit_measure1475137997963
[151] Based on inputs form stakeholders and the APPLiA consumer survey

9. Task 3: Users

Task 3 looks at the consumer side of the products and describes the use patterns in terms of how and how much end-users use the different types of vacuum cleaners and what happens to the products in the end-of-life. An important part of the consumer side for vacuum cleaners is the discussion on consumer relevance and how well the test methodologies reflect the user needs.

9.1 Use pattern of mains-operated household cleaners

The use pattern for the vacuum cleaners included in the scope of the current regulations (i.e. the mains-operated vacuum cleaners) was determined in the preparatory study[152] with the following parameters:

- Average floor area covered per cleaning cycle: 87 m^2
- Average strokes over floor: 2 double (floor covered 4 times)
- Average cleaning cycles per year: 50
- Average duration of cleaning cycles: 1 hour
- The performance will influence the time spend cleaning

These parameters lead to the following formula for calculating annual energy consumption:

$$Annual\ Energy = 4 * 87\ m^2 * 50 * 0.001\ \frac{kWh}{Wh} * Average\ Specific\ Energy\ \frac{Wh}{m^2} * \left(\frac{1-0.20}{dpu-0.20}\right)$$

The assumed average floor space for European homes of 87 m^2 was originally derived from an assumption of 100 m^2 average home size, but subtracting built in kitchen, furniture etc., meaning that only 87 m2 actually needs vacuuming. These numbers are well in line with 2012 statistics that showed and average dwelling size of 96 m^2 [153]. Also the 2014 study on building heat load for HVACs[154] showed that the floor area was around 91 m^2. It is thus not recommended to change the constant in the formula.

The behavioural aspects such as the number of cleaning cycles per year, number of times the nozzle passes over the floor (4 in the formula), and the assumption regarding prolonged cleaning time with lower dust pick-up are more difficult to measure quantitatively. However, a large survey was conducted by the industry organisation APPLiA155 that considered these aspects. Both industry members, consumer organisations and policy makers had the opportunity to comment on the aspects questioned in the survey in order to achieve robust results, and the survey itself was conducted by InSites

[152] https://www.eup-network.de/fileadmin/user_upload/Produktgruppen/Arbeitsplan/eup_lot17_final_report_issue_1.pdf
[153] https://ec.europa.eu/eurostat/statistics-explained/images/1/1e/CH3_PITEU17.xlsx and https://ec.europa.eu/eurostat/statistics-explained/index.php?title=People_in_the_EU_-_statistics_on_housing_conditions
[154] https://ec.europa.eu/energy/sites/ener/files/documents/2014_final_report_eu_building_heat_demand.pdf
[155] https://www.applia-europe.eu/

Consulting. Compared to the values determined in the preparatory study, the APPLiA survey showed the following:

- Average floor area per home: 70% between 51 m^2 and 150 m^2
- Percentage vacuuming the house at least once per week: ~85%
- Average duration of vacuum cleaning per week: 73 minutes

Even though none of the parameters are directly comparable to the ones in the formula, the results indicate that the assumptions in the formula are within the same span. The only directly comparable parameter is the time spent cleaning, which does not enter directly into the regulation formula, but is an underlying assumption. The APPLiA survey shows that the time spend vacuum cleaning is on average 73 minutes per week, compared to 1 hour assumed in the preparatory study. This is in line with the data showing increased floor area to be vacuumed.

Some stakeholders have argued that consumers often over-estimate the time spend cleaning compared to how long the vacuum cleaner is actually on. In one survey from the US where 80 families answered that they cleaned around 50 minutes per week, meters on the vacuum cleaners showed a cleaning time of around 15 minutes per week. However, the APPLiA survey applied not only a quantities survey (online), but also a qualitative survey, where consumers kept a 'diary' of their vacuum cleaning. This qualitative survey asked more in-depth questions, which confirmed that the results reflected the actual cleaning time. This is considered an important difference together with the much larger number of participants and the geographic coverage. However, by not changing the formula, which is based on average area, the additional 13 minutes will not be considered in the energy calculations.

Based on the above findings the use pattern shown in Table 44 is assumed for mains-operated household vacuum cleaners in the calculations in this study.

Table 44: Use pattern for mains-operated household vacuum cleaners

Parameter	Value
Average floor area covered per cleaning cycle	87 m^2
Average strokes over floor	4 (2 double)
Average cleaning cycles per year	50
Average duration of cleaning cycles	73 minutes
Influence of performance on the time spent cleaning	$\left(\frac{1-0.20}{dpu-0.20}\right)$

9.1.1 Formula for calculating annual energy consumption for mains-operated cleaners

While the use pattern and cleaning habits are included as constants in the annual energy calculation, the measured factors are what differentiates the vacuum cleaners. For example the measurement and calculation of the ASE (Average Specific Energy Consumption) and the *dpu* (dust pick-up).

For general purpose vacuum cleaners, the annual energy consumption is calculated as an average of the measured carpet and hard floor energy consumptions and performances. Manufacturers can also choose to specify their products as only for hard floor or only for carpets, thus calculating the AE based on only the one relevant measurement.

It has been argued that the results are skewed towards the hard floor test, as it is possible to achieve above 100% dust pick-up in the hard floor test, but not in the carpet test. This could, however be alleviated with more consumer relevant testing by introducing also a "debris" test as described in section 9.7

Another, opposing, argument has been made that *more* emphasis should be on the hard floor performance and energy consumption, and that the current 50/50 split between hard floor and carpet should be aligned with the average floor area of each type in Europe, which is only around 24% carpet in 2017 according to data shared by CEN TC134[156] on floor coverings. This would reflect real life better, at least for consumers with the average share of carpets in their home. However, the inherent risk of weighing one performance factor over the other is that vacuum cleaners with low carpet performance would be able to obtain high AE ratings, especially since carpet performance is the parameter in which it is most difficult to achieve high rankings[157], this could be a risk. This could be the case in particular for consumers with carpets in some parts of their home, who expect to buy a good general purpose vacuum cleaner (high AE label ranking) to be used on both carpets and hard floors, which then turns out to have poor performance on carpets.

Whether or not to change the weighting therefore depends on what is considered most important: to have an AE value that is as close to the European average situation as possible, or to have an AE value where general purpose vacuum cleaners should have equal emphasis on hard floor and carpet. Based on the principle that consumers purchasing a general purpose vacuum cleaner to clean both floor types in their home should not have to compromise with carpet performance (even if only 24% of their floor is covered with carpets), it is not recommended to change the weighting of the dpu_{hf} and dpu_{c} in the AE formula.

[156] According to industry stakeholder that is a member of CEN TC 134 https://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:6116&cs=16C6F66C6284BD5B1BF6C202B2189F140
[157] At least with the current test standards, see for example the market averages in task2 of this report.

Dust pick-up in the formula

Since the formula includes the performance of the vacuum cleaner, i.e. the dust pick-up, it indicates the efficiency, assuming that the end-user will spend longer time cleaning if the dust pick-up is lower, hence consuming more energy[158]. This makes the formula more complex, but it also gives a more realistic calculation of energy consumption than if not taking performance into account. According to the organisation Topten[159], however, it is unclear if end-users really do adjust their cleaning habits to the performance of the vacuum cleaners[160], or if they will continue to vacuum as per their current habits. They further argue that for other products there are precedence for not mixing the energy consumption and performance into a single parameter. Consumer organisations have argued that the *dpu* performance could be tackled through Ecodesign requirements alone, instead of being a part of the AE formula.

The difference between vacuum cleaners and other products, such as dishwashers or washing machines, is that there is no pre-installed programme with a specific duration that can be referenced, but the cleaning time is fully dependent on the user. It therefore seems reasonable to assume that the end-user will clean until the surface is perceived as "clean", which would take longer the lower the dust pick-up performance. Since the purpose of vacuum cleaners is to remove dust, and products should be compared equally, not having the dust pickup in the formula would make it possible for vacuum cleaners with very small motors to achieve the best energy class, without actually achieving the purpose.

The opposite argument, that there is too little emphasis on the dust pick-up in the annulled energy label formula, has been made by industry members, who argue that picking up dust is the main purpose of a vacuum cleaner. The dust pick-up is therefore considered to be an important part of energy efficiency, which is defined as the ratio between performance and energy consumption. It is argued that improving dust pick-up enough to improve the energy class of a product is so much more expensive than putting in a smaller motor, that the design strategy will almost always be the latter. Therefore there is a risk that end-users purchasing an energy label A[161] product might not get the performance they expect, especially considering the issues with the dust pick-up tests. The same argument is used the other way around, stating that vacuum cleaners with high performance in the *dpu* tests might have issues with high motion resistance, which also affect the user experience negatively.

Based on the above considerations it is not recommended to change the formula, but rather focus on improving the reliability of the measurements, which are used in the formula

[158] http://www.topten.eu/uploads/File/Deliverables%20ACT/D2_1_Criteria_Paper_Vacuum_cleaners.pdf
[159] http://topten.eu/
[160] http://www.topten.eu/uploads/File/Deliverables%20ACT/D2_1_Criteria_Paper_Vacuum_cleaners.pdf
[161] According to the previous, annulled label

(such as the dust pickup) and to potentially add tests and Ecodesign requirements that improve consumer relevance as discussed in section 9.7.

9.2 Use patterns for commercial vacuum cleaners

In the preparatory study, the commercial vacuum cleaners were assumed to have a different use pattern than the household cleaners. In total it was estimated that a commercial cleaner is 1500 hours per year throughout a lifetime of 8 years. This yields an average of 187.5 hours per year. However, according to commercial vacuum cleaner manufacturers this is too few hours per year, since an average year has around 260 working days, and professional vacuum cleaners are not used less than one hour per day. However, the total of 1500 hours over a lifetime might be realistic. Hence, the difference is the lifetime, which is assumed to be 5 instead of 8 years in this study, as also mentioned in chapter 2.3. This gives 300 annual use hours, which corresponds to around 1.15 hours (~70 minutes) per workday.

Table 45: Use pattern for commercial vacuum cleaners

Parameter	Value
Average floor area covered per cleaning cycle[162]	87 m^2
Average strokes over floor	4 (2 double)
Average cleaning cycles per year	260
Average duration of cleaning cycles	70 minutes
Influence of performance on the time spend cleaning	$\left(\frac{1-0.20}{dpu-0.20}\right)$

9.2.1 Formula for calculating annual energy consumption for commercial cleaners

Despite the recognition of this difference in use pattern between commercial and household vacuum cleaners, the same formula is used for both types of products in the current regulation. This was necessary for the sake of the previous, annulled energy label, in order for consumers to be able to compare products between these two categories. However, in the modelling of energy consumption and saving potentials, the commercial use pattern will be used for commercial vacuum cleaners, assuming 300 hours of cleaning per year.

It should be noted though, that the commercial vacuum cleaner manufacturers have suggested a completely different measurement method for commercial vacuum cleaners, which is not based on Annual Energy but on an Energy Index (EI) (see section 9.7.4). Such an index was suggested for the commercial vacuum cleaners to better fit the needs of the end-users. For these users, who primarily clean by visual perception of the area being clean, the debris is especially important, and this is included in the index. The same is the nozzle width, since this influences the time spend cleaning, which is often done as fast as

[162] This is based on the assumption that the nozzle is moved with the same speed over the floor as for domestic cleaners

possible in commercial settings. Therefore, the final unit of the EI is m²/min, but also taking into consideration the quality of the cleaning (i.e. the dpu and debris pick-up). Furthermore, the sound power is included in the EI, since this is important for the work environment of the operators of the vacuum cleaners.

The EI consists of a number of equations, all based on existing test methods, except for the newly approved debris pick-up test for commercial vacuum cleaners:

$$EI_{total} = PI_{total} \times MI_{total} = \left(P_{area} \times C_{Q,total}\right) \times \left(C_{power,total} + C_{noise,total}\right)$$

Where:

$$P_{area} = K_1 \times \frac{w_{nozzle}[m] \times v_{stroke}\left[\frac{m}{min}\right]}{n_{ds}}$$

Where W_{nozzle} is the nozzle width, v_{stroke} is the velocity of the nozzle over the floor, and n_{ds} is the number of double strokes used in the tests when measuring cleaning performance.

$$C_{Q,total} = K_4 \times \left(\frac{dpu_C}{dpu_{C,BaseCase}} + \frac{dpu_{hf} + K_5 \times pu_{debris,hf}}{dpu_{hf,BaseCase} + pu_{debris,hf,BaseCase}}\right)$$

$$C_{power,total} = K_2 \times \left(\frac{power_{C,BaseCase}}{power_C} + \frac{power_{hf,BaseCase}}{power_{hf}}\right)$$

Power here meaning input power measured as watt during the cleaning cycles.

$$C_{noise,total} = K_3 \times \left(\frac{L_{WA_{C,BaseCase}}}{L_{WA_C}} + \frac{L_{WA_{hf,BaseCase}}}{L_{WA_{hf}}}\right)$$

Where L_{WA} is the sound power level. In the current standard for commercial vacuum cleaners, the noise is measured with the nozzle lifted from the floor, hence there is no difference on hard floor and carpet. In the case that standards are aligned with those for domestic vacuum cleaners (where noise is measured when the nozzle is on the floor), however, the equation is prepared for handling separate carpet and hard floor noise.

As seen from the equations, the measured values of dust pick-up, debris pick-up, input power, and noise are all compared to a base case value. These base case values are based on a best not yet available technology (BNAT) commercial vacuum cleaner. In other words, the base values are theoretical best case values. The suggested base values are seen in Table 46.

Table 46: base case values for the suggested equations for the EI for commercial vacuum cleaners

Parameter	Unit	Carpet value	Hard floor value
Nozzle width, w	mm	300	300
Input power	W	200	250
Sound power level	dB(A)	58	58
Dust pick-up, dpu	%	95,0%	115,0%
Debris pick-up, deb	%	-	100,0%

Furthermore, the equations contain constants, denoted "K". These factors are based on numerous measurements and calculations performed by the commercial vacuum cleaner manufacturers, in order to reach a realistic result and sensitivity of the EI to each of the parameters. Based on these analyses the suggested factors in Table 47 were derived. Where the constants equal 1 they can in principle be removed.

Table 47:

Parameter		Factor, Ki
Nozzle width, w	K1	1
Input power,	K2	1
Sound power level	K3	0,5
Dust pick-up, dpu	K4	0,3
Debris pick-up, deb	K5	1

K1, K2 and K5 in are set to 1, and could thus in principle be removed form the equations. K3 (noise) is set to 0.5 because otherwise the influence of noise on the EI index would be too large. The noise is included because this specific product category is used in commercial settings, where noise is an important part of performance due to working environment. For domestic products it is more a question of discomfort than actual health due to the much lower use hours per person. K4 (pick-up incl. debris and fine dust) is set to 0.3 because these values are tested until now with 5 double strokes which means 10 strokes and according to commercial manufacturers the actual cleaning patterns is closer to 3 strokes over the same area, and therefore 3/10=0,3.

The results of the analyses with different EI equations and factors, can be seen in Annex G. The vast majority of the commercial vacuum cleaner manufacturers agree with the above equations and have been involved in the development and measurement work conducted.

9.3 Use pattern of cordless vacuum cleaners

Since cordless vacuum cleaners are often lighter in weight and designed for ease of use for the consumer, it is reasonable to assume that they are often used for lighter cleaning tasks, which implies shorter run times, but with an increase in the number of cleaning cycles. Furthermore, cordless vacuums often do not have sufficient run time to run for as long as mains-operated (50-73 minutes), as most cordless vacuum cleaners have a battery life of 15-40 minutes while only a few can run for up to 60 minutes per time, and not at the highest power[163].

Less research exist about how cordless vacuum cleaners are used than for mains-operated, however a few sources are available, primarily from manufacturers. One survey shows that cordless cleaners are used for around 20 minutes per cleaning cycle, but several times a week. Both this and other sources agree that the average use frequency of a cordless cleaner is 4 times per week[164]. Assuming that they are used for 20 minutes each time, gives an average of 80 minutes per week, which is close to the 73 minutes reported for mains operated cleaners. In order to ensure comparison in calculations, 73 minutes and 87 m^2 cleaned per week will be assumed for cordless vacuum cleaners as well, even though it is spread out over more cleaning cycles.

As mentioned above the battery lifetime will also influence the cleaning time per cycle. Most cordless vacuum cleaners can operate in different power levels (for example, minimum, medium and max), however most cordless cannot operate for 20 minutes in max mode. Also having the cleaner in max mode all the time might not be necessary for the end-user. However, this is the mode in which tests are conducted, and annual energy consumption might therefore be calculated to a higher value than if the cleaner is used in other than the max mode. This is, however, the same for all cordless cleaners, making results comparable.

While the cordless vacuum cleaners are used more frequently it is assumed that they are used to clean the same area as mains-operated per week, since this is based on average home sizes in Europe. Also the assumptions of 2 double strokes and the influence of performance on the cleaning time are assumed to be similar to that of mains-operated vacuum cleaners. The use pattern for cordless vacuum cleaners used for calculations in this study, based on the available information, is shown in Table 48.

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[163] http://www.which.co.uk/reviews/cordless-vacuum-cleaners/article/corded-vs-cordless-vacuum-cleaners
[164] Based on stakeholder inputs in the study

Table 48: use pattern for cordless vacuum cleaners

Parameter	Value
Average floor area covered per cleaning cycle[165]	87/4 = 21.75 m^2
Average strokes over floor	4 (2 double)
Average cleaning cycles per year	200
Average duration of cleaning cycles	20 minutes
Influence of performance on the time spend cleaning	$\left(\frac{1-0.20}{dpu-0.20}\right)$

9.3.1 Formula for calculating annual energy consumption for cordless vacuum cleaners

In addition to the above factors, the fact that cordless are battery powered means that also other parameters are important for their use. One is the battery time, i.e. how long the vacuum cleaner can be used before the battery needs recharging. Another is the charging time, which influences how long it takes until the vacuum cleaner can be used again. The remaining time it is assumed that the cordless vacuum cleaners are standing in the charger, fully charged, only using power for maintenance charging to make up for the battery self-discharge.

While the cleaning time is determined by use patterns, the charging time is determined by technical characteristics. Based on inputs from stakeholders and collection of online data[166] the average weekly time spend charging and in maintenance mode (seen in Table 49) has been determined. This is based on an average of hard floor and carpet cleaning.

Table 49: Average annual running hours in different modes for cordless vacuum cleaners.

	Average time per week	Average time per year
Cleaning (standby of dock without cordless)	73 minutes	63 hours
Charging	13 hours	671 hours
Charged and docked	158 hours	8026 hours

In the current draft standard for the cordless vacuum cleaner test, the energy consumption is measured by running the fully charged cordless cleaner for five minutes on the carpet / hard floor (while measuring the *dpu*) and then measuring the energy necessary for a full re-charge. This way of measuring thus takes into account the efficiency of the power supply, and since the test area is known, an average ASE in kWh/m^2 is easily derived.

[165] This is based on the assumption that the nozzle is moved with the same speed over the floor as for domestic cleaners
[166] Data for 28 different cordless models and their rated charging times and run times was used to calculated the average charging time (given by manufacturer) plus 33 models tested by the Danish organization TÆNK https://taenk.dk.

While this could be used for a simple energy calculation, it would not be comparable with the AE value calculated for mains-operated vacuum cleaners. However, using the AE formula directly would not reflect the annual consumption of cordless vacuum cleaners because of the many hours spent in maintenance mode. It is therefore suggested to add the maintenance mode consumption to the cleaning consumption of cordless vacuum cleaners, and to base the hours spent cleaning / charging / in maintenance mode on the above data. The formula would thus, without changing the area, be:

$$AE = 4 * \left(\frac{87}{4}\right) * 200 * 0.001 * ASE * \left(\frac{1 - 0.20}{dpu - 0.20}\right) + \frac{M_h * 8026}{1000}$$

Where M_h is the maintenance power in "charged and docked" mode in watts. In order to make the calculations comparable, the same area of cleaning per week is assumed, but spread over more cleaning cycles. Despite the difference in use pattern, the total area covered each year would be 4*87*50=17400 for mains and 4*21.75*200 = 17400 for cordless, hence ensuring the comparison of the two types. This will thus be how the energy consumption for cordless vacuum cleaners is calculated in this study.

Regarding the measurement data needed, the maintenance mode power consumption measurement is not yet part of the draft standard, but it should be one of the less complicated tests to develop. A *dpu* test has been drafted for cordless vacuum cleaners, which also gives the *dpu* in %, equivalent to that of mains operated vacuum cleaners.

Rather than having the annual standby hours as a constant, the charging time for the specific vacuum cleaner could be used instead to determine the annual maintenance mode hours. This could be combined with the maintenance mode power measurement (which starts once the charging is finished) and the run time of the appliance, and would need to be defined in a test standard. In this study, the average constant shown in Table 49 and the formula above will be used to calculate AE for cordless vacuum cleaners.

9.4 Use pattern of robot vacuum cleaners

Since robot vacuum cleaners need no human interaction during the cleaning cycle they can run at times when no one is home, which typically leads to a larger number of cleaning cycles. All robot vacuums placed on the market today have a timer setting, making it possible to schedule cleanings during for instance the workday[167]. Many users therefore run their robot vacuum cleaner every day, some run it 5 days a week, while a few runs it weekly[168,169]. Different sources report different use patterns, and in this study, it is assumed that robots are used four times per week, based on the different inputs received.

[167] https://www.robotcleanerstore.com/pages/robot-vacuum-cleaners-frequently-asked-questions
[168] http://www.explainthatstuff.com/how-roomba-works.html
[169] https://www.reddit.com/r/roomba/comments/669dr5/how_often_do_you_use_your_roomba/

Most robot cleaners have a declared run time of 60-90 minutes on a fully charged battery reported at time of sales, i.e. when the battery is new. A comparison of 52 different models showed an average declared run time of 83 minutes[170]. However, this value does not take into account gradual deterioration of the battery or mention the load of the motor while measuring run time. Hence over the course of the lifetime of a robot vacuum cleaner and considering that it might operate at various loads, it is assumed that average cycle time is far less than declared, around 30 minutes. This also takes into account that most robots cannot cross doorsteps and thus when started in one room, cannot cross to another after the room has been cleaned. The mapping technology determines when the room has been fully covered, and it is assumed that the robot will finish cleaning once this happens.

Table 50: use pattern for robot vacuum cleaners

Parameter	Value
Average floor area covered per cleaning cycle[171]	87/4 = 21.75 m^2
Average cleaning cycles per year (50 weeks)	200
Average duration of cleaning cycles	30 minutes
Influence of performance on the time spend cleaning	$\left(\frac{1-0.20}{dpu-0.20}\right)$

9.4.1 Formula for calculating annual energy consumption for robot vacuum cleaners

When the robot vacuum cleaner is not active (cleaning) or charging, it is standing fully charged in the docking station. The same three power modes as for cordless vacuum cleaners are therefore relevant for robot cleaners. The average charging times of robots is based on an online search with 52 models. The assumptions for robot cleaners are summarised in Table 51.

Table 51: Average annual running hours in different modes for robot vacuum cleaners

	Average time per week	Average time per year
Cleaning (standby of dock without cordless)	120 minutes	104 hours
Charging	4.4 hours	211 hours
Charged and docked	162 hours	8445 hours

Even though an average number of cleaning cycles per year and area covered per cleaning cycle can be found for robot cleaners, it is not directly comparable to that of cordless and mains-operated, because the robots drive around autonomously. The assumption of 2

[170] Based on online surveys and results from The Danish Consumer Council THINK
[171] This is based on the assumption that the nozzle is moved with the same speed over the floor as for domestic cleaners

double strokes, i.e. covering the area 4 times in total, can therefore not be assumed for robot vacuum cleaners.

As opposed to manually handled vacuum cleaners, coverage of the area is an important performance parameter for robot cleaners. How well the floor is covered depend highly on the robot navigation system. Some of the older navigation technologies in particular can result in the vacuum cleaner not covering all of the floor, which of course compromise the performance in terms of cleaning. For example, if the robot does not, in an entire cleaning cycle, drive over 4 m^2 out of a 20 m^2 room, the room coverage can be said to be 80%.

Despite the differences in how robot vacuum cleaners cover the floor in comparison to manually handled vacuum cleaners, the energy calculations still need to be comparable. Following the same logic as for the commercial and cordless vacuum cleaners, the area covered each year still needs to be comparable. However, in the calculation for robots, the room coverage should be included in a way where low room coverage leads to higher energy consumption because it de facto decreases the average cleaning area, and having to clean also this part would require extra energy. Furthermore, the maintenance mode and charging times are different for robots than for cordless cleaners as seen in Table 49 and Table 51.

While the cordless cleaner draft test standards make it possible to calculate an ASE value (in Wh/m^2) like for mains-operated vacuum cleaners, this is not the case for robot vacuum cleaners. Instead, the draft test standards specifically define a 20 m^2 test room (which takes around 20-25 minutes), let's the robot clean it, and the measures the energy consumption for charging the battery afterwards. The energy measure is thus rather energy per cleaning cycle instead of energy per square meter.

A suggestion for a formula for annual energy consumption for robot vacuum cleaners, which is used in energy calculations in this study is the following:

$$AE = \left(\frac{E_{measured}}{RCF * 20}\right) * \left(\frac{87}{4}\right) * 200 * 0.001 * \left(\frac{Avg\ dpu}{dpu}\right) + \frac{M_h * 8445}{1000}$$

Where $E_{measured}$ is the output from the test method, i.e. measured re-charging energy after cleaning the 20 m^2 test room. This number is then divided by RCF[172]*20 m^2 and multiplied with the average area assumed to be cleaned in an average robot cleaning cycle. This should be consistent with the area used for the other product types. The addition of the Room Coverage Factor in % (always between 0 and 1) in the denominator gives the actual

[172] Room Coverage Factor

area covered of the 20 m^2 test room. A test method has also been developed to measure this factor.

Since the dust pick-up test for robot cleaners is different from those for manually handled vacuum cleaners (no counting of double strokes, measured on flat floor), as explained in section 7.3, the values cannot be compared directly. Also, the constant 0.2 cannot be used for robots, since it is the standard deviation between 2 and 5 double strokes, which does not make sense for robots. The inclusion of the *dpu* factor in the equation is thus done differently. While the underlying assumption for manually handled vacuum cleaners is that end users will spend less time cleaning if the vacuum cleaner has a high dpu, the assumption for robots is that end users will run them less frequently, if they remove dust better, especially visible dust.

By comparing the AE calculation with the direct energy calculation (typical annual running hours and average consumption in each), it was found that by comparing the measured dust pick-up to the average dust pick-up (for the base case) was the best approximation to calculating the presumed change in user behaviour caused by the effect of dpu. This is of course based on some underlying assumptions about how much the user changes behaviour due to the difference in dpu, i.e. the gradient of the "cleaning time vs dpu" curve. This was found to be too steep when using the benchmark value for dpu, rather than the average, primarily because most robot cleaners have much lower dpu than the benchmark[173].

Furthermore, in including of the dpu in the robot equation, the inputs from stakeholders has been taken into account that the performance on carpet and hard floor should be included separately, due to the large difference between dpu_c and dpu_{hf} for robots.

As for cordless cleaners, it can also be contemplated to include the standby consumption of the docking station standing alone, while the robot is cleaning. This would then be an extra link in the formula and would require that a test standard is developed. This, however, should be a relatively easy parameter to measure, and the energy consumption is very low, so it is not critical to set a requirement. The maintenance mode power measurement is under consideration for the standards being developed by CENELEC, but is not included in the calculations in this study.

At this point there is too little data and information available regarding active charging stations, which can for example empty the dust bin of the robot, to take them into account in the calculations. However, since the maintenance mode consumption covers the entire

[173] Benchmark here meaning the best observed dpu performance found in any robot at the time of the study, which is around 95% on hard floor and 36% on carpet, measured with the IEC 62885-7 (draft) Section 5.6 and Section 5.7, respectively.

system (robot, charging station, power supply etc.), a large part of the consumption is considered covered.

9.5 Alternative calculations methods

During the study several alternative formulas for calculating the annual energy have been suggested, not just how to include dpu (as discussed in section 9.1.1 above), but also the entire structure of the formula. Specifically it is the calculation of an annual energy consumption (AE) in kWh that has received criticism, because the actual annual energy consumption is very much dependent on the individual end user and their behaviour, whereas the AE value is an average based on a number of simplified assumptions about user behaviour. While this is not in itself seen as a problem by most stakeholders, it is the idea of calculating an actual energy consumption which might be far away from what the consumer experiences in real life that is seen as the problem. Especially when this value was shown as a number in kWh on the now annulled energy label.

First, it has been suggested to remove the assumptions about user behaviour from the formula, i.e. the constants for average area (87 m^2), number of double strokes (4) and number of cleaning cycles per year (50). This would also eliminate the problem of comparing household and commercial vacuum cleaners, which have very different use patterns. This leaves the specific energy consumption (ASE) and dust pick-up (dpu) in the formula (as well as standby consumption for cordless and robot vacuum cleaners), which are also the values measured individually for each vacuum cleaner.

Without the constants in the formula, the expression would not yield and annual energy. Instead a type of energy efficiency index has been suggested in various versions by different stakeholders. One of the most useful methods, according to the study team, is to compare the individual product to an average base case or benchmark, as suggested above for including the dpu for robots. This concept could be expanded to the specific energy (Wh/m^2) on carpet and hard floor, so that both the energy consumed, and the dust removed, is compared to a reference value. This could for example be constructed as the following set of equations, following the same idea as with the current formula:

$$EI_{HF} = \frac{Energy_{measured,hf}}{Energy_{Base\ case,hf}} * \frac{DPUhf_{Base\ case}}{DPUhf_{measured}}$$

$$EI_{C} = \frac{Energy_{measured,c}}{Energy_{Base\ case,c}} * \frac{DPUc_{Base\ case}}{DPUc_{measured}}$$

$$EI_{general\ purpose} = 0.5 * EI_{hf} + 0.5 * EI_{c}$$

Alternatively, it could be put into one equation with weighting factors for carpet and hard floor dpu:

$$EI = \frac{Energy_{measured}}{Energy_{Base\ case}} * \left[\frac{DPUc_{Base\ case}}{DPUc_{measured}} * 0.5 + \frac{DPUhf_{Base\ case}}{DPUhf_{measured}} * 0.5\right]$$

However, the latter would have an intrinsic weighting of the two dpus (even without additional weighting factors), because the range of possible values would be different on hard floor and carpet. This could be evened out by adjusting the factors that are not 0.5 for both carpet and hard floor to more appropriate values between 0 and 1.

The inclusion of the dpu factors considers the effect on cleaning time through the dpu as in the current formula, but in a linear manner. For example, if it takes 1 hours to clean a home with a random vacuum cleaner with dpu=100%, the cleaning time with another vacuum cleaner with dpu=75% would be $1h \cdot \frac{100\%}{75\%} = 1.33h$ for the same room. This gives the dpu a more "equal" weight on the overall EI score, compared to now, where an increase from e.g. 75% to 80% has a higher influence that from 100% to 105%, thus increasing the incentive to reach better dust pick-up. This is because the reduced number of double strokes are not taken into account (i.e. the factor 0.2) in this calculation.

The advantages of these formulas are that they do not include a large range of constants, but focus on the measurable performance of vacuum cleaners, making them easier to understand. Furthermore, the concept of calculating an energy index instead of an actual consumption does not lead to any false expectations for end-users (as compared to the current formula which includes multiple assumptions of the use pattern, which might not fit how the individual user cleans), and it is more in line with other household products, which also uses EEI (energy efficiency indexes) in many cases.

Another big advantage for policy makers is that it would be very simple to update the regulation based on technical progress in the market, simply by defining a new base case value in the equations. The base case could either be common for all vacuum cleaners, or be different for each type of vacuum cleaner, e.g. household/commercial, corded/cordless. If the base cases are different, however, it is not possible to compare between the different vacuum cleaner types. This could be relevant if different, incomparable test methods are used to derive the measurement results (e.g. for robots and manually handled vacuum cleaners). If an energy label is then introduced, the design of the label should differ significantly to not give the false impression that these products are comparable.

Since test methods are still in the process of being adjusted to an extent where an adequate base case is difficult to define (especially for the cordless and robot products), it is recommended to look into the possibility of introducing an EI formula in the next revision rather than in the current review.

9.6 Consumer relevance – consumer survey results

This section focuses on what is consumer relevant by highlighting some of the results from the 2018 APPLiA consumer survey and by discussing the specific test aspects that have been mentioned by stakeholders both for existing test standards (mains operated vacuum cleaners) and for the cordless and robot tests being developed.

There are several initiatives aiming at improving standards with regard to a more consumer relevant testing. Recently, a new WG 22 Ad-hoc Group Consumer relevant testing was established at CENELEC TC 59X. The WG (Working Group) have prepared a draft document titled "Consumer Relevant Product Testing" which is intended to support standard makers in assessing standards to reflect 'real-life conditions' while also being suitable for producing measurement protocols with the required repeatability and reproducibility necessary to support Ecodesign and Energy Labelling legislation. Vacuum cleaners are among the examples mentioned in this draft document.

At association level, APPLIA organised four workshops since 2015 with the aim of analysing and discussing how current product testing methods could be improved to better reflect real life use of appliances by consumers. The workshops brought together the major stakeholders (policy makers, NGOs, consumer organisations, Member States representatives, market surveillance authorities, laboratory experts, consultants and industry) to discuss the topic and see practical demonstrations of what product testing is about. Vacuum cleaners were the topic of two of these workshops. Some of the issues discussed in the following sections were findings from these workshops. Standard makers were encouraged - and they agreed - to take the findings of the workshops on board for their future work.

When discussing consumer relevance, it is a trade-off between mimicking the real life use situation as closely as possible and not increasing test complexity to such an extent that tests become too time consuming and uncertainty increases to a level where they cannot be used for regulatory purposes. This trade-off can also be described with accuracy and precision: Accuracy is a measure of how close to /far from the consumers' reality the test results, while precision is how alike the results are each time you test, i.e. how reproducible and repeatable the tests are.

While the most relevant measure to consumers is exactly how much energy is consumed and how much dust is removed from his home with the specific cleaning behaviour, every user is different and have different conditions for cleaning. Therefore tests and calculations are based on averages that makes products comparable on the parameters that are considered most important to the users.

Hence, the consumer relevance includes many aspects, such as which performance parameters are important to end users, how and how much people use their vacuum cleaners in real life, what are the cleaning conditions (floor types, pets, type of dirt etc.). For example, for most vacuum cleaners, multiple tools (different brushes) and modes are available to the end user. In addition the products are getting more and more "intelligent" in terms of detecting which tools are applied, which type of floor is cleaned and how much dust is in the receptacle, and then adjusting their settings to those specific conditions.

In order to maintain a high precision of the measurements, it is not practically or economically possible to take into account all the different modes and tools available for each different vacuum cleaners, in order to obtain high accuracy. However, consumer surveys and consumer organisations as well as accumulating experiences from test laboratories and marketing departments gives good indications of what is important to the end user and how tests can be improved.

9.6.1 Ranking of important parameters

For consumer relevant legislation, it is important to consider what users value when choosing products and how they use them and in which conditions. The industry organisation APPLiA made a large consumer survey for vacuum cleaners in 2018, which gave some information about use preferences.

One of the results from the APPLiA consumer survey ranked importance of different parameters for purchasing a new vacuum cleaner, which is shown in Table 52.

Table 52: Percentage of consumers rating parameters important/very important in a purchase situation

Parameter	Percentage answering "very important" or "important"
I expect it to last a long time	91%
Its performance	90%
The ease of use	89%
The price	87%
The ease of maintenance	86%
The type /stick, robot, canister etc.)	80%
A good filtration of the dust (allergies)	79%
The time spent cleaning	77%
The noise level	67%
The energy efficiency	67%
Having/not having a bag	66%

Parameter	Percentage answering “very important” or “important”
How technologically advanced it is (new features etc.)	64%
The availability of accessories	64%
Its look and feel	56%
The brand	45%

As seen from the table, consumers expect vacuum cleaners to be long lasting, easy to use and easy to maintain. Brand and design (look and feel) are less important than good performance, showing that users are unlikely to change them due to design or fashion, but rather change them when they break, or performance deteriorates. This is also reflected by 70% of the respondents in the APPLiA survey who bought a new vacuum cleaner either because the old was broken or no longer "up to the job".

9.6.2 Floor types

The APPLiA consumer survey also investigated in detail the use conditions and habits of users. One result that is important for the regulations is the distribution of different floor types. In the following only results from the rooms that more than 50% of the respondents had in their homes, seen in Figure 33, are included. i.e. rooms such as garages, present in less than 50% of homes, are not included.

Figure 33: Types of rooms that more than 50% of the respondents in the APPLiA survey have in their homes

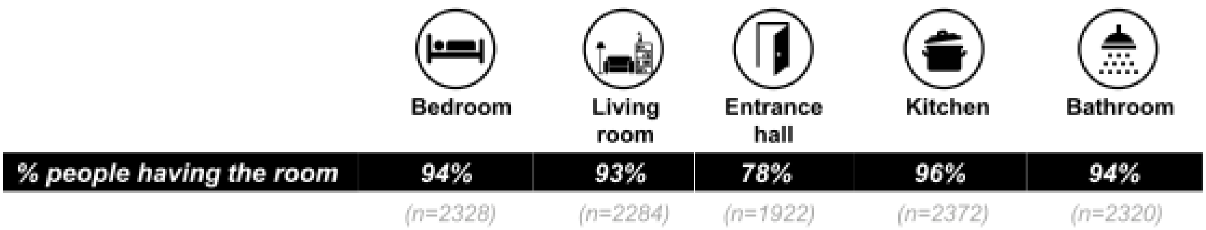
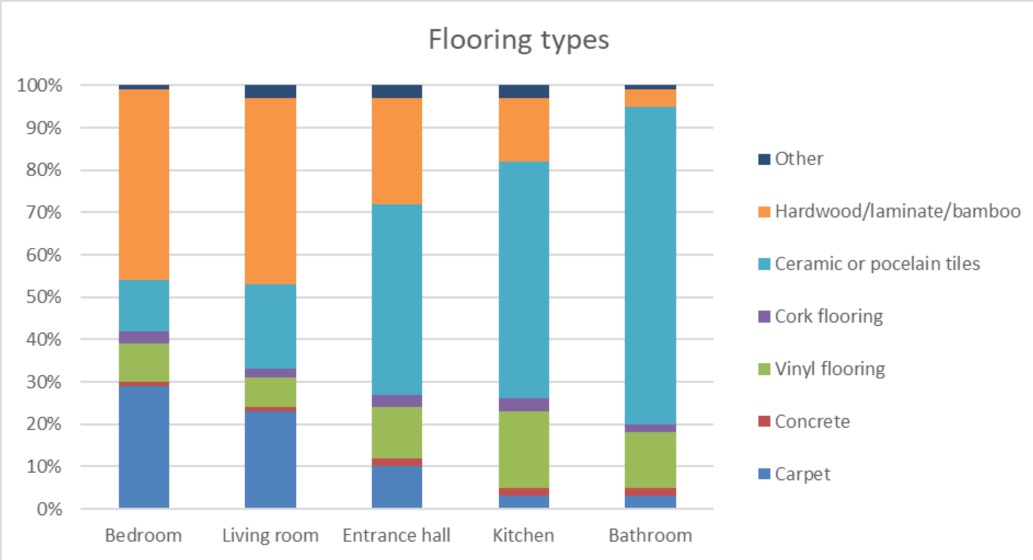


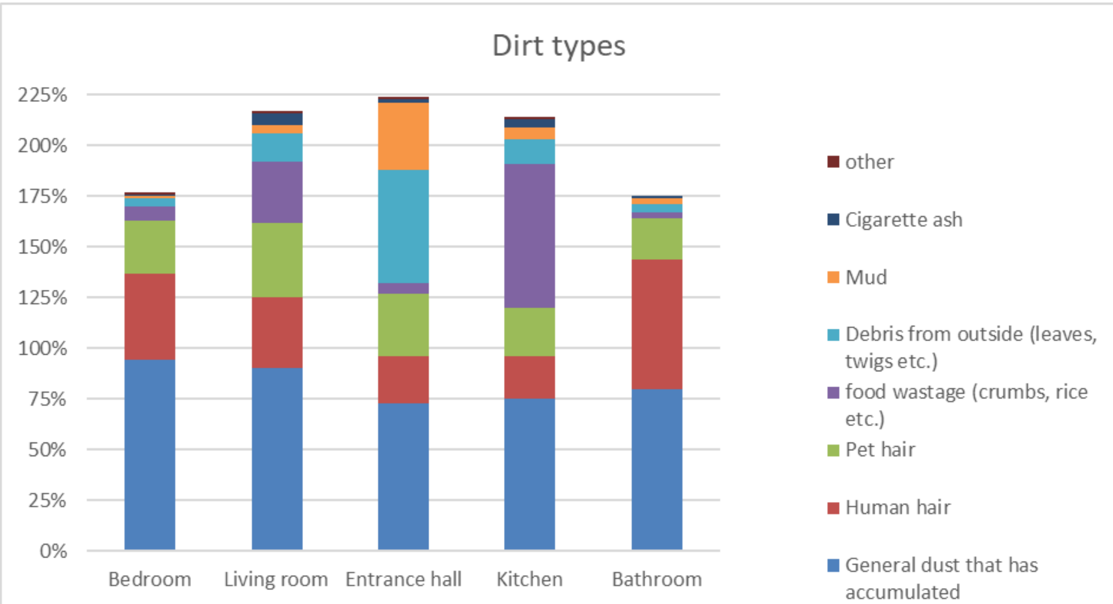
Figure 34 shows the distribution of flooring for each of the five room types. As seen from the graph, the room where people most commonly have a carpet is the bedroom (29%) followed by the living room (23%). The rest of the listed floor type are considered hard floor types. It should be noted, however, that even when there is hard floor in a room, many people have a rug that covers part of the floor and also needs to be vacuumed. In the bedroom and living room, 59% and 67% of respondents had a rug. In the entrance hall and bathroom 44% and 41% had a rug, while the fewest (24%) had a rug in the kitchen. (See also Annex A, 6. Regarding market representative floor types).

Figure 34: Flooring types in the five most commonly occurring room types



Regarding the types of dirt that is cleaned with a vacuum cleaner, by far the largest majority is identified as "general dust that has accumulated", which is experienced in all room types by more than 70% of respondents. This is, for most of the rooms, followed by human hair and pet hair, except for in the kitchen, where more than 70% encounter food wastage, and the entrance hall where 89% encounter debris and mud from outside.

Figure 35: typical dirt types in the five most commonly occurring room types



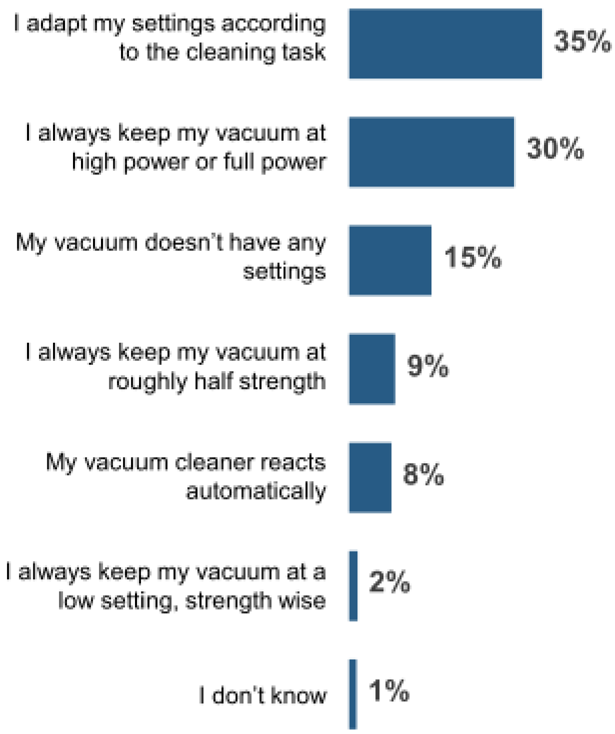
9.6.3 Vacuum cleaner settings

Another interesting finding from the APPLiA consumer survey is how people use the different functions of the vacuum cleaners while they are cleaning. For example, the survey found that around one third (36%) of the respondents changed the nozzle based on the floor type, while 32% merely changed the nozzle setting.

Regarding the different types of nozzles used, 68% of the respondents use the "universal" two-step nozzle that can be switched between carpet and hard floor setting. Around one fourth use the specialised carpet (27%) and hard floor (25%) nozzles. Furthermore 36% of respondents use the special nozzles for furniture, cars, skirting boards etc.

Many vacuum cleaners today let the user adjust the power setting according to the surface being cleaned. Figure 36 shows how respondents of the APPLiA consumer survey use the power adjustment option. This shows that 35% use the manual options, while 8% has a vacuum cleaner that adjust power automatically. Another third (30%) always keep their vacuum at full power, which is also the power setting they are tested with in the energy consumption test. 15% has a vacuum cleaner without power setting option. The remainder of respondents keep their vacuum cleaner at medium (9%) or low (2%) power settings.

Figure 36: User behaviour regarding power settings, according to APPLiA consumer survey.



9.7 Consumer relevance – testing

9.7.1 Carpet test

For the carpet cleaning tests, three cleaning cycles are performed and the measured carpet dust pick-up (dpu_m) is corrected by the dust pick-up of a reference vacuum cleaner when the carpet was new (dpu_{cal}) divided by the reference cleaner dust pick-up at the present state (dpu_{ref}):

$$dpu_c = dpu_m * \left(\frac{dpu_{cal}}{dpu_{ref}}\right)$$

The general reproducibility of the carpet test has been put into question by manufacturers and test labs. The low reproducibility and repeatability are caused by a number of parameters, such as the embedding of the dust to assess the in-depth dust removal, the wear of the carpet and the microclimate in the carpet, which can vary significantly. Therefore 16 labs collaborated on a RR (Round Robin) test, where the same four vacuum cleaners were tested on the labs' own carpet, as well as a piece of carpet that was circulated between the labs[174]. The goal was to derive the expanded uncertainty to be able to quantify the variations that has been observed for the test method. The results are used to assess the verification tolerances in the regulation.

Carpet type

The carpet used in the performance testing is a wool Wilton cut pile carpet[175] produced specifically for the vacuum cleaner test in order to ensure reproducible results. However, a survey made by carpet manufacturers showed that the most sold carpet types are cut pile or looped nylon carpets. Therefore, a comparable testing is ongoing to investigate the difference of performance on wool vs. nylon carpet. In the preparatory stakeholder meeting, it was noted that in the international ASTM test standard, the vacuum cleaner performance is tested on four different types of carpets, which makes it difficult for manufacturers to design product specifically to achieve high performance in the test[176].

Some stakeholders therefore claim that the Wilton wool carpet is not consumer relevant and recommend using for example the ASTM carpets, which are proven to work for testing purposes (e.g. used in North America).

In order to ensure that the test and measured performance is as relevant as possible for consumers, it is recommended to change to testing on a more representative carpet type, as long as it does not add further complications and it can be ensured that the carpet chosen does not vary considerably in quality from batch to batch. However, the choice of carpet and investigation of different carpets' suitability for testing vacuum cleaners requires a lot of test work and therefore would need to be decided within standardisation

[174] See Table 61
[175] http://www.brintons.com.au/construction-types/
[176] Final stakeholder meeting preparatory study, Jan. 2009: Annex C in the Impact Assessment working document. Page 51. COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT (2013) with regard to Ecodesign requirements for vacuum cleaners and the Energy Labelling of vacuum cleaners. http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2013/swd_2013_0240_en.pdf

group. It should be noted that it is not yet known whether another carpet type alone will result in better reproducibility and repeatability of the dpu_c test results.

It has also been discussed that there might be a difference in the carpets used in household and commercial settings. The commercial vacuum cleaner manufacturers see the need for a new test carpet with improved test attributes and which is closer to the real-life condition of commercial end-users. They have therefore suggested a specific test for commercial vacuum cleaners, with a carpet type other than the Wilton. The standardisation group working with household vacuum cleaners are also working on developing a test with a more market representative carpet, however, such a test is far from being introduced, because one of the carpets suggested has a low durability and thus changes characteristics after just a few test runs, and another suggested carpet type needs to be investigated further.

Motion resistance

Another major issue that has been raised by several stakeholders is motion resistance. Motion resistance arises because the vacuum created in the nozzle makes it stick so tightly to the carpet that it is difficult or impossible to move. This very high motion resistance arises because nozzles specially designed for increased dust pick up on carpets are used for the test. However, it is not realistic that the end-user will vacuum with such high motion resistance, because it is simply too much of a physical effort to push the nozzle over the floor. The test rigs used for the performance testing moves the vacuum cleaner and have a push/pull force of up to 100 Newtons, so this is often not a problem during testing. Using the specialised carpet nozzles in real life is thus inconvenient at best, and for some models it might not be possible to move, at least without turning down the suction power.

In any case, the performance measured with specialised carpet nozzles featuring high vacuum is unlikely to reflect the real-life performance if the user decreases suction power or chooses to use the universal nozzle instead, which the APPLiA survey showed that most do as described in section 9.6. However, according to stakeholders it is not enough to require the test to be performed with the universal nozzle to ensure that the nozzle is designed for a variety of cleaning tasks and not only optimised for cleaning the specific type of carpet in used in the test. This is for a number of reasons. For one, the "universal nozzle" would need to be defined in the regulation, which would likely be based on specific design/technology (such as a manual switch between hard floor and carpet), forcing all manufacturers to have such a nozzle for their products. Some vacuum cleaner types, such as uprights and handsticks, do not have these types of nozzles. Furthermore, many universal nozzles exist today that have high motion resistance, so this alone would not ensure that the test is more consumer relevant.

Another method to make the test results more consumer relevant could be to set a limit value for maximum motion resistance during the carpet test. The German product testing organisation, Stiftung Warentest[177], considers push/pull forces over 30 N to be unacceptable for users. For commercial vacuum cleaners, acceptable pull/push forces are not a performance criterion, but a safety requirement mandatory to be fulfilled to comply with the Machinery Directive[178]. For the commercial products the maximum allowable force is 27-30 N, but not measured on the Wilton carpet, which has around double the motion resistance.

Commercial manufacturers have tested products compliant with the Machinery Directive to have motion resistance of up to more than 40 N on the Wilton Carpet, being around double of what is measured on low pile carpets. Examples of the measurements for three nozzles are given in Table 53.

Table 53: measurement of motion resistance on Wilton carpet vs a low pile carpet, performed by commercial vacuum cleaner manufacturers.

Cleaner	Resistance Wilton	Resistance low pile "office" carpet
800W nozzle A	30N	15N
800W nozzle B	34N	17N
800W nozzle C	41N	20N

Others have also made user panel tests to find the maximum acceptable pushing force (forward motion resistance) for commercial use cleaning more than 4 hours/day. This limit was found to be around 20 N on a short pile carpet (common office carpet) and then translated (through testing) to correspond to around 40 N on the Wilton carpet. Based on these findings the 30N used as a guideline by Stiftung Warentest is a bit too low, while 40 N is more adequate as market entry limit.

Carpet debris test

Regarding the end-user relevance of the carpet performance test, it has been recommended to add a debris pick-up test, to simulate the removal of larger pieces of dirt from the carpet. It has been noted by multiple stakeholders that end-users often clean based on what they can see, hence until the floor is visibly clean, rather than based on removing the embedded dust in carpets. While the in-depth cleaning is still important, the debris pick-up test could be added to the carpet cleaning performance in order to nuance the performance criteria and make the test more consumer relevant. A Debris pick-up test

[177] https://www.test.de/Staubsauger-im-Test-1838262-1838266/ (Google translate: Since 2011, the testers have also measured the dust absorption at a sliding force of 30 Newtons. This is roughly equivalent to the strength that an adult finds acceptable in dust suction. For this test vacuum cleaners with empty dust bag or container. The testers regulate the suction power of the vacuum cleaners so far that the nozzles can be pushed with 30 Newtons.)
[178] European standard EN 1005-4, harmonized under the MD, gives an evaluation procedure for maximum acceptable forces

on carpet is under development both for commercial and household vacuum cleaners that could be used for measurements.

Another parameter that is often used by consumer organisations when testing vacuum cleaner performance is a fibre pick-up test on carpet. As described in section 9.6.2, hair is indeed an often encountered type of dirt, and removing it from carpets is one of the trickier cleaning tasks. However, since a fibre pick-up test is not being developed at the moment, there are no reliable data or test results regarding performance and repeatability and reproducibility. This parameter is therefore not suitable for this revision, but could be considered for future revisions. However, it should be considered whether fibre pick-up remains broadly relevant to consumers, if the debris pick-up is included in this revision.

9.7.2 Hard floor test

The hard floor performance test is based on removing a special type of standardised dust from a 3-mm wide crevice in an otherwise flat, hard floor. As with the carpet test, the hard floor test is often performed using a nozzle designed to optimise dust pick up from the crevice. This often means a nozzle with high downwards vacuum and closed around the sides with little or no openings. This in turn leads to dust pick-up above 100% as the dust in the crevice outside the nozzle itself is also picked up. In real-life situations, however, flat parts of the floor need to be cleaned, and not only crevices or grooves in the floor. The nozzles optimised for the crevice test often push debris over the floor rather than cleaning as a result of the closed sides, not allowing the dirt to be sucked in. This so-called crevice test is not very consumer relevant, and has been found to result in test-optimised nozzles that are not optimal for the types of floors and dirt encountered in real life situations.

A suggestion to make the test more user relevant is to not only test hard floor dust pick-up with the crevice test, but to add a standardised debris test, where larger types of debris are removed from a flat hard floor surface. Different materials have been discussed as representative of the debris found in real life situations: from organic grains such as rice or lentils, to small Lego bricks and brass nuts. In order to ensure repeatability and reproducibility of the flat floor debris test, the use of organic types of debris has been discarded, since it is difficult ensure homogeneity because the grain size, density, shape etc. Legos and metal nuts, on the other hand, are standardised in terms of size, density and shape and small M3 brass nuts have been found by commercial vacuum cleaner manufacturers to provide the best type of debris, while for household vacuum cleaners, aluminium has been discussed.

As noted by some stakeholders, it should be kept in mind that no matter which type of debris is chosen, there is a risk to repeat the current problems, that products are specialised and optimised to do well in the test, i.e. to pick up the specific type of debris chosen. However, this is again a question of the trade-off between high accuracy that comes close the real life and keeping the test to a simplified situation, to avoid testing several types of dust/debris/dirt on several types of floor. The task will be to find a representative type of debris concerning size and destiny. By testing larger pieces of debris as well as dust, all the sizes of dust/debris in between would indirectly be taken into account.

An important aspect of the additional debris test on hard floor is that it should be conducted with the same nozzle and nozzle settings as the crevice test to avoid sub-optimisation for each for the two parts of the tests and ensure the end-users a nozzle that is useful for the full range of hard floor types they might encounter.

9.7.3 Specialised nozzles

The current test standards for the carpet and the hard floor *dpu* tests both result in specialised nozzles optimised for the specific test conditions in order to obtain good performance ratings on both parameters. However, the special designs compromise the practical usability of the nozzles as explained above: the carpet nozzles obtain too high motion resistance and the hard floor nozzle is shielded to a degree that it pushed debris around instead of removing it.

The test-optimised design of the nozzles means that they are not useful for the end-users in real-life situations, because they will often differ significantly from the test set-up. Hence, the user will not get the performance they think they buy, based on the label ratings. This is a problem for both the end-users and for the credibility of the previous, annulled energy label and the manufacturers.

While adding the debris test as a parameter for hard floor cleaning performance and the fibre pick-up test for carpet cleaning performance will most likely result in nozzles designed for more varying situations, still 68% of users use the universal nozzle, while only one fourth use the specialised carpet (27%) and hard floor (25%) nozzles[179]. A suggestion to require all tests to be performed with the universal nozzle to ensure that the 68% of end-users using the universal nozzle will actually experience the performance shown in the label, was criticised by stakeholders. The main arguments against such a requirement was that not all vacuum cleaners are equipped with what is broadly called a universal nozzle, which would also need to be defined in the regulation, and there would be a risk to be too design-specific, removing the manufacturers' freedom to provide specialised tools for specific tasks.

[179] 2018 APPLiA consumer survey

Such a test requirement would, however, not prevent manufacturers from also developing nozzles specialised for specific floor types, but it would prevent putting them in the box solely to justify a performance rating. At the very least it is crucial that tests performed on the same floor type (e.g. dust and debris pick-up on hard floor) are both performed with the same nozzle and nozzle settings, as is also stated in the draft standard.

9.7.4 Commercial vacuum cleaner test

Commercial vacuum cleaners are currently tested using the same test standards as household vacuum cleaners, however, commercial vacuum cleaner manufacturers argue that the actual use conditions are different and that the tests should be adjusted in order to reflect these differences. Commercial vacuum cleaner manufacturers have therefore suggested a specific commercial vacuum cleaner performance test for debris pick-up on hard floor. The test is based on picking up M3 brass nuts and washers, laid out in a specific pattern to avoid strategic design of the nozzle to fit the test. Brass is used to simulate a "worst case" scenario with heavy debris, since the density is high, thus brass nuts and washers are more difficult to pick up than any lighter materials. The test is to be performed with the same nozzle and settings as the crevice hard floor test.

Besides the difference in test methods, it is suggested to introduce a different additional performance parameter, namely the productivity in terms of area cleaned per time interval (often m^2 per hour). According to commercial vacuum cleaner manufacturers such a productivity parameter better reflects the demands of commercial end-users and is often requested by them, since the salary for professional cleaning personnel is an important cost. The equations seen in section 9.2.1 are therefore suggested to replace the annual energy calculations for commercial vacuum cleaners, specifically. In this way the use pattern of 50 cleaning cycles of 87 m^2 vacuum per year is removed from the commercial calculations, which makes it more relevant for the commercial end-users.

Specific suggestions for commercial vacuum cleaner test

In the proposed standard, the hard floor crevice test is suggested to be backed by a debris test on flat floor. The debris suggested is M3 nuts and washers[180], because they are ISO standardized and readily available for purchase anywhere. The idea with this double test is to avoid nozzles specialized for the crevice test specifically, but to have one nozzle that is designed to handle both dust and debris on flat floor and floors with crevices. Therefore, a crucial condition for the suggested double hard floor test is that each part should be performed with the same nozzle and nozzle settings in order to better mimic real life.

[180] M3 nuts and washers were chosen after almost 1500 tests with seven different debris combinations including paper clips, rice and lentils, 1x1 round Lego bricks, paper and cotton threads.

For the commercial carpet test the most important change suggested is the type of carpet. The commercial vacuum cleaner manufacturers see the need for a new test carpet with improved test attributes and which is closer to the real-life condition of commercial end-users. The type of carpet is suggested to be chosen based on the prevailing type sold in Europe and tests of several carpets have been and are still being conducted. However, a better carpet with better attributes has not yet been found. Unless a more suitable carpet is found, the commercial vacuum cleaner standard will be harmonized in this regard with the household vacuum cleaner standard.

The tests are performed to ensure repeatability, reproducibility, user relevance as well as testing efficiency and distinction between vacuum cleaners on the different carpets. This would bring down the test costs significantly as the current carpet type is quite expensive (in the range of 350 euros per meter test length) and would also be more representative of the actual environment in which the vacuum cleaners are used. For the carpet test, commercial vacuum cleaner manufacturers suggest setting a maximum limit for push/pull forces, since this is an important factor especially for commercial end-users, who vacuum many hours per day.

9.7.5 Definition of rated power input

As discussed in paragraph 7.3.2 there are some possible flaws in the use of EN IEC 60335-2-2 as the harmonised standard for 'rated power input'. There are several options for improvement. The first option is to request CENELEC to complete the standard and in Annex ZZ only refer to the main text –without the note on exceptions on booster setting-- of the clause 3.1.4 of the standard as a reference for 'rated power input'. Furthermore, to fight possible ambiguity as regards the verification tolerances, it is recommended to include explicitly the verification tolerances for 'rated power input' in a reviewed regulation and no longer leave the definition of that regulated parameter to the standard. Given that the booster setting option no longer applies and that 'the average effective power intake' during the performance test –according to EN 60312:2017—is never higher that the 'safe' 'rated power input' there should be no ambiguity. It stands to reason that the verification tolerances for the rated power input are lower than those for the energy consumption (±10%).

The second option is to stop using EN IEC 60335-2-2 as a harmonised standard for presumption of conformity and instead use the value of 'the average effective power intake' during the heaviest performance test[181] according to EN 60312:2017 as the parameter to be regulated under Ecodesign.

[181] Currently this is the carpet cleaning test, but this may change in a future regulation. Furthermore, for 'hard-floor only' vacuum cleaners there is no carpet cleaning test and thus the power intake during the 'hard floor' cleaning test is the yardstick.

The third option is to change the content of the standard EN IEC 60335-2-2 to make it less ambiguous, but given the time this would take (up to 5 years), this is not a practical solution.

9.7.6 Cordless and robot vacuum cleaner tests

For cordless and robot vacuum cleaners, other parameters are relevant to the consumers besides those tested for mains-operated cleaners, Factors related to the battery are particularly important, e.g. battery run time, charging time, maintenance consumption and battery life. This is in addition to the performance parameters discussed for mains-operated vacuum cleaners, e.g. debris pick-up on hard floor and fibre pick-up on carpets.

The standard for cordless vacuum cleaners includes specific measurement methods relevant for cordless vacuum cleaners including run time while maintaining a reasonable suction power. Such a test is intended to ensure that the declared run time and suction power are measured simultaneously and are thus not mutually exclusive in practice. E.g. the longest possible run time obtainable with a cordless cleaner might be while suction power is at the lowest setting, while the highest setting suction power will result in lower run times. In order for the consumer not to be misled, the declared run time should thus be measured on the same suction power setting as the performance is measured with, in order to give the consumers a coherent picture of the cordless vacuum cleaners' capabilities.

For robot vacuum cleaners, the battery performance is also important, but in addition factors related to autonomous operation are important such as floor coverage (i.e. navigation system) and obstacle overcome capacity. These factors are handled by setting up a test room in standard IEC (EN) 62929:2014.

Another important factor for both cordless and robot vacuum cleaners is the energy consumption in the docking station in terms of maintenance power as discussed previously in this chapter.

9.8 Testing with part load

The empty vs. part load testing is one of the key debates regarding the performance test of vacuum cleaners and is highly linked to consumer relevance. In the existing standard, the vacuum cleaners are tested as new (i.e. out of the box), without adding dust or dirt to the receptacle prior to the test. This means that the receptacle (bag or otherwise) as well as filters and crevices and nooks inside the vacuum cleaner are completely clean when initiating the test.

The main argument against this methodology is that testing vacuum cleaners while empty does not reflect real-life use conditions very well, as vacuum cleaners are almost never empty in real-life[182] and never completely clean from dust except when they are new. Some organisations and manufacturers therefore argue that the annual energy consumption stated on the label is not an accurate representation of real-life consumption[183]. A measurement method with partly filled receptacle has therefore been suggested to better reflect real-life usage. However, as noted in the Special Review Study on durability, half-load testing will increase the uncertainty of the test compared to empty receptacle testing, thus creating further problems with test reproducibility. In order to achieve high repeatability and reproducibility, highly trained personnel and special equipment would be needed, increasing the test cost[184], which would not only imply increased cost for manufacturers (and eventually consumers), but it would also make MSAs less likely to perform tests.

As described in the special review study[185], the motor durability test[186] that entered into force with tier II on 1 September 2017, is performed with half full bag/receptacle according to the regulation. Some industry experts have argued that the half load might actually be an advantage for universal motors in terms of lifetime, as the extra resistance created by a loaded receptacle decreases the airflow through the motor and thus increase the number of revolutions per minute, making it 'easier' for the motor to run, because less air has to be pushed through the system. This will in turn cause the carbon brushes on the motor to wear more slowly, decreasing the wear of the motor[187]. At the same time, however, less air will mean less cooling of the motor, which will cause the motor to wear faster. However, there is no general way to predict how different motors will be affected by the receptacle load, and testing with half load can either increase or decrease the lifetime.

9.8.1 Dyson vs European Commission

The importance of the discussion of testing with part load was underlined in the Court case of Dyson vs the European Commission[188], which was ongoing before and during the review.

NOTE this is just an example why good test standards in general, and part load specifically, are important, it does not reflect the official opinion of the European Commission or the study team.

[182] TOPten criteria paper
[183] Topten criteria paper
[184] Special review study on durability tests According to Article 7(2) of Commission Regulation (EU) No 666/2013 with regard to Ecodesign requirements for vacuum cleaners FINAL REPORT Prepared by VHK for the European Commission 2016. page 16. http://www.ia-vc-art7.eu/downloads/FINAL%20REPORT%20VC%20Durability%20Test%2020160623.pdf ,
[185] Special review study on durability tests According to Article 7(2) of Commission Regulation (EU) No 666/2013 with regard to Ecodesign requirements for vacuum cleaners FINAL REPORT Prepared by VHK for the European Commission 23 June 2016. http://www.ia-vc-art7.eu/downloads/FINAL%20REPORT%20VC%20Durability%20Test%2020160623.pdf
[186] Harmonised standard: Durability of the hose and operational motor lifetime, EN 60312-1:2013
[187] Special review, Annex IV, p 31
[188] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:62013TJ0544(01)

In 2013 Dyson sued the European Commission with the claim that the tests used to establish the energy consumption of vacuum cleaners were flawed as the energy performance is measured only through tests conducted with an empty receptacle. The vacuuming performance of a vacuum cleaner with a dust-loaded receptacle and, therefore, the resulting energy efficiency, may be reduced due to dust accumulation.

On 8 November 2018 the General Court annulled the regulation on the energy labelling of vacuum cleaners[189] on the grounds that the Commission had exceeded the limits of its empowerment by basing the energy performance on a test with an empty bag, which was not close enough to actual use conditions as required by the enabling act. The General Court found it impossible to annul only the calculation method based on an empty receptacle, and therefore annulled the whole regulation.

The Commission did not appeal against this judgment, and the annulment took effect as of 18 January 2019.

9.8.2 Definition of part load

The major problem related to the motor test, and also to the suggested part load energy performance test, is that the part load has yet to be defined. The lack of a definition means that the tests are currently run with empty receptacles, which according to TopTen is not in accordance with the standard[190], however it has been allowed to test the motor lifetime with empty receptacle but for an increased number of hours, 550 instead of 500.

The Regulation indicates that the durability test for motors should be run with half-loaded receptacle. The major problem with "half-load" or other definitions depending on a percentage load, is the difficulty of defining *full load*. If the full load of the receptacle is not known, neither is the 50% or another percentage hereof. The same problem arises when seeking to define partly loaded as a specific amount of standardised dust per Litre of usable volume, since the "usable volume" would have to be defined first, and this might not be the same as "full".

An obvious choice would be to define full load based on the "bag-full" indicator present on most vacuum cleaners, typically as a red bar that moves under a transparent plastic cover as the bag fills, as seen in Figure 37. Bagless cleaners often have a clear bin receptacle and the indication is typically 'max' mark on the side, indicating that when the dirt inside reach the max mark, it should be emptied.

[189] https://curia.europa.eu/jcms/upload/docs/application/pdf/2018-11/cp180168en.pdf
[190] TopTen Vacuum cleaners: Recommendations for policy design, October 2017

Figure 37: Typical bag-full indicator on bagged vacuum cleaner (left) and bagless vacuum cleaner (right)

However, using the "full" indicator, poses a number of problems:

- What if the vacuum cleaner has no indicator?
    - Not all vacuum cleaners have a bag-full indicator or max filling level indicator. In that case, another definition needs to be applied.
- Which angle should bagless cleaners be held when the dust-fill level is determined?
    - Many vacuum cleaners, especially cylinder, can be in at least two positions. Switching from one to the other changes how the dust is placed in the bin, and how much dust is needed to reach the Max mark.
- Should the vacuum cleaner be turned on or off when the dust-fill level is determined?
    - Bagged vacuum full-bag indicators are often only activated when it is turned on
    - When bagless cleaners are turned on the dust is swirled around, distributing it in the entire bin and making it impossible to determine whether the max mark is reached. When it is turned off, the dust might not settle evenly.

In general, using the bag-full indicator for determining full load of a vacuum cleaner is very uncertain. Even if the above questions were answered, it is not unambiguously clear when the bag-full indicator is activated, or exactly when the dust reaches the max mark. The judgement will in any case be up to manufacturers, hence adding a high amount of uncertainty to the test, potentially decreasing reproducibility of the test results, depending on the influence of bag filling level on the performance. Furthermore, if this definition was used in the standard, products designed to optimise test results could be a risk, i.e. designing the indicator to show "bag full" before it actually is and thereby potentially get a better performance rating.

Another way to determine when the receptacle is full, is to base it on manufacturers' declaration. However, this procedure requires that all manufacturers have the same understanding and use the same definition of full. Is it for instance when the bag has to be changed or the bagless receptacle needs to be emptied? And is it supposed to be emptied when physically full, or only at a partly full state? For instance, the max mark on bagless cleaners is not at the top of the receptacle (see Figure 37), and the bag-full indicator might not activate when the bag is completely full, but a while before. Hence this approach largely brings the same uncertainties and questions as the bag-full indicator or max mark definition.

An outdated criterion for measuring when the receptacle is full, is when the vacuum (i.e. pressure difference) has dropped to 40% of the vacuum measured when the receptacle is empty. This criterion is based on paper-bags that were previously used in most vacuum cleaners, and quite fast deteriorated the cleaning performance due to clogging. However, the far majority of bagged vacuum cleaners today use fleece bags, which are more effective and can take considerably more fine dust before losing performance. Furthermore, this criterion does not work for some types of bagless vacuum cleaners that are marketed as not losing any suction power as it fills[191], whereas other bagless does[192].

Instead of basing the part load definition on a share of the full load, an approach with a fixed amount of dust can be followed, such as the one used by the German consumer organisation Stiftung Warentest[193]. In their vacuum cleaner performance tests, they test the vacuum cleaner performance with empty receptacle, with 200 g and with 400 g standardised DMT8 dust. If the vacuum cleaner cannot hold all the dust, the loading is stopped, and the test performed with the amount of dust that can fit into the receptacle. The main advantage of this approach is that it eliminates the need for defining what is the full load of each receptacle. It has to be resolved, however, how to handle vacuum cleaners that cannot hold the specified amount of dust. This might especially be a problem for battery operated and robot vacuum cleaners, and not so much for mains-operated. It will also have to be decided whether the amounts shall be 200 g and 400 g, or other values. The approach will increase test costs, since three tests (with different loads) have to be performed instead of one. Alternatively, just one of the filling points could be chosen.

9.8.3 Current part load definition

Currently, the difficulty of defining full and part load is handled by using three different criteria for when the receptacle is full:

1. The bag-full indicator, whether it is mechanic or electronic
2. When air pressure has dropped to 40% of air pressure at empty receptacle
3. Adding 100 g of DMT8 dust for each L of receptacle capacity

Whichever of the criteria is reached first is used as the definition of "full" receptacle for the specific vacuum cleaner being tested (i.e. if the bag full indicator comes on before the receptacle has been filled with 100 g dust/L, this will be the "full" criteria used for that

[191] https://www.dyson.dk/stovsugere.aspx
[192] https://learn.allergyandair.com/bagged-vs-bagless-vacuum-cleaners/
[193] Füllungen jeweils 200 Gramm, danach 400 Gramm DMT8-Staub. https://www.test.de/Staubsauger-im-Test-1838262-1838266/

specific cleaner). The problem with this way of defining full, is that it is easy for manufacturers to misuse the criteria to get better performance ratings. For example, the bag full indicator could be designed to be triggered when the receptacle is only "almost" full, to ensure tests are made with less loading than actually intended. The same is the case for adding dust based on receptacle capacity, since this capacity is declared by the manufacturer, who could again declare a lower volume than the actual volume of the receptacle[194]. The problem with the air pressure measurement is a bit different, but still easily circumvented, for example by designing a product that adjust the motor power to keep a constant air pressure when the receptacle is loaded.

Hence, all the above criteria entail some loopholes that could easily be utilised by manufacturers wanting their products to look better than they are. However, this is the best option that there is for defining part load at the moment.

9.8.4 Part load of bagged vs bagless vacuum cleaners

For most bagged vacuum cleaners it is generally anticipated that a loaded receptacle test will decrease the performance because the bag itself functions as both the dust receptacle and the primary filter, and as it fills the flow is restricted and the pressure drops. In practice the user thus switches from lowest to highest air performance every time the bag is replaced. This effect can be simulated over a single filling of the dust receptacle in the test lab. Hence, somewhere in between the empty and the fully loaded receptacle is the average performance that users experience. While this average differs depending on user behaviour (how often they change bags), testing with some load would be closer to 'real life' than testing with empty receptacle for bagged vacuum cleaners. However, the influence on the results for dust pick-up and energy consumption seem to be small.

Another aspect of receptacle loading that has been mentioned by consumer organisations, and which is especially crucial for bagless products is the effect of repeated loading that is experienced in real life, which result in dust accumulating in filters. Most bagless vacuum cleaners today use the "cyclone" technology to remove the majority of the dust from the airflow inside the vacuum cleaners. The dust ends up in the receptacle and does not lead to a restriction of the flow and hence no drop in pressure will appear. The share of the dust that is not removed from the airflow by the cyclone is instead captured by the secondary filters. The accumulation of dust in these filters over time restricts the airflow and reduces the performances of the vacuum cleaner. In practice the user thus switches from lowest to highest air performance every time the filter is cleaned/replaced. In order to simulate this in a laboratory test, the receptacle would need to be filled repeatedly to simulate use corresponding to half of the time before users change filters, i.e. halfway to the "filter

[194] Results of a Round Robin Test show that measuring the maximum volume entails large uncertainties between labs, i.e. low reproducibility. See section 9.8.5 on available data for part load testing.

change needed" mark or half a years' use (see Figure 40) in order to measure at the average point experienced by consumers. Furthermore such a test approach would require defining when the filter needs to be changed in order to define the halfway point. However, just as for the bagged products, the average condition actually experienced by end-users depends largely on the maintenance behaviour.

Hence, a more consumer relevant test could be achieved relatively simple for bagged vacuum cleaners by testing with partly loaded receptacles, but in order to capture the same consumer relevance for bagless products, they would need to be tested with partially dust loaded filters. This would in turn require multiple dust loadings of the receptacle, making the test substantially more time consuming and thus more expensive. This would lead to different test methods for the two technologies, which would then not be entirely comparable.

In other words the performance of a bagged product oscillates from minimum to maximum every time the bag is replaced, while the performance of a bagless product oscillates from minimum to maximum each time the filter is changed/cleaned. Hence the overall performance experienced by the user (over years of use) might be the same on average, but the frequency of the cycle from maximum to minimum is different and most likely higher for bagged vacuum cleaners (i.e. bag changed more frequently than filter). The fairest would thus be to test all vacuum cleaners at their "average" performance state, whether this point is determined by the loading of receptacle or filters. However, determining this point and adding dust to simulate this point complicates the test procedure significantly and increases uncertainty of the results to an extent that it is not practically possible to determining this "average" point.

Another important factor to consider when choosing how to test vacuum cleaner performance is that the dust receptacle volume of bagged vacuum cleaners is usually larger than that of bagless vacuum cleaners. Generally speaking, bagless cleaners have dust receptacles of around 1/2 to 1/3 the volume of bagged vacuum cleaners of similar size and weight. Hence loading with a fixed amount of dust will not represent the same level of "full" for the two types of vacuum cleaners, and could be especially problematic for cordless and robot vacuum cleaners, due to the even smaller receptacles that these vacuum cleaner types typically have. On the other hand, loading with a specific share (50%) of "full" would lead to bagged products generally being loaded with a larger amount (in absolute value) due to the larger receptacles. Hence, a manufacturer could choose to make the receptacles smaller to obtain better results, at the cost of the consumer, who would then need to empty the receptacle more often.

9.8.5 Available data for part load testing

In order to determine the consequences of part load testing, it is necessary to determine the difference in the obtained test results from testing with empty load and the different part load options, and whether testing with part load changes the results significantly. According to some stakeholders, the empty receptacle performance test is enough to compare different models fairly and that that part load testing will not make a difference in relative ranking of products. Others argue that empty receptacle tests favours bagged products, while loaded receptacle tests (single load) favours bagless products. It still remains unclear which effects the different options will have on test results, and whether it will change which vacuum cleaners can comply with the Ecodesign requirements and if it will change how they are ranked on the energy label. However, any test approach that systematically favours one product type (e.g. bagged or bagless) over the other should be avoided, whether it is the empty receptacle option or any of the part load options.

There is no comprehensive data on how testing with partly loaded receptacle affects the measurement results for vacuum cleaners, however, fragmented data from different sources have been found.

Ongoing Round Robin Test

In order to obtain more comprehensive data, a Round Robin Test (RRT)[195] is being carried out in order to establish the measurement uncertainty, repeatability and reproducibility of testing with a "partly loaded receptacle". The first part of the RTT has been finished. The focus of this part was on volume, namely Maximum Usable Volume (MUV) and conditions for a loaded receptacle as well as the uncertainty of air data for empty receptacle, partly loaded receptacle and with a 200g loaded dust receptacle. The second part aiming to determine reproducibility and expanded uncertainty for performance tests with a partly loaded receptacle has not yet been finalised. The results of this part of the RRT have to be taken into account when defining intervals for label classes and tolerances for market surveillance.

The measurement of MUV is an important parameter for part load testing, since the maximum volume of the vacuum cleaner needs to be determined in order to fill the receptacle with DMT8 dust in the range 100 g/L (criteria 3 for full load). The determination of MUV was made for 3 vacuum cleaners in 6 different labs by filling the vacuum cleaners with moulding granules. The results showed large variance in when the different labs perceived the receptacles to be full, i.e. have reached the MUV point. The results are seen in Table 54. As seen in the table, the vacuum cleaner with the largest variance had an average measured MUV of 1.7 L with an expanded uncertainty of +/- 0.64 L, i.e. around

[195] Seven test labs are involved

38%. The uncertainty of this measurement alone gives a good idea of the difficulties of measuring with part load.

Table 54: Uncertainty of measuring MUV, results from RRT by CENELC TC59X WG6

Calculated parameters	Vac 1	Vac 2	Vac 3
Average MUV, L	1.0	5.2	1.7
Repeatability, standard deviation	0.04	0.22	0.04
Reproducibility, standard deviation	0.10	0.78	0.32
Expanded Uncertainty, L	0.19	1.57	0.64

The other parameter measured in the RRT was the amount of DMT8 dust loaded in the receptacles of the three vacuum cleaners, according to each of the three criteria mentioned in section 9.8.3. Here the uncertainties were not calculated, but Table 55 shows the average amount of dust (in grams) the 6 laboratories added as well as the range of filling and the range in %. The range is the difference between the largest and the lowest amount of dust added in thee labs. For example for the bag full indicator (criteria 1), the difference between the lab that added most and least dust was 150 g, out of an average added 284 g. This indicates are very large uncertainty in measuring dust loading, that is observed for all three criteria.

Table 55: Results on variation in DMT8 filling according to each of the three "bag full" criteria. Range indicating largest minus lowest measured value

Conditions		Vac 1	Vac 2	Vac 3
Condition 1, grams of DMT8 dust (bag full indicator)	Average	284	N.A.	731
	Range	150	N.A.	506
	Range, %	53%	N.A.	69%
Condition 2, grams of DMT8 dust (suction power 40%)	Average	569	1.831	213
	Range	230	401	374
	Range, %	40%	22%	176%
Condition 3, grams of DMT8 dust (filling 100 g/L)	Average	99	518	167
	Range	21	225	78
	Range, %	21%	43%	47%

The third parameter measured was the air data uncertainty with empty, half load and 200g load. The tables below show the average suction power (in watts) for three tested vacuum cleaners tested at 6 different labs, along with the standard deviation (repeatability and reproducibility) and expanded uncertainty.

Table 56 to Table 58 below show the suction power data for the three tested vacuum cleaners at peak air power. Other parameters were measured as well, but not shown here, e.g. vacuum in box and air flow.

The results in the tables show that there is also quite a large uncertainty in the air data measurements, which might not so much be due to uncertainty of the test method itself, but rather carried over from the uncertainties of the loading and MUV procedures. There is, however, no final conclusion of this yet.

Table 56: suction power uncertainty for vacuum cleaner no. 1 (bagless, upright vacuum cleaner)

Vacuum cleaner 1	Empty	½ load	200 g load
Average watts	125.0	124.1	120.5
Repeatability	1.73	1.39	2.27
Reproducibility	7.11	10.5	9.77
Expanded Uncertainty (+/-)	14.22	21.00	19.54

Table 57: suction power uncertainty for vacuum cleaner no. 2 (bagged, cylinder/barrel with large bag)

Vacuum cleaner 2	Empty	½ load	200 g load
Average watts	208.1	192.9	190.7
Repeatability	0.82	5.81	4.12
Reproducibility	8.85	10.50	16.07
Expanded Uncertainty (+/-)	17.69	21.00	32.15

Table 58: suction power uncertainty for vacuum cleaner no. 3 (bagged, cylinder with small bag)

Vacuum cleaner 3	Empty	½ load	200 g load
Average watts	212.1	126.7	120.5
Repeatability	3.47	9.41	4.23
Reproducibility	12.71	15.00	17.31
Expanded Uncertainty (+/-)	25.41	30.00	34.62

The suction power data also shows the performance losses with empty, half load and 200g load. The results in the tables above show that for two of the vacuum cleaners there is only small changes in the loss of suction power, but for one vacuum cleaner (cylinder vacuum cleaner no. 3 with small bag) the loss in suction power was 43%. This illustrates the difference between individual models, but it is not possible to define whether this uncertainty comes from the MUV measurement or is due to the test method itself, or why this specific vacuum cleaners is affected by the loading.

Data from Stiftung Warentest on carpet

Test results from the German consumer test organisation Stiftung Warentest (StiWa) were provided for the standardisation group CENELC TC59X WG6. Please note that data provided here is based on a draft report from the working group, and some members might still have comments before the final version of the report is published.

The data was based on tests of 27 corded bagged vacuum cleaners and 21 corded bagless vacuum cleaners as well as 18 cordless bagless vacuum cleaners. The data shows the difference in dust pick-up and input power for the vacuum cleaners at empty receptacle and at a load of 200 g and 400 g of DMT8 dust (25 g and 50 g for cordless).

It is important to note that the dust loading might also affect other parameters, such as dpu on hard floor, dust re-emission and noise, and therefore it does not provide a complete picture of the effect of dust loading for all parameters. Table 59 and Table 60 show the effect the loading has on the vacuum cleaners' performance in terms of dpu_c and input power.

Table 59: Effect on dust pick-up (carpet) at part load (200g/25g) and full load (400g/50g) compared to empty

Effect on DPU_C	Partly loaded		Fully loaded	
	Average	Max	Average	Max
Bagged	-1.5 %-points	-5.5 %-points	-2.5 %-points	-7.5 %-points
Bagless	-1.5 %-points	-8 %-points	-2.0 %-points	-9 %-points
Cordless	-7 %-points	-	- 25 %-points	-

Table 60: Effect on input power at part load (200g/25g) and full load (400g/50g) compared to empty

Effect on	Partly loaded		Fully loaded	
	Average	Max	Average	Max
Bagged	-6 W	-40 W	-14 W	-50 W
Bagless	-4 W	-33 W	-6W	-39 W

For cordless cleaners there is not data for full load, since too few of the devices could be filled with 50 g dust to give a result. This is due to the small dust receptacle volume of these devices, which was on average 0.7L compared to 2 L for the corded bagless devices. The input power cannot be measured for cordless cleaners because this is measured from the power socket, and the energy for these cleaners comes from the battery.

Overall it can be observed that the average effect on performance of dust loading for bagged and bagless is quite similar. However, the data set also reveals that it is not possible to draw any general conclusions that bagged cleaners respond worse to clogging that bagless cleaners. Cordless cleaners, on the other hand, do not respond well to dust loading and has very large decreases in dust pick-up.

Hence, there are examples of both bagged and bagless cleaners that show considerable drop in both dpu_c and power input because the machines are clogged thus restricting the air flow. At the same time there are also both bagged and bagless cleaners that show no drop in dpu_c or input power.

Overall, it was concluded that the two effects 'lower dpu_c' and 'lower power input' almost cancel each other out in the AE calculation, and the variation in annual energy consumption on carpet due to dust loading is therefore considerable low, and for the majority of the products tested, the change was smaller than the interval of the energy label class corresponding to the now annulled energy label regulation.

It should be noted that the test data from StiWa is solely based on carpet testing and might deviate from the harmonised standard on some points. The impact of dust loading on carpet performance is expected to be lower than on hard floor, because the air flow is already restricted to a certain degree by the carpet itself, when the nozzle 'stick' itself to the carpet due to the under pressure.

A test of a single vacuum cleaner on carpet and hard floor respectively, showed that at an air flow restriction corresponding to 200 g DMT8 dust loading, the airflow on carpet was reduced about 1.5%, while on hard floor it was reduced about 4%[196]. Hence, the dust loading indeed seems to have a larger effect on hard floor performance, but more comprehensive data is needed to say anything more certain.

Other sources

A German television programme from October 2017[197] addresses the issue of performance vs. receptacle load and whether the label value would be the same with both test procedures. The testing was performed by the VDE Testing and Certification Institute in Offenbach[198], who loaded the receptacles by 70% (according to own procedure) and repeated the dust pick-up measurements. The test included only 5 vacuum cleaners, but indicated that the loaded receptacle had only small influence on the declared values, as four of the five vacuum cleaners achieved the same performance class, and the last one just barely missed the declared value. These test results indicted, even though the sample was limited, that part load testing would not give additional information to the consumer.

9.8.6 Possible options for considering part load testing

It is clear that the consequences of testing with partly loaded receptacle is not easy to predict and does not affect all vacuum cleaners (even of the same type) equally. While

[196] This was based on simulations and by measuring air flow with a clamp attached to the hose of the vacuum cleaner restricting the airflow to an extent corresponding to 200 g dust loading.
[197] https://www1.wdr.de/mediathek/video/sendungen/der-haushaltscheck/video-sauber-ohne-aufwand--wie-gut-sind-smarte-helfer-im-haushalt-100.html (link to television programme, in German)
[198] https://www.vde.com/tic-en

there might be a difference between bagged and bagless vacuum cleaners' performance with partly loaded receptacles, the differences between individual products is much larger. However, based on the data shown above and due to the ruling by the General Court on 8 November 2018[199], testing with part load needs to be considered for vacuum cleaners.

To summarize, the following four options have been identified for how to proceed regarding part load:

1. **Status quo:** Continue to test all products as new with empty receptacle.
2. **Part load test option:** Perform measurements with loaded receptacle: use the three loading criteria from the standard EN 60312:2013 (bag full indicator/40% decrease in suction power/100g/L) and measure with whichever is reached first.
3. **Simulated part load testing:** measure the drop in air flow for the specific vacuum cleaner with the decided "filling principle" (from part load option 1-3), then using a clamp on the hose to simulate the air flow restriction during performance testing.
4. **Simulated part load calculation:** calculate a factor for air flow restrictions by measuring with empty and with loaded receptacle, then using this factor in the calculation of dust pick-up to correct for the dust loading effect.
5. **A combination of the above:** perform some of the tests with part load, other with simulated calculations.

As stated above, keeping the status quo would entail continued testing with empty receptacle, but since this has been ruled unsuitable for an energy label, this would be applicable only to an Ecodesign Regulation. Hence, in case of introduction of a new energy label regulation, one of the other options must be followed.

The second option entails part load testing, meaning that the receptacle for the vacuum cleaner is filled with DMT8 dust and then all performance requirements are tested as now, but with the partly loaded receptacle. While this might seem simple to do, a procedure like this is expected to increase test uncertainty greatly, to the extent where it would no longer be possible to differentiate the products into different classes. The reason that the reproducibility and repeatability is reduced drastically is that the way the dust settles inside the receptacle can have a big influence on how the vacuum cleaner performs and this can be changed by simple movements such as shaking or putting down the vacuum cleaner on the floor. The rate at which the dust is loaded (i.e. vacuumed) into the vacuum cleaner also affects how it settles. As shown by the preliminary air data from the ongoing RRT there are very large uncertainties related to just loading the vacuum cleaner similarly

[199] https://curia.europa.eu/jcms/upload/docs/application/pdf/2018-11/cp180168en.pdf

across laboratories. This method is therefore not foreseen to be possible within at least a few years.

The simulated part load testing is a way of testing the vacuum cleaner with a simulated part load, without the uncertainties of how the dust settles. It entails measuring the air flow (and air pressure, suction power etc.) of the vacuum cleaner empty and loaded and then adding a clamp around the vacuum cleaner hose to simulate the drop in air flow caused by the loading and then measuring all the performance parameter with the restricted airflow (i.e. with the clamp on). This would eliminate the uncertainties of the dust settling inside the receptacle, but not of the degree of loading (i.e. determination of MUV), which in itself causes great uncertainty. Furthermore, it requires that the vacuum cleaner has a soft hose that can be closed partly by mounting a clamp (or similar) on it.

The fourth option is to simulate the part load through calculations. This entails deriving a part load factor for each individual product from the airflow with empty loaded receptacle. The air flow should be measured in the BEP (Best Efficiency Point)[200] for each machine with empty receptacle (Q_{empty}) and with partly loaded receptacle ($Q_{part\ load}$) and the following Part Load Factor (PLF) could then be derived:

$$PLF = \frac{Q_{part\ load}}{Q_{empty}}$$

The limit value ≤1 should be assigned to this factor (values above 1 could theoretically be derived due to the uncertainties in the test methods). The PFL should then be multiplied with the dust pick-up performance for both carpet and hard floor, before the AE value is calculated[201]. This would result in lower (or equal) dust pick-up values than measured with empty receptacle. The air flow is, however, only an approximation to the effect of part load on dpu and in reality, the effect might be different for dpu_{hf} and dpu_{c}.

While this option works for dust pick-up and for energy consumption, which can be correlated to the air flow, it does not give the results with part load for dust re-emission and noise.

The final option is thus to use a combination of the above methods to derive the most accurate and precise results. The above PLF could be used for correcting the dust pick-up (measured with empty receptacle) for the effect of loading. The energy consumption could be measured with the clamp (according to option 3 above), while dust re-emission and

[200] The existing test standard measures the airflow (Q) vs the vacuum/pressure (P) from fully open to fully closed during 10-15 measurements, to derive the Q vs P curve. The BEP can then be derived from this curve. This test should be repeated with partly loaded receptacle, and the part load BEP should likewise be derived. The PLF should be calculated from the air flows in BEP (which would also be the point where the difference between the two curves is the largest)
[201] The air flow factor should be multiplied only to the dpu values, not the AE value itself

noise could be measured with the actual, part loaded receptacle in accordance with option 2 above.

Conclusion

Ultimately, when choosing a method for part load testing, a careful balance must be found between the simulation of real life conditions on the one hand and cost/complexity and uncertainty on the other. Seen from a technical point of view, either the uncertainties need to be decreased drastically (if even possible) for the test with part load (as in option 2), or other approximations (as in option 3-5) must be made, in order to have a test that can be used for regulatory purposes. At the moment, not test data is available on noise, dpu_{hf}, or dust re-emission with part load, and it is therefore not possible to point to the best method for approximation for each of these parameters. At the same time the actual test with part load is not possible with the current uncertainties. The conclusion is therefore that more (or just some) tests need to be made for these parameters before deciding upon the methodology.

9.9 Verification tolerances

The verification tolerances stated in the regulations are to be used by market surveillance authorities when testing products to account for uncertainties in the tests and variations in production. The verification tolerances are closely related to the tests and the uncertainties of them, and the standardisation group for household vacuum cleaners (CLC TC59X WG6) has performed Round Robin tests to determine the uncertainty of the test methods. These are shown in Table 61 for each parameter together with the label class width and verification tolerance set out in the regulations. The expanded uncertainties describe the uncertainties of the measuring methods alone, without the variance of the products and are expressed as ± values. The measurements were conducted in accordance with the current harmonised standard EN 60312-1:2017, i.e. without debris pick-up and with the Wilton carpet and crevice test.

Please note that these results and the analysis in regard to label classes is based on the existing test standards, in order to give some context to what the sizes of the uncertainties are.

Table 61: Verification tolerances set out in the regulations and preliminary indication of expanded uncertainties[202]

Test parameter	Verification tolerance	Label class width	Expanded uncertainty (preliminary)
Annual energy consumption, kWh/year	10% of declared value	6 kWh/year	Up to ± 3.5%*
Dust pick-up on carpet, dpu_c	0.03 (3 percentage points)	0.04 (4 percentage points)	Up to ± 0.057 (5.7 percentage points)
Dust pick-up on hard floor, dpu_{hf}	0.03 (3 percentage points)	0.03 (3 percentage points)	Up to ± 0.023 (2.3 percentage points)
Dust re-emission, %	15% of declared value	Variable intervals of 0.06% to 0.40%	Up to ± 0.0012 (0.12 percentage points)
Sound power level, dB	0%	No classes	No measurements
Operational motor life time, Hours	5%	No classes	No measurements
*Expanded uncertainty measured for average power, which is equivalent to AE			

The measured expanded uncertainty shows, as indicated in the sections above, that especially the dust pick-up on carpet is subject to large uncertainties, and the 0.03 tolerances as well as the 0.04 label class width is according to multiple stakeholders not appropriate for the current test standard as it is. According to some test laboratories a difference of up to 3 carpet dust pick-up classes has been found for the same vacuum cleaner in the same laboratory, which is also shown by the expanded uncertainty.

The standardisations groups are currently looking into other carpet types to increase representativeness of the tests, but it is not guaranteed that lower uncertainties can be achieved by changing to another (lower pile) type of carpet. Furthermore, finding a carpet that is both representative and durable enough to not change properties of the course of many test runs requires a lot of test work, and according to the standardisation group a new carpet type is far from being introduced.

In general, it is recommended that actual uncertainties of the test methods are taken into account when setting the verification tolerances. For the carpet test, this means that the current tolerance and label class width is not appropriate with the current test standard, as the uncertainty (+/-) is higher than the label class width. And this is without taking into consideration the variance between products.

One stakeholder recommends removing the carpet cleaning performance entirely from both regulations, however seeing that performance is a relevant parameter for

[202] Source for uncertainty data: standardisation group CLC TC59X WG6 measurements in RRT including 10 laboratories.

consumers[203], less drastic action could be taken to still give consumers an indication of carpet performance. For example, the number of classes could be reduced to 4 instead of 7 (as is possible with the new Energy Labelling Framework Regulation[204]) to increase the class width[205].

Such a solution could also be relevant for the other performance parameters (hard floor *dpu* and dust re-emission). Even though the measurement method has better repeatability, it is questionable whether the label class width may be smaller than the range of expanded uncertainty, which is a problem. Also, the dust re-emission needs to be addressed, since the smallest intervals are smaller than the expanded uncertainty. The standardisation group proposes changing the dust re-emission scale entirely to a logarithmic scale rather than a linear one, similar to the logarithmic scale for HEPA filter declarations.

Only the method for average power (measuring of ASE, i.e. equivalent to annual energy consumption) has an expanded uncertainty well within the tolerance and the label classes and a decrease in the tolerance could even be argued.

New test procedures and uncertainties

In relation to the above it should be noted that it is not yet clear what the uncertainties of the potential new test parameters are (debris pick-up tests and part load testing) and inclusion of any further test parameters and measurement methods would require further testing to determine the uncertainty as well as the repeatability and reproducibility and setting the verification tolerances. The same is the case for introducing more market representative floors in the test standards, for example a new carpet type.

The number of classes and suggestions above are thus related to the now annulled energy label, and not relevant for any possible new energy label, since the test methods must change (at least regarding part load) if such a method is to be introduced. The RRT to obtain the uncertainty with part load is still ongoing, and no results are available yet. The results on air data and MUV (see section 9.8.5) however, indicate that the loading itself entails a large degree of uncertainty. Any new or updated test methods would have to be assessed against the thresholds suggested, since the uncertainties will change when the test method is changed.

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[203] 91% of respondents considered performance (as a whole) to be important/very important in the 2018 APPLiA consumer survey.
[204] Regulation (EU) 2017/1369 setting a Framework for Energy Labelling
[205] According to Article 11, point 11 this is possible under certain circumstances

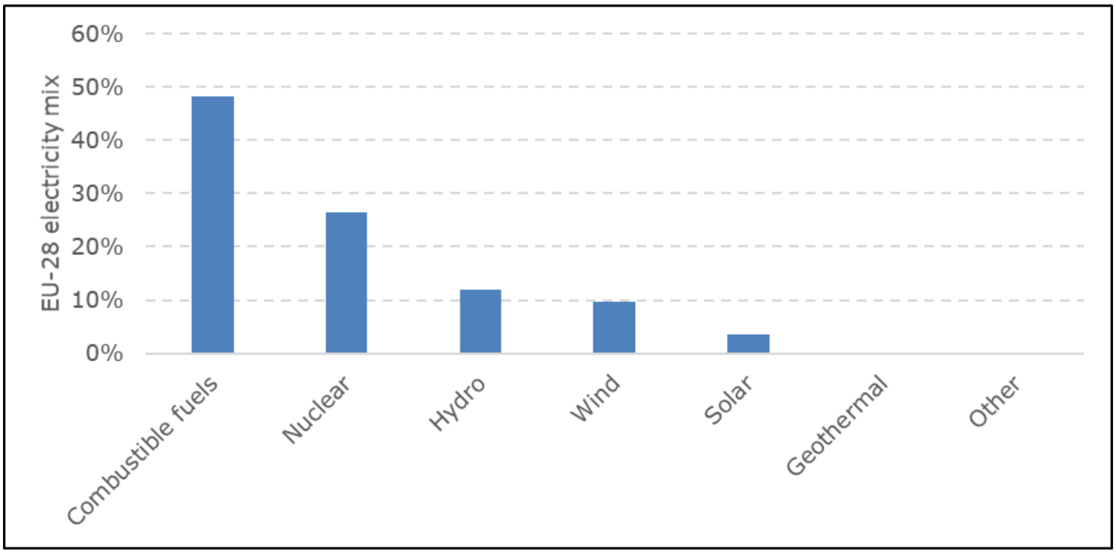
9.10 Local infra-structure

9.10.1 Electricity

The power sector is in a transition state moving from fossil fuels to renewable energy. The origin of the electricity is very important factor to consider both regarding the environmental impact of using vacuum cleaners 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[206]. The overall target within the EU is 20% final energy consumption from renewable sources. To achieve this goal the different EU countries has 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%[207].

The electricity consumption is a major part of the final energy consumption and the electricity mix is highly relevant for vacuum cleaners. The electricity mix in EU in 2015 is shown in Figure 38. Almost half of the electricity consumption still originated from combustible fuels and renewable energy sources only constituted about 25 % of the electricity generation in 2015.

Figure 38: Net electricity generation, EU-28, 2015 (% of total, based on GWh)



The reliability of the electricity grid could be in some degree 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 bi-directional transfer of energy. Due to technological development, the reliability in many EU countries is ensured by the expansion of the electricity grid (transmissions lines across Europe) 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 release a Global Energy

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[206] https://ec.europa.eu/energy/en/topics/renewable-energy

[207] http://ec.europa.eu/eurostat/documents/2995521/7905983/8-14032017-BP-EN.pdf/af8b4671-fb2a-477b-b7cf-d9a28cb8beea

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[208]. The 10 highest scoring countries are presented in Table 62.

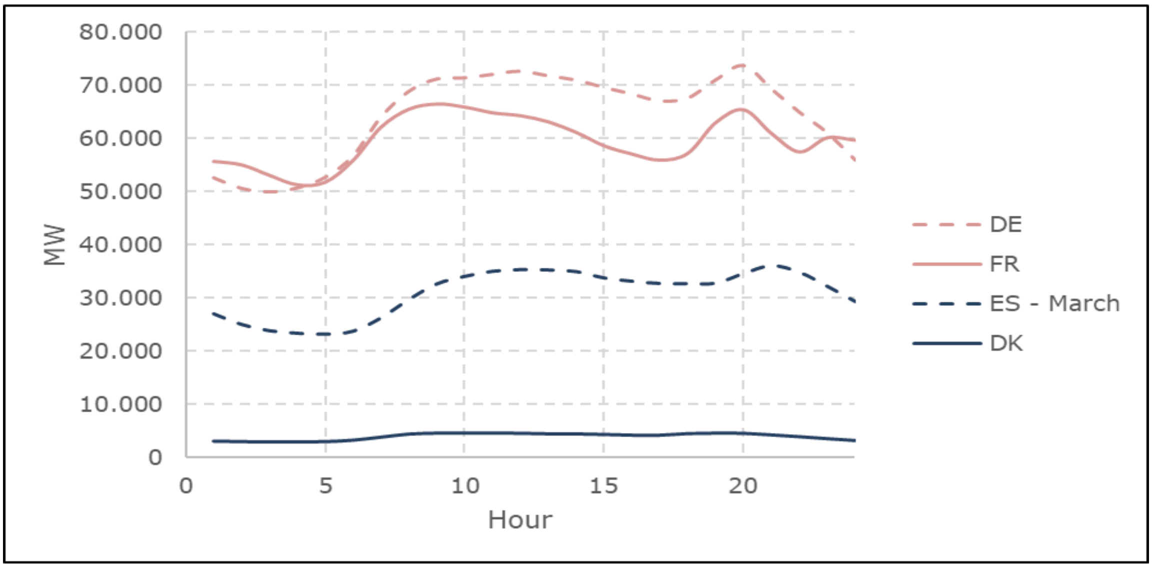
Table 62: Global Energy Architecture Performance Index report – best performing countries

Country	2017 score	Economic growth and development	Environmental sustainability	Energy access and security
Switzerland	0.8	0.74	0.77	0.88
Norway	0.79	0.67	0.75	0.95
Sweden	0.78	0.63	0.8	0.9
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	0.9
Uruguay	0.74	0.69	0.71	0.82

Consumer behaviour regarding vacuum cleaners is only assumed to have a limited effect on the electricity system as people use their vacuum cleaners at the same rate throughout the year at different times. Robotic vacuum cleaners and vacuum cleaners with batteries can in theory add some flexibility to the electricity system as they can be charged whenever there is an excess of renewable energy in the system or the energy consumption is low. The hourly load values for a random Wednesday in March 2015 for selected countries are presented in Figure 39.

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

Figure 39: Hourly load values a random day in March[209]



All the four countries represented in the graph have similar hourly load values with two peaks, one in the morning and one in the evening, even though it is barely visible for Denmark due to the scale of the graph. There are small differences in the timing of the peaks, but the first peak fits well with the start of the workday and the second peak fits with the end of the workday. Between the two peaks there is a falling trend in the energy consumption. The lowest electricity consumption across the different countries are at 5 AM. For most countries, this hourly load curve fits this description the majority of the days. For months and days with a higher or lower consumption, the profile is the same but shifted up or down.

Products that can respond to an external stimulus (smart appliances) can provide balance and flexibility to the energy system, but the impact of vacuum clearness is currently assumed being low. In the future, vacuum cleaners with batteries, and especially robotic vacuum cleaners, which can have flexible cleaning times, can be charged during the night when the energy consumption is low. The potential depends on the future stock and energy consumption of battery driven vacuum cleaners.

9.11 Use of auxiliary products

During the use phase many vacuum cleaners use auxiliary products in the form of bags (only in bagged vacuums) and filters (all types). Changing the bag and filters regularly is important for continued optimal operation of the vacuum cleaner, since excess amounts of dust and particles can otherwise clog the vacuum cleaner, blocking the air flow.

It has not been possible to find any cordless or robot vacuum cleaners using bags, and it is thus assumed that bags are only used in bagged mains-operated vacuum cleaners.

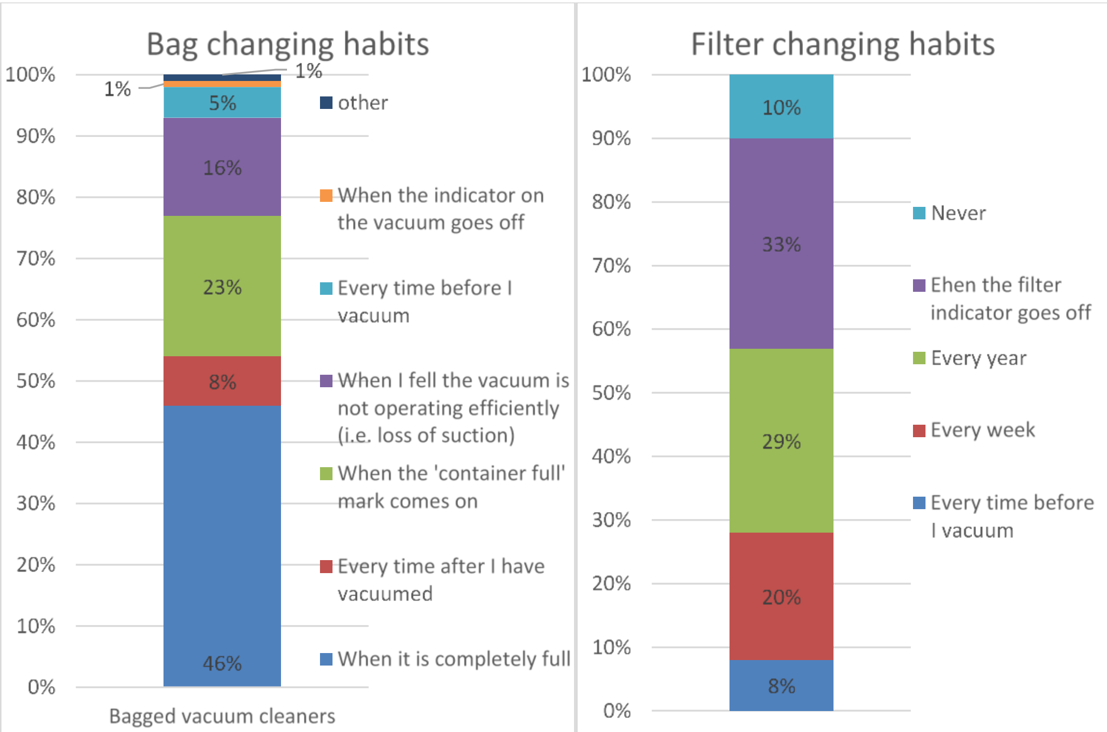
[209] Data provided by ENTSO-E

Previously vacuum cleaner bags were often made of paper, but today the far majority is so-called fleece bags made of poly-propylene material.

Most bagged vacuum cleaners are equipped with an indicator, showing the user when the bag should be changed, however the frequency is highly dependent on the type and amount of dirt that is collected as well as user preferences. In the preparatory study, an amount of 10 bags per year was proposed based on the number of bags offered by manufacturers in free bag schemes[210], however also 6 and 5 bags per year have been suggested[211], and in this study 6 bags per year on average is therefore used.

According to the APPLiA consumer survey results (shown in Figure 40), 46% of respondents with a bagged vacuum cleaner empties the bag only when it is completely full, while 24% change it when the bag full indicator shows it is necessary, and 13% changes it after each time either before or after vacuuming. 16% change the bag only when they can fell that the vacuum cleaner loses suction power, which can, however, also have to do with the need for changing the filter.

Figure 40: Consumer habits regarding changing bags and filter of their main vacuum cleaner, according to the APPLiA consumer survey



[210] Preparatory Studies for Eco-Design Requirements of EuPs (II), Lot 17 Vacuum cleaners, TREN/D3/390-2006, Final Report February 2009, carried out by AEA Energy & Environment, Intertek, and Consumer Research Associates between November 2007 and January 2009. https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/vacuum-cleaners/vacuum-cleaners-ecodesign-study-final-report-eup-lot-17-final-report.pdf page 32, according to Electrolux website accessed 1 May 2008 http://www.electrolux.co.uk/Files/United_Kingdom_English/Files/Electrolux07_SpecBrochure_8pp.pdf
Miele UK website accessed 1 May 2008
http://www.miele.co.uk/Resources/CustomerSupport/GuaranteesWarranties/Vacuum_Guarantee.pdf
[211] Abele et al. (2005) and Kemna et al. (2005) According to JRC report,

Filters in vacuum cleaners are used to prevent dust and particles reaching the motor and returning to the room through the exhaust air. Some vacuum cleaners might have both a primary and a secondary filter, but today fleece bags often function as filter as well, rendering the secondary filter redundant. Filters can be made from different materials such as cloth, foam, pleated paper, and fleece or other synthetic materials. Some vacuum cleaners are fitted with HEPA filters (High Efficiency Particulate Air), which let only through 5 (HEPA 14) to 50 (HEPA 13) particles per litre of air[212], for particles sizes down to 0.3 microns. HEPA filters are especially relevant for people suffering from asthma or allergies, as they remove the allergens and particulates that triggers these conditions. Of course, filters are only efficient if the vacuum cleaner is air-tight, not letting air out from the appliance before the airflow reaches the filter. As in the preparatory study, it is assumed that filters are replaced once a year. However, some models come with washable filters, which are assumed not to be replaced unless they are damaged. In that case it would count as a repair, and not as maintenance.

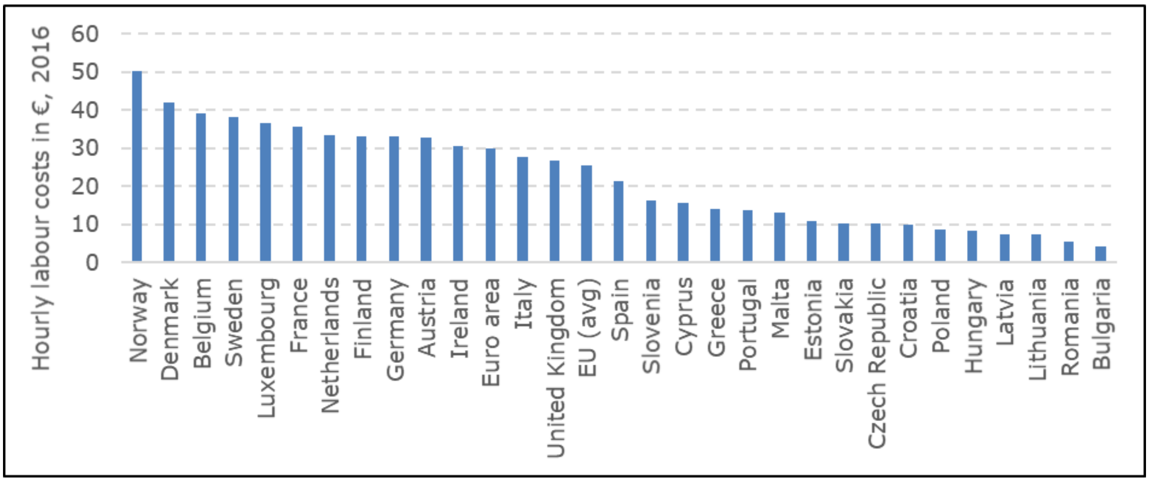
9.12 Repair practice

Repair is an important factor for increasing the product lifetime and depending on the type of repair, it can be done by either end-users or professionals. Repairs such as exchanging a hose or suction head can be done by the end-users, while problems with e.g. the motor or electrical components is done by professionals for safety reasons[213]. If the repair is done by professionals, the repair cost is dependent on the labour cost, which varies greatly across Europe as seen in Figure 41. Based on labour costs alone, the amount of repair by professionals is expected to be low in northern countries and higher in southern and eastern countries. Another important factor for whether the end-users chooses to repair the vacuum cleaner is its age. In the end of the lifetime, it might be perceived as too expensive to repair compared to the cost and ease of buying a new model.

[212] https://consumer.nilfisk.dk/da/cases/About%20Vacuum%20Cleaners/Pages/Nilfisk-stovsuger-filtrering.aspx and https://www.whiteaway.com/hverdagen/post/derfor-skal-du-overveje-en-stovsuger-med-hepa-filter/

[213] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC96942/lb-na-27512-en-n_.pdf

Figure 41: Hourly labour cost in €, 2016 for European countries



The most common failures of both upright vacuum cleaners and cylinder vacuum cleaners are related to suction and blocked filters as shown in Table 63[214]. These problems can be interconnected and are also related to the lack of maintenance (such as changing bags and filters), and might in some cases be possible to solve by repairing or exchanging faulty parts. At some point the motor is also likely to fail, since universal motors are used in many vacuum cleaners[215]. However, most motors are likely to function for at least 600 hours regardless of the purchase price of the vacuum cleaner[216], and at least 500 hours is required by the current Ecodesign Regulation.

Table 63: Faults experienced with upright vacuum cleaners and cylinder vacuum cleaners[217]

Upright vacuum cleaners, Faults experienced	%		Cylinder vacuum cleaners, Faults experienced	%
Suction deteriorated	24.3%		Suction deteriorated	19.5%
Blocked filters	21.7%		Blocked filters	17.8%
Belt broken (drive-belt rotating brush)	16.9%		Other	15.7%
Split hose	13.7%		Broken accessories	12.2%
Motor broken	13.4%		Brush not working properly	10.8%
Brush not working properly	12.0%		Casing cracked/chipped/broken	10.1%
No suction	10.0%		Overheating	8.7%
Brush not working at all	9.4%		Split hose	7.7%
Casing cracked/chipped/broken	8.9%		Motor broken	6.6%
Other	8.6%		Power cutting out	5.2%
Broken accessories	8.3%		Power cable faulty	5.2%
Overheating	6.3%		No suction	5.2%
Power cable faulty	5.1%		Brush not working at all	4.9%

[214] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC96942/lb-na-27512-en-n_.pdf
[215] Special review study on durability tests According to Article 7(2) of Commission Regulation (EU) No 666/2013 with regard to Ecodesign requirements for vacuum cleaners FINAL REPORT Prepared by VHK for the European Commission 23 June 2016. http://www.ia-vc-art7.eu/downloads/FINAL%20REPORT%20VC%20Durability%20Test%2020160623.pdf
[216] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC96942/lb-na-27512-en-n_.pdf
[217] https://www.vhk.nl/downloads/Reports/2016/VHK%20546%20FINAL%20REPORT%20VC%20Durability%20Test%2020160623.pdf

Wheels/castors broken	4.9%		Handle broken	3.8%
Handle broken	4.6%		Power not working at all	3.8%
Power not working at all	3.7%		Controls broken	2.4%
Power cutting out	3.1%		Wheels/castors broken	2.4%
Handle loose	2.3%		Belt broken (drive-belt rotating brush)	2.1%
Controls broken	0.60%		Handle loose	1.7%

For robot vacuum cleaners, less data is available as the technology is both new and in a transition state with frequent improvements. Based on troubleshooting guides available on the internet possible problems with robotic vacuum cleaners are related to:

- The belts and drive systems can break or be worn so the performance of the vacuum cleaner is reduced. These parts can often be replaced
- The battery performance can be reduced
- The electronics and advanced controls can be faulty after a period of time as data interrupting the function can be stored on the memory board. Sometimes a reset can fix this problem
- The motor can be faulty or damaged and has to be replaced.

To avoid break downs, it is important to have proper maintenance of the vacuum cleaner and simple maintenance instructions are often provided in the user manual. In some cases, the user guide is also available online with additional drawings and exploded views[218].

Spare parts are widely available on the internet from third party dealers[219] and the manufacturers[220]. However, a stakeholder has mentioned that even though spare parts may seem available on the internet, it may not always be the case for independent repair centres, or it is not always possible for the consumer to receive the actual spare parts within a reasonable time and cost.

A manufacturer[221] has stated that critical spare parts (parts important for the vacuum cleaner to function) are available as long as 10 years after the last product is purchased and minimum 10 years after the production of the last product. This is not considered to be the standard availability of spare parts from manufacturers, as other manufacturers have different spare part policies.

It is not known how often repair actions are carried out or which types of repair are conducted. Consequently, it is not possible to estimate additional material for repair. The standard value in the EcoReport tool of 1 % of the materials are used for the amount of

[218] https://www.dysonspares.ie/index.php?route=information/information&information_id=70
[219] https://www.partswarehouse.com/default.asp
[220] https://consumer.nilfisk.com/en/products/Pages/product.aspx?fid=16718
[221] BSH Hausgeräte GmbH

spare parts. 1 % of the materials corresponds to 70 grams for a vacuum cleaner of 7 kilos which seems reasonable as not all consumers are expected to buy spare parts.

9.13 End of life behaviour

The material consumption and resource impact from products is closely related to the end of life processing. Vacuum cleaners are collected at end of life and send to a facility for reprocessing. Illegal trade and sales of scrap challenge the collection rate for some product categories. The statistics from Eurostat shows products put on the market and waste collected for small household appliances. This statistic does not refine the actual number of vacuum cleaners collected so the actual collection rate can be difficult to quantify.

From 2019 onwards, the minimum collection rate to be achieved annually shall be 65% of the average weight of EEE (Electric and Electronic Equipment) placed on the market in the three preceding years in the Member State concerned, or alternatively 85% of WEEE generated on the territory of that Member State[222]. In Annex D the collection rate is calculated for small household appliances based on the average weight of EEE placed on the market in the three preceding years in the Member State concerned[223]. The calculated average collection rate for the EU was below 40% in 2014. The collection rate does also cover other appliances, but it is assumed that the rates are representative for vacuum cleaners. The collection rate should be improved to 65% in 2019. The low collection rate of vacuum cleaners cannot be addressed in the Ecodesign Regulation but should be addressed by each EU country which should decide how to fulfil their obligation regarding the WEEE Directive.

9.13.1 Estimated second-hand use

The estimated second-hand market is based on a survey on Ebay and other similar homepages. Overall vacuum cleaners are available on the second-hand market as used consumer products and as refurbished products[224]. Refurbished products are described in the medical device regulation as[225]: *'fully refurbishing', for the purposes of the definition of manufacturer, means the complete rebuilding of a device already placed on the market or put into service, or the making of a new device from used devices, to bring it into conformity with this Regulation, combined with the assignment of a new lifetime to the refurbished device.*

Vacuum cleaners are not expected to be fully refurbished as described in the medical device regulation, but only partly, so the vacuum cleaners are repaired, reconditioned and tested

222 http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waselee&lang=en
223 http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waselee&lang=en
224 http://www.ebay.co.uk/bhp/manufacturer-refurbished-vacuum
225 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L:2017:117:FULL&from=EN

before they are sold again by the manufacturers or specialised repair shops. The market of refurbished consumer vacuum cleaners is limited and have no impact on the later tasks.

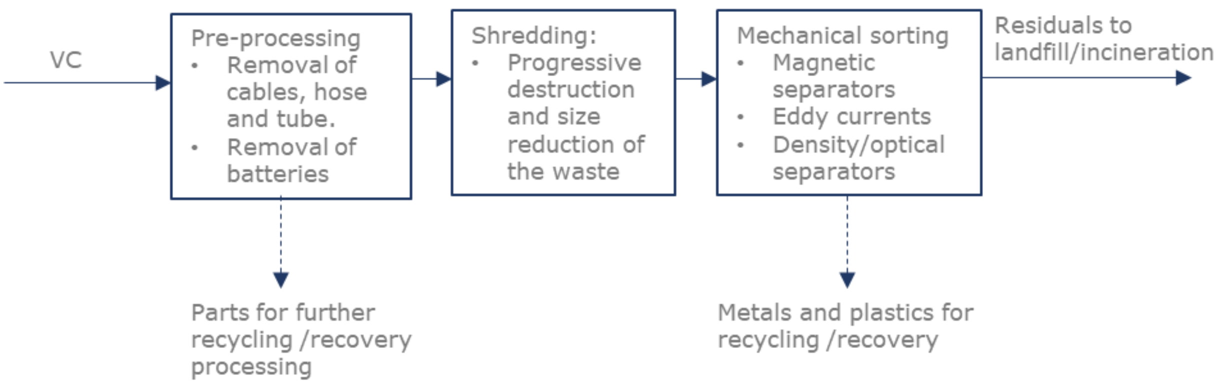
The regular second-hand market, where consumers sell their old appliances to other consumers, is considerably larger and consists of a large variety of products from almost new products to products that have been in operation for many years, and premium products to low budget products.

On the internet buying guides are also available[226], pinpointing pros and cons of second-hand vacuum cleaners. Though the market exists, the impact of the second-hand market is expected to be limited as the functional operation of vacuum cleaners are expected to be unchanged. Therefore, the second-hand market is not included in later tasks.

9.13.2 Recyclability of vacuum cleaners

After collection the electronic scrap is treated at specialised facilities which mechanically process the appliances. The expected waste process flow for vacuum cleaners are visualised in Figure 42. Note that vacuum cleaners are mixed and shredded with other types of products at end of life, and the following only relates to the handling of vacuum cleaners.

Figure 42: Expected reprocessing of vacuum cleaners at End of life



The pre-processing is the first step in the recycling process of vacuum cleaners. This first step often consists of manual removing of targeted components and/or materials for further treatment. The pre-processing is very important in connection with an effective recycling process by reducing the risk of contamination, quickly recover selected valuable materials for further reprocessing and allow compliances with current directive on hazardous substances[227] and waste[228] and prevent damage to the facility in the following steps. According to the WEEE Directive components such as electronic components (e.g.

[226] https://learn.allergyandair.com/buying-a-used-vacuum-cleaner/
[227] http://ec.europa.eu/environment/waste/rohs_eee/index_en.htm
[228] http://ec.europa.eu/environment/waste/weee/index_en.htm

printed circuit boards, capacitors, switches, thermostats, liquid crystal displays) and batteries are additionally dismantled when present (see section below).

Next is a series of shredders, which reduces the vacuum cleaners to smaller pieces, so the different materials can be sorted. The dust is removed and captured by cyclones. When the equipment is shredded into smaller pieces (approximately 1 cm to 10 cm) different technologies handles the sorting. These technologies are often[229]:

- Magnetic separation removing ferrous metals
- Eddy current separators removing non-ferrous metals such as copper, aluminium, and zinc
- Density separators: Different types of plastic.

The effectiveness or recycling rate of the shredder (the share of recovered, recycled, and reused materials) in this study is based on the EcoReport tool[230] but updated regarding plastic[231]. The values used in the current study is presented in Table 64.

Table 64: Re-use, recycling, heat recovery, incineration and landfill rates assumed for the End of life handling of vacuum cleaners

	Fraction to re-use, (%)	Fraction to (materials) recycling, (%)	Fraction to (heat) recovery (%)	Fraction to non-recoverable incineration,(%)	Fraction to landfill/ missing/ fugitive (%)
Bulk Plastics, TecPlastics*	1%	29%	40%	0%	31%
Ferro, Non-ferro, Coating	1%	94%	0%	0%	5%
Electronics	1%	50%	0%	30%	19%
Misc.	1%	64%	1%	5%	29%
Auxiliaries (Bags)*	0%	0%	50%	25%	25%

**Adjusted values compared to the EcoReport tool*[232]

With these numbers the total recycling rate (including incineration) will be above 70 % for products that are shredded. The numbers also show high recycling rates for metals and lower rates for plastic. Traditionally it is also easier for recycling facilities to recover metals than plastic. Plastic are often mixed with other types of plastics which challenge the quality of the recycled plastic. Often recycled plastic is downgraded if it is not properly separated.

229 http://www.sciencedirect.com/science/article/pii/B9780128033630000031
230 http://ec.europa.eu/growth/industry/sustainability/ecodesign_da
231 Plastic Europe, Available at: http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf
232 Plastic Europe, Available at: http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf.

10. Task 4: Technical analysis

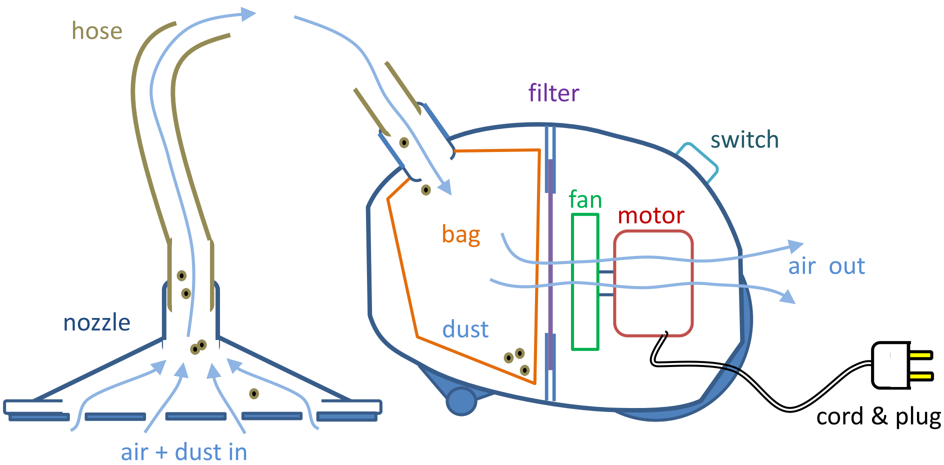
Task 4 contains the technical description of key components in vacuum cleaners as well as descriptions of the different product types (working towards base case definitions) including average performance and energy consumption levels. Furthermore, it contains a section about material and resource consumption in different types of vacuum cleaners including Bills-of-Materials (BOMs) and End of life (EoL).

Combined with the outcomes of task 1-3, task 4 forms the basis for further analyses in the following tasks, including environmental and economic impacts (task 5) as well as improvement options (task 6).

10.1 Components

In Task 1 the various vacuum cleaner categories - cylinder, upright, cordless and robot - were introduced. This section will start with a description of the most popular type in Europe, the mains-operated cylinder vacuum cleaner, and will then add further information for the other types. Figure 43 shows the main components in a mains-operated vacuum cleaner: motor, fan, receptacle, filter, hose and nozzle, which will be discussed hereafter.

Figure 43: Key components in a mains-operated vacuum cleaner

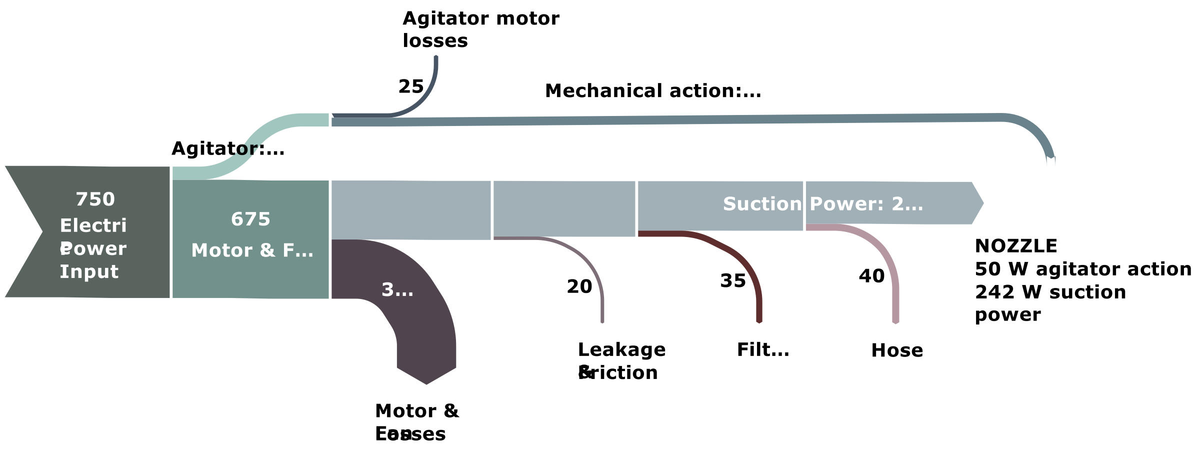


The overall energy flows related to these components are given in the Sankey-diagram in Figure 44. It relates to a well-designed 750 W cylinder vacuum cleaner as described in the 2007 preparatory study. It uses an agitator (active nozzle) because, according to the preparatory study[233], it is the most effective and efficient way to clean carpets. For hard floor cleaning it is not a necessary feature and a passive nozzle is sufficient[234].

[233] AEA Energy & Environment, Final Report EuP (II) Lot 17 Vacuum Cleaners, Final Report, February 2009

[234] To complete the energy effort, also the manual operation of the product and/or the nozzle should be included. At test-conditions this means a manual power of 20 N to move the nozzle at a speed of 0.5 m/s. This comes down to human power of 10W to be added.

Figure 44: Sankey-diagram of energy flows in a mains-operated cylinder vacuum cleaner (source: VHK 2017 graph on the basis of AEA Ricardo 2009 data)



The suction power of 242 W relates to an empty bag and filter and might drop to 227 W (6.4%) when the bag is full. The minimum pressure drop should be in the range of 18-25 kPa and flow should be at least 8.5 L/s when the bag is full and probably 15-20 L/s in best conditions. The 50% efficiency of fan plus motor is very ambitious. Still, even in this ambitious setting motor and fan losses constitute by far the highest losses (338 W), corresponding to almost three-quarters of losses. After that, the corrugated primary hose of a cylinder type (as opposed to the straight tube of other types) cause considerable aerodynamic friction losses (40 W) as well as the bag and filter (35 W). The motor losses of the agitator are also significant (25 W).

10.1.1 Motor

In only a few years, the Ecodesign Regulation and the annulled Energy Labelling Regulation have revolutionised the vacuum cleaner market. European vacuum cleaner suppliers have switched in their top-models from a motor-type with arguably the worst efficiency (30%) to a motor with the best efficiency around (80% or more). In these models the so-called Universal AC/DC motors with carbon brushes was replaced by brushless electronically commutating (EC) motors, with or without permanent magnets[235]. Motors in the range of 2000 W or more are now replaced with motors in the range of 600-800 W (electric input power), without any loss in cleaning performance. The technical product life of these motors, which are also quieter, is at least 5 times better than what was the average before the regulations.

[235] PM stands for Permanent Magnet motor, which also the most common form of Brushless DC Motor (BLDC). SRM stands for Switched Reluctance Motor, a motor that does not require permanent magnets and thus also not contain Neodymium. Neodymium is currently on the EU's Critical Raw Material (CRM) list.

EC-motors, like Brushless DC (BLDC) or Switched Reluctance Motors (SRM), are the most efficient electric motors on the market, comparable to IE4 or IE5 efficiency grades as defined in the ecodesign electric motor Regulation[236]. In laboratory circumstances, efficiencies as high as 96% can be reached. In practice, efficiency also depends on the load and probably the very best BLDCs for vacuum cleaners may achieve 85% over the (variable torque) operating range.

The technical motor life, mainly determined by the length of the carbon brushes for universal motors[237] and for universal motors in the order of 600 hours, will for BLDC motors be 3000-4000 hours or more at empty receptacle[238]. At 50 hours usage per year, which is currently taken as average vacuum cleaner usage in the regulation, this implies a technical product life of 60 to 80 years. This is probably at least twice as long as the economic life of a standard product, i.e. the time where 99% of consumers would discard the product for another reason (breaking of other vacuum cleaner parts, consumers attracted by new features, etc.). The increased product-life also changes the perspective on the need for reparability of the motor. Of course, if robot vacuum-cleaners come into scope that could possibly vacuum your house e.g. 4 hours per week (100 hours per year), then a longer motor lifetime would be required for them. Note that robot suction motors are smaller than the regular VC suction, comparable to blower motors in e.g. large computer fans. They will be of the BLDC-type.

Last but not least, a positive effect of a more efficient motor, especially a PM motor, is that it also produces less noise (sound power, expressed in dB(A)) than the universal motor with its mechanical commutators (carbon brushes).

As was assessed in the 2016 Special Review Study, this comes at a price: A universal AC/DC vacuum cleaner motor can be found for as little as 4 € per unit. In January 2016, A BLDC motor with inverter for vacuum cleaner-applications cost around 33 €. Currently, over 2 years later (Sept. 2017), BLDC prices appear to have been decreased by 20%. Still, in consumer prices and with the factor 3.77 mark-up[239], this means that top-range vacuum cleaners may cost at least 100 € more than with the universal motor[240].

10.1.2 Fan

The typical household vacuum cleaner uses a centrifugal fan to create ‘suction power’ (a negative pressure difference). In principle, as mentioned in the 2007 preparatory vacuum cleaner study, there are other possibilities to create suction power, including reciprocating

[236] *OJ L 191, 23.7.2009, p. 26–34,* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009R0640
[237] Other aspects such as overheating, or just poor build quality can also influence the technical motor life
[238] Note that 3000h is not a proposal for a minimum lifetime requirement of a standard product, because testing costs and a fast reaction time for market surveillance authorities also play an important role.
[239] Based on difference in manufacturer selling price and consumer purchase price from PRODCOM and GfK
[240] Based on costs from Belgium

solutions with pistons, scroll-geometry, screws, etc. and including turbo-compressor type solutions. In a laboratory and using clean air, some of these solutions can even be more efficient than the current vacuum cleaner centrifugal fan[241]. However, to reach and maintain these efficiencies in a 'dusty' vacuum cleaner environment requires precision geometry and very narrow tolerances, typically achieved with machined steel parts and thus at prohibitive prices for a mass-produced consumer product.

Hence, the vacuum cleaner uses a backward curved centrifugal fan, i.e. where the air enters at the centre in the front and is then spun sideways using centrifugal force. A centrifugal fan is defined as 'backward-curved' if centrifugal blade angle $\beta \leq -1°$, 'radial' if $-1° < \beta < 1°$ and 'forward-curved' if $\beta \geq 1°$ (see Figure 45).

Of all the fan-types (axial, mixed flow, centrifugal) and sub-types (forward curved, radial, backward curved, backward inclined), the backward curved (BC) centrifugal fan is the most efficient for this and many other applications. In the latest draft Ecodesign proposal for industrial fans, intended to replace Commission Regulation (EU) 327/2011 ('fan regulation') in one or two years, the proposed total efficiency limit for fans with electric power input Pe<10 kW is η_{min} = 0.0456 LN(Pe) – 0.105 + N, where N=0.67 for BC centrifugal fans in category B and D.

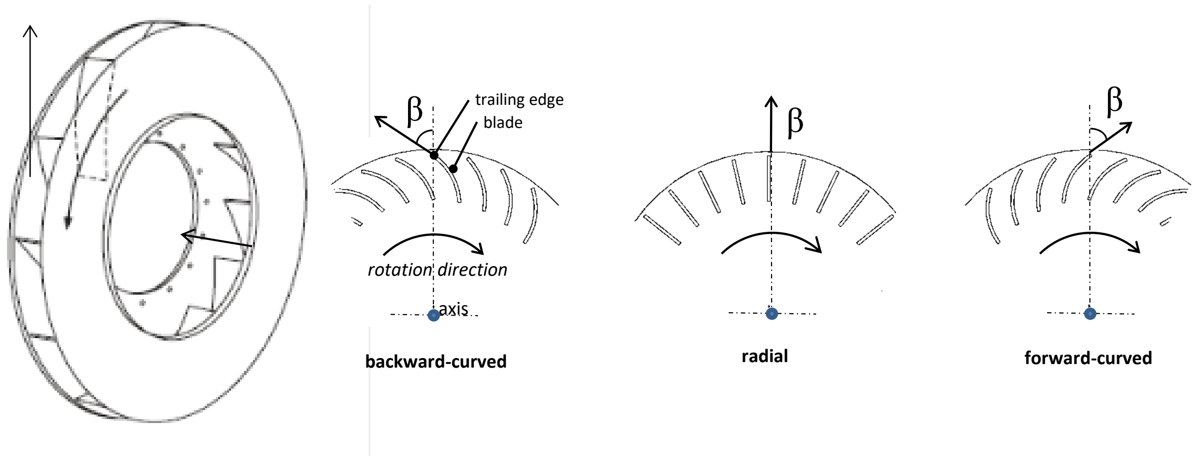
This means e.g. a minimum total efficiency of 55% for a fan with electric power input Pe=0.7 kW. This efficiency goes up for bigger fans up to 10 kW, which has 67% efficiency.

However, the typical vacuum cleaner fan is no ordinary fan: it operates at a flow rate *qv* in the range of 8-40 dm³/s (3-15 m³/h) and a pressure difference *dP* as high as 10-20 kPa (10,000-20,000 Pa). For comparison, the flow is 10 times lower and the pressure difference is 30-50 times more than in a 'normal' fan for a residential ventilation unit.

It is referred to as a High Pressure Low Volume (HPLV) 'fan' or 'blower'. The efficiency of this types is lower than that of a normal centrifugal backwards curved fan, because the slim design (relatively high diameter D, compared to thickness between front and back-plate) causes high friction losses and the gas (air) is starting to operate in the compressible range.

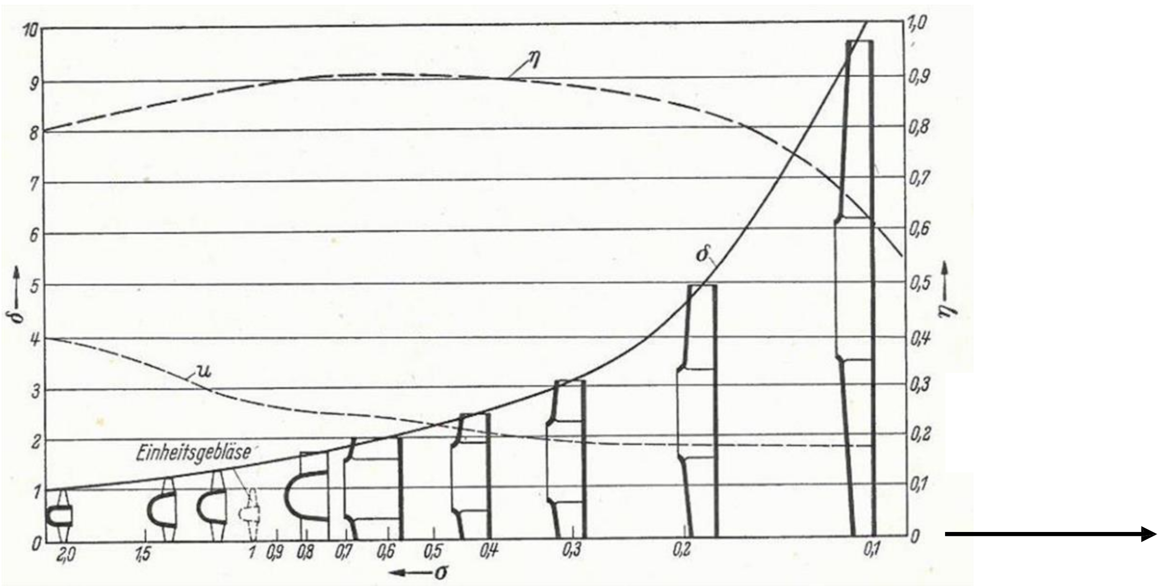
[241] This applies to some of the reciprocating solutions. Small turbo-compressors at the operating range of vacuum cleaners are less efficient than the VC fan.

Figure 45: Backwards curved centrifugal fan (left) and fan definitions using the centrifugal



The empirical Cordier diagram in Figure 46 gives a good illustration of the interrelation between specific speed σ, diameter δ (compared to a unitary reference fan) and efficiency η. It indicates that fans with small σ (<< 0.3) generally have a significantly lower efficiency than centrifugal fans with σ= 0.3...0.6[242].

Figure 46: Cordier diagram (Eurovent/EVIA 2016 citing Eck 2003)



A HPLV-fan is defined in the draft proposal for an Ecodesign Fan Regulation[243] as a fan with a specific speed σ_{bep} <0.12. The specific speed σ_{bep} of centrifugal fans with electrical input power input P_e < 10 kW is defined as:

[242] Note that the Cordier diagram is based on empirical tests of fan designs in the 1950s. Although it is a good illustration of the principle in this case, it is no longer considered 100% state-of-the-art for all aspects.
[243] *OJ L 90, 6.4.2011, p. 8–21,* Commission Regulation (EU) No 327/2011, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32011R0327

$$\sigma_{bep} = n \cdot \frac{2 \cdot \sqrt{\pi \cdot q_{v.bep}}}{\left(2 \cdot \frac{p_{f.bep}}{\rho}\right)^{0.75}}$$

where

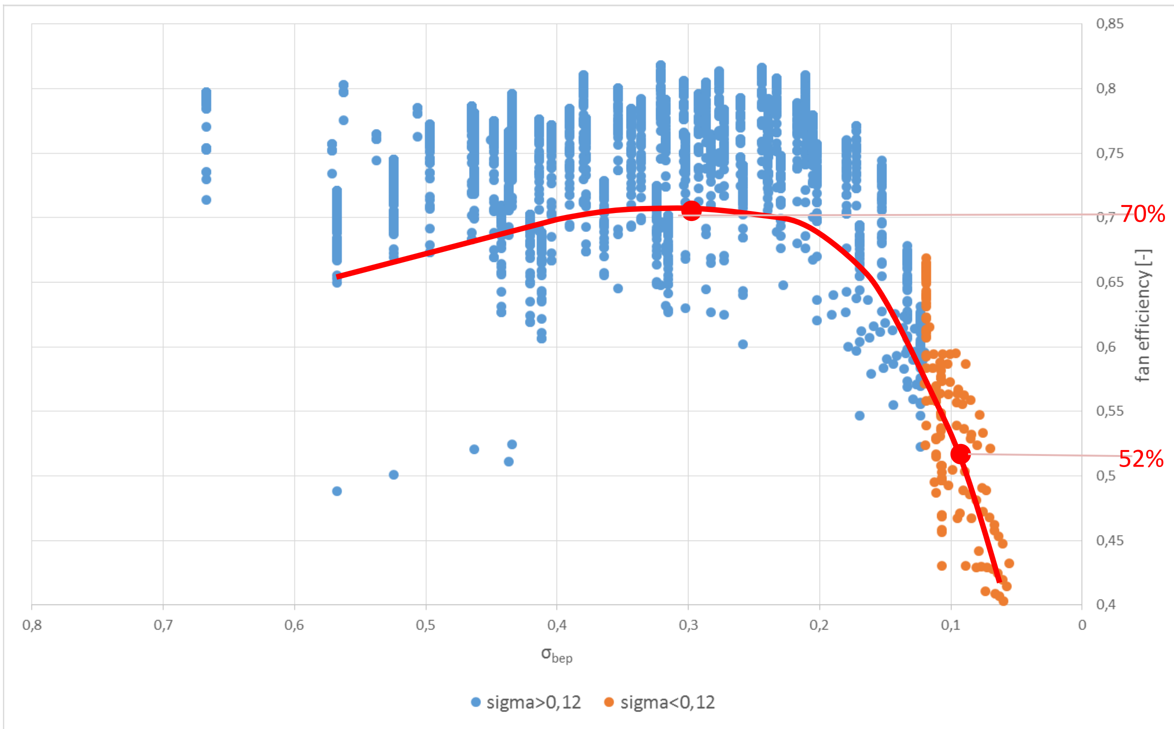
- σ_{bep} is specific speed (dimensionless);
- n is fan speed in revolutions per second (rps);
- ρ is air density 1.2 kg/m³;
- $q_{v,bep}$ is volume flow rate at best efficiency point bep, in m³/s;
- $p_{f,bep}$ is total fan pressure at bep, in Pa;
- π is the number pi (3.14…)

Figure 47 gives an overview of total fan efficiency, i.e. based on the total pressure difference, for a centrifugal backwards curved fan as a function of the specific speed σ_{bep} ('sigma' in the figure) for industrial fans on the market in 2016.

Interpretation of this diagram requires caution. The best efficiency values of ~82%, at $0.2<\sigma_{bep}<0.45$, apply to large fans probably in the range of 10 kW or more. As mentioned before, and is clear also from proposed limit values, the best efficiency values for the current vacuum cleaner fans (0.7 kW) are some 12%-points lower, i.e. at around 70%. Likewise, for efficiencies at $\sigma_{bep}<0.12$ one can assume efficiencies 10-12% lower, e.g. 52% instead of 60% at $\sigma_{bep}=0.1$.

Based on this, a 0.7 kW vacuum cleaner fan, a reference line has been drawn in the diagram delivered by Eurovent/EVIA. It shows that the best vacuum cleaner fan efficiency of 70% is reached at a specific speed σ_{bep} between 0.22 and 0.4 (0.3 in the figure). At lower specific speed the maximum efficiency rapidly declines and is only 52% at $\sigma_{bep}=0.1$.

Figure 47: Fan efficiency as a function of specific speed for industrial centrifugal fans in the range up to 10 kW (source: Eurovent, EVIA. pers. comm.)



For a traditional vacuum cleaner fan, from before 2014, with the following characteristics:

- a speed *n* of 20,000 rpm (333 rps), which is fast for a fan with a traditional universal motor,
- a total fan pressure of 20,000 Pa and
- a volume flow rate of 40 litres/s (0.04 m³)

the specific σ_{bep} is close to 0.1 and thus vacuum cleaner fan efficiency is 52%.

With the new EC-motors a fan speed *n* of 80,000 rpm (1332 rps) was reached in 2016. Using the given formula, this means a specific speed σ_{bep} =0.38. As the graph in Figure 47 indicates, this means the best vacuum cleaner fan efficiency is 70%. In other words, the BLDC or SRM motor with its possibility to realise extremely high rotational speed, also improves the strict fan performance with some 30-35%. In the latest Dyson V10 model, released in 2018, a fan speed of 125,000 rpm (2083 rps) is reported. The fan geometry of that model is compact and closer to that of a turbo-compressor than a traditional fan. The fan-axis is made of a ceramic material rather than steel.

Last but not least, the new motor types are necessarily equipped with an inverter, i.e. some powerful electronics that allow not only to efficiently regulate the motor speed but also relatively easy and at low cost can accommodate sensors and other control options. For instance, some manufacturers have introduced a sensor to keep the suction power constant, independently of how full the receptacle is.

Furthermore, as with the motor efficiency, it must be taken into account that the energy efficiency of the fan/drive/motor combination depends on the load and depends on how the designer chooses the best efficiency point.

Traditionally in engineering the best efficiency point (BEP) of a fan-motor combination is at around two-thirds to 80% of the maximum load. But the design-engineer may also choose a different optimum as long as he/she stays in the stable operating range (without severe stall, surge phenomena).

In that context the so-called 'affinity laws' are relevant, which say that at constant fan diameter, the flow varies linearly with speed (rpm), the pressure varies quadratic with speed and the power varies with the cube of speed. For instance, at 80% of the nominal speed, the pressure drops to 64% of nominal pressure but the power drops to 51% of the original power. Possibly, depending on the total of technical parameters, this might be an optimal control setting for a particular load situation.

Note that the above discussion of fan design phenomena is only illustrative and aims to give a plausible explanation of certain design phenomena. The actual optimisation of fan aerodynamics, control options, etc. is very complex and requires not only sophisticated computer modelling but also extensive empirical testing.

Costs play an important role. For instance, only the high-end models feature ultra-high rotational speed values that allow to reach 70% efficiency. As will be elaborated in Task 6, the costs that are associated with these design improvements are usually far beyond the Least Life Cycle Costs point. For more economical models, even those using the low-end versions of BLDC and SRM, fan/drive/motor efficiency values of 50% are more representative of the Base Case.

10.1.3 Receptacle

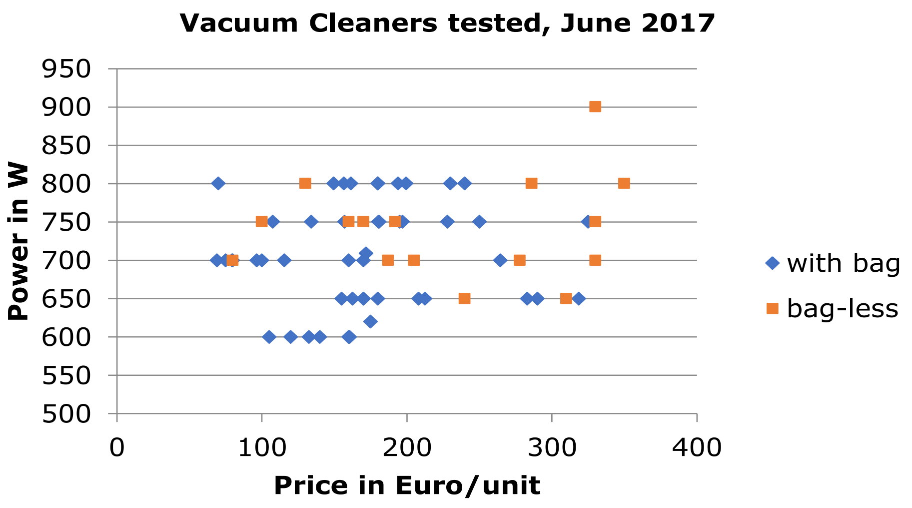
Most consumer associations and manufacturers seem now to have accepted that there is a market for bagless vacuum cleaners and a market for vacuum cleaners that have a bag as the receptacle. Energetically there is not much difference. The 'cyclone'-principle that puts a swirl in the airstream to push out dust particles by centrifugal power does not cost less energy than the pressure drop caused by a bag. The claim that the bag-less vacuum cleaner keeps up performance regardless of how full the receptacle is was relevant in the days of simple universal motors for vacuum cleaners. But especially with control-features of EC-motors such performance can be realised at relatively low costs as well. Anyway, consumer associations that test performance (also) with full bag did not find a significant difference in performance between products with and without bags.

The main consumer choice is whether you want to pay for the bags to facilitate clean emptying of the receptacle or not. Belgium consumer association Test-Achats stresses that also bag-less models need to have the receptacle thoroughly cleaned and that filters need to be changed. In their 2017 test they focus on testing vacuum cleaners with bags, because '*c'est (souvent) mieux avec un sac*' (it's often better with a sac) and 56% of vacuum cleaners sold by the end of 2016 were with bag[244],[245].

Likewise, the German Stiftung Warentest remarks that the consumer saves costs of the bags but the bag-less models are more expensive and manual cleaning of the receptacle isn't easy[246].

Figure 48 shows the power consumption and price of 48 models with bags and 16 bagless models tested in June/July 2017 by consumer associations in Germany, Belgium and the Netherlands. Only models with power ≤900W were taken into account. The average price for the whole population was 187 €/unit at an average power consumption of 717 W. The average bagless model cost 230 € at a power use of 749 W. The models with bag cost 172 € (33% less) and have a power input of 709 W (5-6% less). The overall score in the consumer-tests for models with or without bags was comparable, with bag-less models having a slightly better score on carpet cleaning and models with bag being more silent and re-emitting less dust. More details are given in Annex E.

Figure 48: The volume of the receptacle is between 1.3 and 3.4 litres. Average size in the most recent tests is 2.2 litres



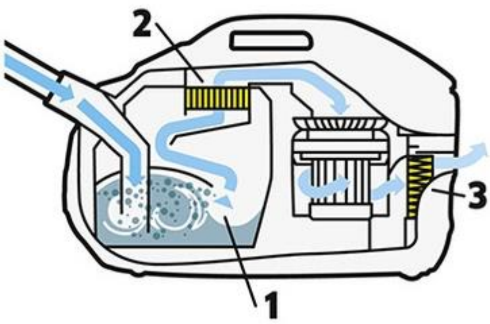
[244] Test –Achats 609, juin 2016, *'Avec sac, c'est (souvent) mieux'*, p. 41-43.
[245] Test-Achats 620, juin 2017, *'En plain dans le Miele'*, p. 51-53
[246] Test 7/2017, *'Sauber mit weniger Watt'*, p.52-55

10.1.4 Filters

The vacuum cleaner filter separates the dust particles from the air-stream. This is usually at least a two-stage process: The first filter step can be:

- a paper/non-woven bag.
- in a bagless vacuum cleaner the separation of dust though centrifugal ("cyclone") forces.
- in a water filter, i.e. the air flow with dirt is forced through the water before it is exhausted out of the vacuum. These vacuum cleaners must be emptied after each cleaning, but they can clean dry and wet surfaces and even larger liquid spills. Note that dry vacuum cleaners with a water filter are in the scope of the current regulation.

Figure 49 The principle of a dry vacuum cleaner with a water filter (picture source: Kärcher 2018)



The dust stays in the bag, falls in the receptacle or stays in the water for later disposal. The air moves on to the second stage, nowadays typically a HEPA (High Efficiency Particle Air) filter, that takes out the last 0.1% of dust particles and prevents (together with appropriate seals) re-emission of dust into the room.

In fact, in the dispute between bagged and bagless vacuum cleaners, the former suspect that the cyclone-concept of a bagless vacuum cleaner is less effective than the filtering of the bag and thus a larger part of the filter-burden is taken on by the HEPA-filter. This is fine in the first cycle when the HEPA filter is fresh, but after a number of cycles the HEPA-filter of a bag-less machine should be cleaned while the HEPA-filter of the bagged machine can carry on for more cycles.

In the European Union, filtration is defined by standard EN 1822:2009. This standard defines several classes of EPA/HEPA/ULPA air filters by their ability to retain the most penetrating particle size (MPPS) particles, as shown in Table 65. MPPS for most filters is in the range of 0.1 to 0.3 micrometers.

Table 65: Filter classes according to EN 1822:2009

Filter Group	Integral Value*	Local Value

	Filter Class	Filtration Efficiency	Penetration	Filtration Efficiency	Penetration
EPA- Efficiency Particulate Air filter	E10	85.0%	15.0%	-	-
	E11	95.0%	5.0%	-	-
	E12	99.5%	0.5%	-	-
HEPA- High Efficiency Particulate Air filter	H13	99.95%	0.05%	99.75%	0.25%
	H14	100.00%	0.01%	99.98%	0.03%
ULPA- Ultra Low Penetration Air Filters	U15	100.00%	0.00%	100.00%	0.00%
	U16	100.00%	0.00%	100.00%	0.00%
	U17	100.00%	0.00%	100.00%	0.00%

* Integral value shows efficiency of the air filter as a system and that is what average user should be focused on. EN 1822 standard doesn't define Local Values for E10-E12 filters.

The HEPA filter can be combined with active carbon, which can absorb various chemicals on a molecular basis, but can be problematic with larger particles. Also, a combination with scent, to give an extra feeling of freshness, is quite common. For obvious reasons 'scent' does not combine well with active carbon in a filter configuration.

In more exotic models, not typical for the EU market, the filtering in a vacuum cleaner can be combined with an ioniser, to clean the air electrostatically, or with UV light, to kill germs. Both solutions may not be without health risk as (traces of) ozone may be generated[247].

The pressure-drop caused by a typical HEPA filter is around 250-300 Pa when the filter is empty and twice as much 500-600 Pa when it is 'full'. As a general rule of thumb replacement every 6 months is recommended. Compared to the suction power in a cylinder vacuum cleaner (10-20 kPa) the filter takes up some 2-4%, depending on how full the bag is. From the 'A' dust re-emission Energy-Label rating on most models and the consumer association tests on this aspect, the HEPA filter solutions seems to be doing a good job, at least when starting out with a fresh filter.

10.1.5 Hose

The hose of a cylinder vacuum cleaner is typically a flexible corrugated plastic tube, reinforced with a metal spiral wire. Inner diameter is around 30-35 mm and the outer diameter is some 10 mm more. As was established in the special review study, the current lifetime test in the regulation (at least 40.000 flexes) and the associated standard is adequate for the primary hose of a cylinder vacuum cleaner. Attached to the hose is a steel cylinder with diameter of around 30-32 mm and a length of on average 95 cm. The cylinder is used to manipulate the attached nozzle.

[247] http://www.pickvacuumcleaner.com/exhaust-filtration.html

The corrugated flexible hose causes a significant pressure-drop (VHK estimate 300 Pa, 2-3% of power). One of the advantages of upright, handstick and robot vacuum cleaners is that they don't use a flexible hose and thus pressure loss is much lower (<50-100 Pa). The disadvantage of the first two types is of course in the ergonomics of having to manipulate not just the nozzle but the full weight of the fan and motor.

For the secondary hose of an upright vacuum cleaner, which is typically made for elongation and not only flexing, the test needs to be revised.

The hose is one of the components that may need to be replaced during the lifespan of the vacuum cleaner. In general, replacement is easy and spare parts are amply available. The reason for the hose breaking is rarely a break in the middle (as it would from the largest stress in a bending test) but would be a break where it is attached to a rigid part, i.e. the attachment to the metal tube or the attachment to the vacuum cleaner casing.

10.1.6 Nozzle

In recent years there has been discussion on the use of special nozzles that are part of the product package, but which, apart from when testing the cleaning performance in an energy label test[248], are hardly used in normal practice. For instance this is the case for some hard floor nozzles that adhere perfectly to the floor and pick up the dust from the crevices very well in the test but that in practice are not so useful because they do not pick up, but rather push around, the larger debris and hairs. In fact, most consumer associations advocate the use of the universal nozzle fit for both hard-floor and carpet cleaning for performance testing, especially since the nozzle design has large impact on the cleaning performance. Consumer surveys in the Netherlands show that more than half of the consumers never use any other nozzle (See Annex E). The other half might use the smaller nozzles for cleaning furniture, curtains or automobile-interiors.

In nozzle-design there are two philosophies: the passive nozzle, popular in continental Europe for its simplicity and effectiveness on all sorts of floors, and the active nozzle, popular in the UK and Ireland and praised for its superior performance on carpets. "Active" implies that the nozzle is equipped with a 'beat & brush' agitator, e.g. a rotating roll with brushes, that gives a mechanical stir to the carpet to facilitate better dust removal from the carpet. It is traditionally found on upright vacuum cleaners and on some handstick vacuum cleaners. It is reported to be especially effective with the removal of hair and fibres from the carpet. Consumer associations mention that the active nozzle brings additional material use and add a risk for product failure.

[248] According to the previous, annulled Energy Labelling Regulation

From the point of view of energy efficiency, it is difficult to say whether the active nozzle has a positive or a negative impact. On one hand, the agitator takes up extra motor power, often drawing its electricity from a (rechargeable) battery. On the other hand, it appears from consumer association tests that the main fan motor power can be reduced to e.g. 650 W instead of 750 W to get the same carpet cleaning performance. According to some stakeholders the active nozzles are more likely to break and thus contributes to larger material consumption.

10.1.7 Batteries

In the current regulation all types are mains-operated, except for a possible battery-driven active nozzle. But the possible newcomers cordless and robot vacuum cleaners both have batteries and thus battery chargers. In task 3 the running hours of cordless and robot types in the various modes were assessed, while charging, while operating as a vacuum cleaner and when fully charged and docked.

The power consumption in those modes can be estimated from consumer tests (see Annex E) and sometimes from product specification sheets. The Stiftung Warentest assessment of February 2018[249] specifies for instance the running time in maximum and minimum power mode. The two best performing cordless vacuum cleaners have a maximum power in the range of 400-450 W with a runtime of 8 to 15 minutes. This means an effective battery capacity of 60 to 100 Wh. At minimum power the runtime becomes 27 and 82 minutes, respectively. There are 5 models with a maximum power in the range of 250-350 W with a runtime of 14 to 37 minutes, meaning that the battery capacity is in the range of 50 to 80 Wh. Prices for the replacement batteries for cordless vacuum cleaners in the test vary between 30 € for a low capacity (ca. 30 Wh) NiMH battery and 105 € for a 100 Wh Li-ion battery. At the moment, Li-ion batteries are the most popular, despite their higher prices.

Vacuum cleaner batteries are typically of the Ni-MH (Nickel Metal Hydride) type or Li-ion (Lithium-ion) type[250]. The former features a product-life of ~400 charges and has a memory effect that may reduce long-term capacity[251]; the latter will recharge 1000 times (or more) and has no memory effect.

At for instance 5 recharges per week, a Ni-MH battery will last less than 2 years and the Li-ion battery lasts 4 years. Furthermore, the self-discharge of Li-ion batteries is in the

[249] Viel Lärm um nichts, Test 2/2018, p. 52-56
[250] Note that NiCd (Nickel Cadmium) batteries are now banned in the EU
[251] Memory effect relates to a diminished battery capacity in time, as a result of supoptimal (incomplete, or too soon) charging. In some cases the effect is reversible e.g. by applying a full discharge/charge cycle.

order of <5% per month. For NiMH it is in the order of 5% in the first week and 50% in the first month[252,253].

This means, for instance, that a large 100 Wh Li-ion battery loses less than 5 Wh/month. On a continuous basis (1 month is 720 hours) this is 0.007 W. For a NiMH battery of the same capacity the power loss is 10 times more.

It is important not to overcharge the Li-ion batteries, this is one of the reasons why the Li-ion cells are not 'trickle charged'. Trickle charging is charging at a very low current, just enough to compensate for self-discharge, to spare battery-life. It is typical a strategy for lead-acid and the now forbidden NiCd batteries.[254] Unfortunately it is also applied to Ni-MH batteries in some vacuum cleaners and can then lead to maintenance' (charged and docked) losses of 4.5 W, whereas in fact the self-discharge is only 0.07 W in a worst case. Furthermore, it might spare battery life when done correctly, but also for Ni-MH overcharging is sub-optimal for battery life.

Charging conventional Ni-MH batteries is slow, at 10-12 hours per charge, whereas the Li-ion batteries can be recharged in 1 to 3 hours. Li-ion cells have a higher voltage than Ni-MH cells: 3.6 V versus 1.2 V. Vacuum cleaner batteries will thus show a voltage that is a multiple of 3.6 V, usually between 18 and 36 V. [255]

An important energy-related feature of batteries is the charging efficiency, i.e. the ratio of electric power output and the electric power input for charging. For Li-ion batteries this amounts to 85%. For Ni-MH batteries a typical value is 69%.

Last but not least, the efficiency of the battery charger plays a role. A battery charger is basically an external power supply (EPS) and a regulator. The Impact Assessment report on External Power Supplies mentions EU proposals no-load power use of 0.3 W for a multiple voltage EPS with PO (power output) < 250W source and an active efficiency of 86%[256]. Assuming the 2012 US DoE standards for EPS to be representative of the average power supply cost, the EU proposal for e.g. a 120 W PO would cost 1.99 € more (consumer price incl. VAT). When saving 30 kWh/year at 0.20 €/kWh the EU consumer would pay back this 1.99 € in 4 months.

The European consumer association ANEC/BEUC notes that the maintenance mode of battery load in portable appliances (trickle charge) is considerable[257]. The consumer test-

[252] https://turbofuture.com/misc/Which-is-better-Nickel-Metal-Hydride-NiMH-or-Lithium-Ion-Li-ion-batteries
[253] There are low-self discharge (LSD) rate types available. They are more reliable than the standard NiMH but they have lower capacities, usually around 2000mAh.
[254] https://batteryuniversity.com/learn/article/charging_lithium_ion_batteries
[255] The capacity of a 3.6V Li-ion cell is around 1.5Ah (→ 4.4Wh), so often the capacity can be calculated in that way. E.g. a 36V Li-ion battery will have 10 cells and thus a capacity of 44Wh. A Ni-MH cell, at 1.2V, will have a typical capacity of 2.2Ah.
[256] Viegand Maagøe A/S, internal draft. 2018.
[257] Comment by ANEC/BEUC on the draft interim report, January 2018.

institute ICRT[258] tests of cordless vacuum cleaners and robot vacuum cleaners show that the average load over 24 hours in the 'charged and docked' condition of models over the past years varied between <0.5 and 8 W. This means a yearly 'maintenance mode' energy use of 60 kWh, which is higher than the total yearly energy use of regulated canister vacuum cleaners. ANEC/BEUC suggests that values of 0.5 W or maybe 1 W max for this condition are perfectly possible, as some of the models currently on the market already would comply. Setting a requirement on a 24-hours average would still allow docking stations to use more energy for a short time to perform relevant tasks such as updates. This is close to the limits set in the standby regulation[259] effective from January 2019, which differentiates between three standby modes. A similar solution could be considered for battery operated vacuum cleaners.

While on most energy and environment aspects the Li-ion batteries score best, there is the problem of the cobalt content. Cobalt makes up 10-20% of the battery weight. The Li-ion battery's specific capacity is around 100 Wh/kg and the average household cordless stick vacuum cleaner battery weighs around 0.4-0.7 kg (say 0.5 kg on average). So each of these contains 0.05-0.1 kg of cobalt. Note that there are several Li-ion types and not all use cobalt. Dyson vacuum cleaners, for instance, uses Aluminium Nickel instead of cobalt. This changes the battery properties. No cost information could be found to compare the different Li-ion battery types, but the recent article by Charles Amoabeng Nuamah[260] gives an overview of relevant selection criteria and typical characteristics of 6 Li-ion types.

The criteria are

- Specific energy: this defines the battery capacity in weight (Wh/kg). The capacity relates to the runtime. Products requiring long runtimes at moderate load are optimized for high specific energy.
- Specific power: this is the ability to deliver high current and indicates loading capability. Batteries for power tools are made for high specific power and come with reduced specific energy.
- Performance: how well the battery works over a wide range of temperature. Most batteries are sensitive to heat and cold and require climate control. Heat reduces the battery lifetime, and cold lowers the battery performance temporarily.
- Lifespan: this reflects cycle life and longevity and is related to factors such as temperature, depth of discharge and load. Hot climates accelerate capacity loss. Cobalt blended lithium ion batteries also usually have a graphite anode that limits the cycle life.
- Safety: this relates to factors such as the thermal stability of the materials used in the batteries. The materials should have the ability to sustain high temperatures before becoming unstable. Instability can lead to thermal runaway in which flaming

[258] http://www.international-testing.org/
[259] *OJ L 225, 23.8.2013, p. 1–12,* COMMISSION REGULATION (EU) No 801/2013 https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/energy-efficient-products/mode-standby-and-networked-standby_en
[260] See https://owlcation.com/stem/Comparing-6-Lithium-ion-Battery-Types

gases are vented. Fully charging the battery and keeping it beyond the designated age reduces safety.
- Cost: cost of lithium-ion batteries plays a major role in determining the initial product price. Hence cost is an important factor when selecting the type of lithium-ion battery.

Table 66: Comparison properties of Li-ion battery types (L =Low, M=Moderate, H=high)

Lithium-ion battery Types	SP	SE	SF	LS	CS	PF
	Specific power	Specific energy	Safety	Lifespan	Costs	Perfor-mance
Lithium Cobalt Oxide	L	H	L	L	L	M
Lithium Manganese Oxide	M	M	M	L	L	L
Lithium Nickel Manganese Cobalt Oxide (NMC)	M	H	M	M	L	M
Lithium Iron Phosphate	H	L	H	H	L	M
Lithium Nickel Cobalt Aluminum Oxide (NCA)	M	H	L	M	M	M
Lithium Titanate	M	L	H	H	H	H

NMC batteries are the most popular type for vacuum cleaners. There are two subtypes, i.e. NCM 1-1-1 with equal parts of Ni, Co and Mn (molar ratio) and NCM 5-3-2. Dyson (and e.g. Tesla for cars) is using NCA.

For batteries in robots nearly all of the above applies, except that the power consumption of the robot is lower and the battery capacity smaller. Battery capacity, in Ampere hours, depends on the power consumption of the robot vacuum cleaner. Top models may have a power consumption of 70-80W and feature batteries with capacities of 3.6 Ah to 5.2 Ah batteries. They will typically use Li-ion cells. Low-end robot vacuum cleaners may feature a power consumption of only 11-24 W and battery capacities lower than 2 Ah. They will typically use Ni-MH types.

The endurance of batteries, in terms of how many cycles they can withstand without losing capacity, is highly dependent on how they are used and charged. In Table 67 the estimated number of discharge/charge cycles for Li-ion batteries before the capacity drops to 70% is shown. The depth of discharge (DoD) constitutes a full charge followed by a discharge to the indicated percentage. Partial charge and discharge reduce stress to the battery and therefore prolong the battery life[261].

Table 67: Cycle life of LI-ion batteries as a function of DoD.

Depth of discharge	Discharge cycles (NMC / LiPO4)

[261] https://batteryuniversity.com/learn/article/how_to_prolong_lithium_based_batteries

100% DoD	~300 / 600
80% DoD	~400 / 900
60% DoD	~600 / 1,500
40% DoD	~1,000 / 3,000
20% DoD	~2,000 / 9,000
10% DoD	~6,000 / 15,000

10.1.8 Plug and power cord

On average, according to the latest test by Stiftung Warentest, a cylinder vacuum cleaner has a power cord of 10-11 metres. The power cord is retractable, using a mechanical spring. The retraction mechanism of the power cord is one of the components that most frequently needs repair and is often not easy to repair.

10.2 Materials and resource level

Resource efficiency is a growing concern within Europe and globally. More raw materials are categorised as critical and the dependency of these materials are increasing. APPLIA has initiated a collaboration with Digital Europe and recyclers (e.g. EEra[262]) to assess the possibilities of how to comply with the information requirements in the WEEE directive (article 15, specified in Annex 7). They have discussed how the information should be made available, and came up with the idea of an online joint platform[263], which contain necessary information on all product categories (also taking into account different technologies).

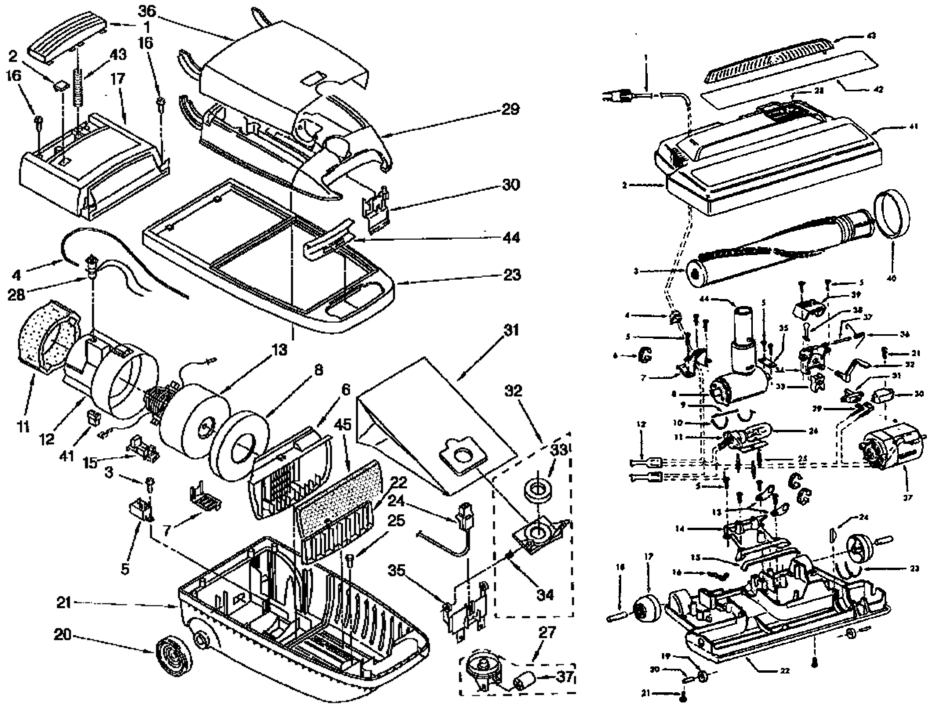
The following section provides an overview of the material composition and distribution of vacuum cleaners, and compare typical products to best available technology to support the resource efficiency assessment. The inputs will be used to model the environmental footprint in later tasks. The material composition provides also valuable inputs to the discussion on resources.

10.2.1 Material consumption in vacuum cleaners

In November 2015, JRC-IES Ispra published its case study on durability of vacuum cleaners264. As such, the study not only looked at the durability aspects but made a complete analysis of all environmental impacts, based on a product analysis of a recent cylinder vacuum cleaner. As such it constitutes the most recent Bill-of-Materials available of a random cylinder vacuum cleaner. Below is an exploded view of a vacuum cleaner presented in Figure 50.

262 http://www.eera-recyclers.com/about-us
263 To the knowledge of the study team, this platform has not yet been launched.
264 Silvia Bobba, Fulvio Ardente, Fabrice Mathieux, Durability assessment of vacuum cleaners, JRC-IES, Technical support for Environmental Footprinting, material efficiency in product policy and the European Platform on LCA, November 2015.

Figure 50: Example of an exploded drawing and spare parts listing for the canister (left) and the nozzle plate (right)



In Table 68 is the bill-of-materials of an average vacuum cleaner from the JRC study presented. The bill-of-materials presented only serves as an example of the variety of materials included in vacuum cleaners and which components the different materials are present. In general, the material composition and weight of vacuum cleaners are expected to be very similar to the values presented in the preparatory study. Only the material composition of robot vacuum cleaners has been added, which is derived from a study on end of life resource recovery from emerging electronic products[265].

Table 68: Bill-of-materials, Cylinder Vacuum Cleaner (source: JRC-IES 2015)

Component	Material	Mass (kg)
Hose	ABS	0.461
	PE	0.214
	PP	0.018
	Rubber	0.003
Motor	Aluminum (cast)	0.042
	Brass (CuZn20)	0.025
	Copper sheet	0.124
	Copper windings	0.0326
	Core	0.271
	Mounting	0.0579

[265] Parajuly, K., Habib, K., Cimpan, C., Liu, G. and Wenzel, H. (2016). End-of-life resource recovery from emerging electronic products – A case study of robotic vacuum cleaners. Journal of Cleaner Production, 137, pp.652-666.

Component	Material	Mass (kg)
	BMC-GF (polyester- glass-fibre reinforced)	0.267
	Graphite	0.007
	PE	0.016
	PP	0.259
	Rubber sealing compound	0.133
	Steel	0.614
Canister case	ABS	2
	POM	0.042
	Rubber	0.002
	Steel	0.004
Cord Reel	Brass	0.004
	ABS	0.142
	PE	0.021
	Rubber	0.002
	Steel	0.052
Plug & cord	PVC	0.194
	Copper	0.089
Nozzle plate	ABS.PP	0.052
	PE-HD	0.02
	PP	0.219
	Steel	0.019
Filter	PE-HD	0.017
Wheels	PP	0.209
Cables	Brass	0.002
	PE	0.015
	PVC	0.011
	Wires	0.005
Cables	Brass	0.001
	PVC	0.002
	Wires	0.002
Printed Circuit Board (PCB)	PCB	0.012
	Steel	0.014
Packaging	PE-LD	0.06
Manual	Paper	0.1
Packaging	Cardboard	1.1
TOTAL		**6.957**

The weight in grams and percentage distribution of various materials can be seen in Table 69 for typical representative products for each vacuum cleaner type.

Table 69: The assumed material composition in the current study.

Category	Materials	Household mains-operated	Commercial	Cordless	Robot
		g	g	g	g
Bulk Plastics	11 -ABS	3643	5795	1624	2657
TecPlastics	12 -PA 6	638	144	286.5	337
Ferro	24 -Cast iron	863	1436	400	823
Non-ferro	31 -Cu tube/sheet	307	766	354.5	224
Non-ferro	27 -Al sheet/extrusion	544	1336	480.5	344
Coating		6	0	0	0
Electronics	98 -controller board (PCB)	55	2	295	607
Misc.	various other materials	728	1631	0	0
Total weight		**6780**	**11110**	**3440**	**5041**
		%	%	%	%
Bulk Plastics	11 -ABS	54%	52%	47%	53%
TecPlastics	12 -PA 6	9%	1%	8%	7%
Ferro	24 -Cast iron	13%	13%	12%	16%
Non-ferro	31 -Cu tube/sheet	5%	7%	10%	4%
Non-ferro	27 -Al sheet/extrusion	8%	12%	14%	7%
Coating		0%	0%	0%	0%
Electronics	98 -controller board (PCB)	1%	0%	9%	12%
Misc.	various other materials	11%	15%	0%	0%
Total		**100%**	**100%**	**100%**	**100%**

All vacuum cleaner types are mainly made of plastics, the share ranging from 50% plastics for cordless vacuum cleaners to 56% for household mains-operated vacuum cleaners. A notable difference is in the amount of electronics, where robotic vacuum cleaners have the highest share and amount. Note that the batteries are included in the non-ferro materials and weighs approximately 500 grams in robotic vacuum cleaners.

Many vacuum cleaners use consumables in terms of bags and filters during their use phase. Based on a JRC report, the following assumptions are made regarding the composition and weight of bags and filters[266]:

[266] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC96942/lb-na-27512-en-n .pdf

- Bags made of propylene, estimated weight per bag: 0.04 kg.
- Filters made of PE-HD, estimated weight per filter: 0.0017 kg.

The impact of bags will be quantified in later tasks based on these assumptions, but the dust bags and filters can also be made of other materials e.g. dust bags made of fleece (PET)[267] and filters of polyester[268].

10.2.2 Critical materials and components

The awareness of critical resources is increasing, and the Commission carries out a criticality assessment at EU level on a wide range of non-energy and non-agricultural raw materials. In 2017 the criticality assessment was carried out for 61 candidate materials (58 individual materials and 3 material groups: heavy rare earth elements, light rare earth elements, platinum group metals, amounting to 78 materials in total). The updated list of critical raw materials is presented in Table 70.

Table 70: List of critical raw materials

Critical raw materials 2017			
Antimony	Fluorspar	LREEs*	Phosphorus
Baryte	Gallium	Magnesium	Scandium
Beryllium	Germanium	Natural graphite	Silicon metal
Bismuth	Hafnium	Natural rubber	Tantalum
Borate	Helium	Niobium	Tungsten
Cobalt	HREEs*	PGMs*	Vanadium
Coking coal	Indium	Phosphate rock	

*HREEs=heavy rare earth elements, LREEs=light rare earth elements, PGMs=platinum group metals

Each type of vacuum cleaner may contain several raw materials categorised as critical. Raw materials such as vanadium and phosphorous are in some designations of steel used as alloying elements. These alloying elements are not included in this assessment as they are very difficult to quantify, and more obvious choices are present such as:

- Printed circuit boards which may contain several critical materials such as palladium, antimony, bismuth, tantalum etc.[269]
- Motors which may contain rare earths
- Cobalt in batteries

Simple printed circuit boards are present in most mains-operated vacuum cleaners, e.g. to hold switches, resistors, etc. Only in the (rare) case of using frequency converters the electronics can become a little more complex. But gold-bumps to hold ICs (Integrated Circuits) are not generally present in most vacuum cleaners. Instead, cordless vacuum

[267] https://www.miele.co.uk/domestic/1779.htm?info=200046044-ZST
[268] https://www.nilfiskcfm.com/filtration/filters/
[269]http://www.wrap.org.uk/sites/files/wrap/Techniques%20for%20recovering%20printed%20circuit%20boards%2C%20final.pdf

cleaners will feature battery chargers, usually a power supply with a regulator (but no ICs with gold-bumps) and of course the battery cells (with cobalt).

Proper electronics boards, as referenced in the Ecoreport, can be found in all robot vacuum cleaners. But the amount of critical raw materials is properly higher in robotic vacuum cleaners as they contain the highest amount of printed circuit boards and at the highest grade. The average composition of a printed circuit board is assumed as follows[270]:

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

This means that robot vacuum cleaners contain gold in the range of 0.03 grams which originates from the printed circuit boards. The grade[271] of printed circuit boards in vacuum cleaners can be discussed, but the complexity of robots is increasing which imposes higher grades of printed circuit boards to be used. For robots the grade is assumed to be comparable to a midrange laptop.

The printed circuit boards and wires are already targeted components according to the WEEE-directive. The same goes for batteries and electronic displays.

Copper is also very important to remove before shredding, not only because it is identified as a critical raw material, but to minimise the risk of copper contamination in the iron fraction since it can directly influence the mechanical properties of the recycled iron/steel[272]. Avoiding contaminants is one of the key points of design for recycling. In order to avoid contamination, it is important to[273]:

- Reduce the use of materials, and especially the materials that will cause contamination in the recycling process (e.g. metal screws in plastics or combination of steel and copper). It should be considered how the materials would behave in the sorting and processing at end of life.
- Identify materials in assemblies combined in an inappropriate way so resources are lost during recycling. E.g. the connection between a metal screws and plastic, where one of the materials may be lost due to incomplete separation.

270 http://www.wrap.org.uk/sites/files/wrap/Techniques%20for%20recovering%20printed%20circuit%20boards%2C%20final.pdf

271 The grade of PCBs is dependent on the amount of precious metals (e.g. gold and silver), which can vary between the category of WEEE and its age.

272 http://www.rmz-mg.com/letniki/rmz50/rmz50_0627-0641.pdf

273 Reuter, M.A. & Schaik, A.V.A.N., 2013. 10 Design for Recycling Rules , Product Centric Recycling & Urban / Landfill Mining. , pp.1–15.

10.2.3 Manufacturing and distribution

During manufacturing primary scrap is generated, but the primary scrap production is estimated to be negligible. It is assumed that cuttings and residues are directly reused into new materials within the factories, making material losses very low.

Additional materials are used in the distribution of products. Usually cardboard, plastic and expanded polystyrene are used to protect the product during transport. Packaging materials are sorted by the end-user and recycled, burned or landfilled. Cardboard is easily recyclable while the plastic is probably burned or recycled. Regarding the expanded polystyrene it can be compressed and recycled into polystyrene. The problem is the density and volume of the expanded polystyrene. It must be compressed to make it both affordable and environmentally sound.

The distribution of products depends on the location of sales and production, but generally large cargo ships are used for intercontinental transport, while trains and road transportation are used for shorter distances. The impact depends on the specific product and its geographical route, but in most life cycle assessments the transportation impact turns out to be negligible compared to the environmental impact of the rest of the product. Vacuum cleaners are no exception, as most are assumed to be shipped by freight ship or by truck. Both alternatives in general have a low impact in the final assessment.

10.2.4 Recycled content

Hereafter a brief discussion of the recycled content of vacuum cleaner materials is given. Note that in this report 'recycled content' always refers to material input (in g) that is derived from post-consumer waste. Recycling waste from primary scrap, which is a common and profitable activity in industry, is not included.

- The non-ferro metals in vacuum cleaners are mainly copper and aluminium. Globally, more than half of the copper products are made from recycled copper. However, this percentage mostly comes from recycled content of tube and sheet alloys (bronze, brass), which are not in vacuum cleaners. The wire windings of the motor have to be very pure for optimal electric conductivity. The same goes, although to a lesser degree, for the copper wire in power cords. Overall for copper in the vacuum cleaners a recycled content of 10% is assumed. The aluminium in vacuum cleaners is usually situated around the motor, as part of the frame or motor/fan housing. Typically, it will be aluminium diecast, which uses 85% recycled content.
- The ferro-materials relate mostly to the core material of the motor, some small steel parts (e.g. axes for wheels, spiral wire) and the tube holding the nozzle. For the core material of the motor there are numerous alternatives, e.g. soft iron, steel

laminates, etc. There is no environmental profile in the EcoReport, but assuming a laminated steel core, the galvanised steel sheet with a recycled content of 5%, probably comes closest. Cast iron (85% recycled content) could be used for the motor frame. The chromed hose could be rolled from sheet (5% recycled content).

- Technical plastics, actually usually thermosets like epoxy resin or polyester compounds, are only a small fraction of the total plastics. They are used where temperature-resistance is required and/or as casing/mounting plate of electric parts (switches, etc.). Recycled content of thermosets is usually 0%.
- Bulk plastics, like PP (polypropylene) and ABS, constitute half or more than half of product weight. Most goes into the casing. Normally, the recycled content is 0%, but since a few years there are some manufacturers that have started to use considerable fractions of recycled PP and ABS, up to 70%. Assuming that these manufacturers might constitute 20% of the market it means that on average there is a 14% recycled content for bulk-plastics. Note that PP is also a common non-woven material for filters and bags.
- As regards electronics (including batteries) only very small fractions of recycled content, i.e. those relating to valuable materials like gold (in robot VCs), palladium (in condensers), cobalt (batteries), etc. can be assumed. Given that they constitute a high environmental impact, it can be said that the recycled content represents a negligible mass, but at least 20-30% (say 25%) of the impact.
- The packaging of vacuum cleaners is now mainly an LD-PE (low-density polyethylene) bag, a cardboard box, possibly with cardboard or EPS (expanded polystyrene) inserts for the corners. The cardboard is 90% made of recycled material. The manual is made of printing paper, very often also from recycled material (50% assumed).

10.2.5 Use phase

There are two main non-energy material strategies linked to the use phase:

- Reduction of the consumption of bags and filters, e.g. by re-usable/washable filter-boxes, cyclone separation ('bagless'), etc.
- A longer product life to slow down the material cycle of vacuum cleaners and thus save materials in production and end of life. This can be achieved by increasing reparability by setting minimum technical life requirements on certain components and keeping spare parts available

Both directions will be discussed in section 12.

10.2.6 End of life

At end of life the waste stream can be split into re-use, recycling, heat recovery, incineration without heat recovery (of hazardous materials in general) and landfill.

Furthermore, especially if the product sales were increasing or declining rapidly over a relatively brief period in time, there is a mismatch between the mass of materials in production and the mass being discarded. This is caused by the time displacement between acquisition and disposal of the products, which means that in the meantime the material is in the stock. For instance, for cordless and robot vacuum cleaners this 'in-stock' material plays an important role, causing a delay from purchase to disposal of materials (i.e. the vacuum cleaners bought today will not be seen in disposal until 5-6 years time). For the more traditional vacuum cleaners where the markets are more mature, the 'stock' plays a minor role, since the input and output of products to and from the stock is more or less constant.

The starting point for the end of life process is the collection, which was discussed in section 9. While, according to the WEEE Directive, the collection rate should become 65% in 2019, the collection rate for small appliances (including vacuum cleaners) was only 40% in 2014. This means that 60% ended up in the mixed household fraction, where there is also recycling, e.g. of the metals, batteries and possibly robot-PCBs (Printed Circuit Boards), but where e.g. vacuum plastic plastics are usually not singled out and go to heat recovery.

As regards 're-use' there is something of a definition problem. In the German study on obsolescence re-use could be perceived as people giving away the product either to family and friends or to a 'green' shop. That is a route that the first users may follow in 7-8% of the disposals. It will help to really get to the projected product life of 8 years (for mains-operated household vacuum cleaners), but there is very little in terms of design, and thus also in terms of Ecodesign Regulations, to do about it.

In this study re-use is assumed to be the case if there is systematic refurbishment of the product and that is much rarer and more estimated to happen only in 1% of the disposals.

From the viewpoint of designing a new product, which is the perspective of Ecodesign measures, recycling relates to two aspects: recyclability of the product at the end of life and maximum use of post-consumer recycled content for the new product. If the two are in balance, there is a true 'circular economy'. However, after a life of intensive use, most products and their materials degrade and thus there is inevitably some downgrading.

As regards 'Design for Recycling' there are different directions. The concept dates back to the late 1970s and was initially synonymous only to 'design for disassembly', i.e. facilitating mainly manually separate material fractions of discarded products. However, over the last 50 years the economic reality of recycling EEE (Electric and Electronic Equipment) did not evolve in the direction of sophisticated manual dismantling, but instead (apart from some worthwhile components specified in the WEEE-Directive) focused on a first very rough manual split, feeding a shredder and then physical/chemical processes (magnetism, floating, etc.). In the case of vacuum cleaners, for instance, the recyclers cut off the power cord for its copper content to be gained from specialised processing. In cordless vacuum cleaners the batteries are of course removed and in the case of robot vacuum cleaners, the printed circuit boards (PCB) are also removed beforehand to follow a different processing route, usually also involving a shredder.

After the shredder, the metal parts are separated by physical means (magnetic, eddy-current, specific weight). In the remaining flow the bulk-plastics PE, PP, PS and ABS are separated individually on the basis of specific weight[274]. The diversity of the remaining plastics types is too large and their total quantity too small to make the potential gains to be derived from their separation worth the extra costs involved in the process.

The most used plastics in vacuum cleaners are PP (polypropylene) and ABS (Acrylic Butadiene Styrene). As mentioned, the post-shredder separation of these two plastics is current practice and thus there is no need for detailed Design for Disassembly. However, it is important to keep the PP and ABS as pure as possible in each moulded part, i.e. to avoid glass-fibre reinforcements, fillers or large quantities of additives such as (halogenated) flame retardants. Also blends and co-polymers of PP and ABS in single parts should be avoided as much as possible. However, and this has led to misunderstandings when using simplified matrices of 'compatible' plastics, there is no significant negative effect for recycling to use different parts of ABS or PP or any plastic in one product as long as each part is pure. Also it is not problematic to use metallic fasteners[275]. Finally, in this case the marking of larger plastic parts, which manufacturers anyway undertake on a voluntary basis, is useful in case of extensive disassembly. If there is no such disassembly of every component the impact of marking will be insignificant.

With the motors (metal) becoming smaller and with increased use of plastics, the plastics are now 60% or more of the total material input and thus 60% of the future waste stream when the products currently put on the market reach their end of life.

The recycling rates in this study are based on the EcoReport tool[276] but updated regarding plastic[277]. The values used in the current study are presented in Table 64 in section 9. At the moment some 29% of the plastics is considered to be recycled, 40% goes to heat

[274] http://www.ecodesignlink.be/en/basic-plastic-types?parent=176
[275] Based on the stakeholder inputs care must also be taken towards vague description such as "It must be possible to separate the connections easily" since it is imposible for the market surveailince authorities to control this.
[276] http://ec.europa.eu/growth/industry/sustainability/ecodesign_da
[277] Plastic Europe, Available at: http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf

recovery, 31% to landfill (see section 9). The credit for recycling in Ecoreport amounts to 40% of all impacts[278].

After having missed the recycling stage, it is important for possible *heat recovery* from the remaining fractions, mainly plastics and electronics, that there are no hazardous materials included. Apart from the materials mentioned in RoHS, for which no special action would be required, this includes "Substances of Very High Concern" in REACH and plastic-additives such as halogenated flame retardants.

If any of these hazardous materials are present, the fractions need to be incinerated without heat recovery or there is the risk that they end up in landfill. Otherwise, at least for those fractions with a combustion value, they will contribute to heat recovery. For these materials there is a credit of 30% for all environmental impacts according to EcoReport.

10.2.7 Blue Angel requirements

The best available vacuum cleaners regarding resource efficiency are considered to be those who are awarded the German eco-label the Blue Angel as this eco-label also sets requirements concerning the resource efficiency besides more common requirements as the energy consumption. The Blue Angel requirements concerning the resource efficiency are:

Material requirements for the plastics used in housings, housing parts and accessory parts (suction tube/hose, nozzle etc.) No substances may be added to the plastics as constituent parts which are classified as:

- Carcinogenic of categories 1A or 1B according to Table 3.1 of Annex VI to Regulation (EC) 1272/2008
- mutagenic of categories 1A or 1B according to Table 3.1 of Annex VI to Regulation (EC) 1272/2008 According to DIN EN 60312-1, para. 3.4.
- Toxic to reproduction of categories 1A or 1B according to Table 3.1 of Annex VI to Regulation (EC) 1272/2008
- Toxic to reproduction of categories 1A or 1B according to Table 3.1 of Annex VI to Regulation (EC) 1272/2008
- Being of very high concern for other reasons according to the criteria of Annex XIII to the REACH Regulation, provided that they have been included in the List (so-called Candidate List) prepared in accordance with REACH, Article 59, paragraph 1
- Halogenated polymers shall not be permitted. Nor may halogenated organic compounds be added as flame retardants. Moreover, no flame retardants may be added which are classified pursuant to Table 3.1 or 3.2 in Annex VI to Regulation (EC) 1272/2008 as very toxic to aquatic organisms with long-term adverse effect and have been assigned the Hazard Statement H 410 or Risk Phrase R 50/53.

[278] Another solution, not taken into account, is to improve the recycling facilities by investing in improved sorting technologies or new technologies such as carbon capture technologies . Carbon capture technologies can in the future use CO2 (e.g. from combustion of plastic) as a feedstock for polymers. See https://setis.ec.europa.eu/setis-reports/setis-magazine/carbon-capture-utilisation-and-storage/co2-feedstock-polymers

Recyclable and easy-to-maintain design. The appliance shall be so designed as to allow quick and easy disassembly with a view to facilitating repair and separation of valuable components and materials. This means that:

- It must be possible to separate the connections concerned by the use of ordinary tools and the points of connection must be easily accessible
- Plastics should consist of one polymer only and plastic parts greater than 25 g in mass must be marked according to ISO 11469 to allow for a sorting of plastics by type
- Disassembly instructions must be made available to end of life recyclers or treatment facilities in order to recover as many valuable resources as possible,
- The plastics used should consist of recycled material, if possible.

Durability. The appliances shall meet the following durability requirements:

- The motor shall have a minimum service life of 600 hours
- The suction nozzle must be able to withstand the impact of at least 600 drum rotations (or 1200 falls from as high as 80 cm).
- The suction hose must withstand at least 40,000 deformations
- A threshold and doorpost impact test of at least 500 cycles.

Spare Parts Supply. The applicant undertakes to ensure spare parts supply for appliance repair for at least 8 years from the time that production ceases. Spare parts are those parts which, typically, may break down within the scope of the ordinary use of a product - whereas those parts which normally exceed the average life of the product are not to be considered as spare parts. Also, the applicant undertakes to provide after-sales services. The product documentation shall include information on the above requirements.

Currently there is only one vacuum cleaner awarded the Blue Angel Ecolabel[279] and this is considered the BAT regarding resource efficiency. Note that no disassembly requirements are included in the requirements which probably is due to the shredding at end of life. Instead the focus is on maintainable design, durability and the spare parts. These are all factors that can improve the lifetime of products. The impacts of an improved lifetime should be thoroughly assessed in later task to determine the possible trade-offs between improved lifetime and energy efficiency.

10.3 Products

Based on the sections above, the average technologies and Best Available Technologies (BAT) for each main product type will be examined in this section. A suggestion for the Best Not Available Technologies (BNAT) is also given for each type.

[279] https://www.blauer-engel.de/en/products/home-living/staubsauger

10.3.1 Mains-operated household vacuum cleaners

Average technology

This category includes mains-operated cylinder, upright and mains-operated handstick (also called 'compact') vacuum cleaners, which are all covered by the current Ecodesign Regulation and the annulled Energy Labelling Regulations. These types have different form factors leading to different ergonomic advantages and disadvantages:

- Lightweight vs. heavy
- Lightweight but noisy
- Lightweight as a whole product but not easy to handle
- Heavy but easy and versatile to handle due to hose plus cleaning head
- Easy to store versus taking up a considerable storage space and time to set up
- Standard equipped with a sturdy agitator in the cleaning head ('active nozzle') and a secondary hose for non-floor cleaning tasks, etc.

These differences co-exist and serve different audiences with different preferences. However, for the purpose of setting Ecodesign requirements and Energy Label class limits these differences are not decisive for the current or, for that matter, a possibly revised regulation.

In section 8.5 the mains-operated vacuum cleaners were the prime subject as regards performance data. For the BAU (Business as Usual) reference year 2016 the average performance values are:

- Energy consumption *AE* of 38 kWh/year
- Power input P_{eff} 881 W
- Hard floor cleaning dpu_{hf} is 1.08
- Carpet cleaning dpu_{c} is 0.81
- Dust re-emission d_{re} is 0.3%
- Average (linear) sound power 80 dB(A)

<u>BAT</u>

In section 10.1 several options for improvement at component level were suggested, which ultimately lead to the Best Available Technology (BAT). As regards the consequences for the vacuum cleaner performance, the study team did its desk research of manufacturer's sites, Swiss Topten[280], consumer associations (see Annex E), met with manufacturers in - and outside the stakeholder meetings. The conclusion is that for mains-operated household vacuum cleaners there are models in the highest energy label classes[281] for energy efficiency (A+++)[282] and performance classes (A)[282], but never for the same model. For example, the Electrolux PURED9 GREEN model has an energy class A+++[282] (9.9

[280] www.topten.eu
[281] According to the the previous, annulled Energy Labelling Regulation
[282] According to the previous, annulled Energy Labelling Regulation

kWh/year, 350W) but a carpet cleaning class of 'C'[283],[282]. Of the same model there is also a version DELUXE with carpet cleaning class 'A'[282], but then the energy class is 'A++' [282] (16 kWh/year, 400 W)[284]. The price of this new model is 400 € at the moment[285].

This illustrates that there is a clear inverse relationship between carpet cleaning performance dpu_c and energy efficiency. This cannot be said about the hard floor cleaning performance. Rather, every type of vacuum cleaner, even with very low suction power, can get a good hard floor cleaning dpu_{hf} rating with the current crevice test. In the energy efficiency rating of the general purpose vacuum cleaner, the most popular type, both the dpu_c and dpu_{hf} play an equal role and the dpu_{hf} thus tends to 'soften' the inferior carpet cleaning performance of some products.

The cleaning performance ratings of the annulled energy label are not always in sync with the findings of consumer associations, who generally perform also debris (rice, lentils) and fibre pick-up tests (simulating pet hair). Especially for the latter, the 'active' nozzle is reported to make a large difference, whereas in the standard carpet tests the 'passive' nozzle is performing just as well.

For all these reasons, energy efficiency is to be seen in conjunction with performance.

As regards recycling the 'PURED9 GREEN' model is best-in-class with 70% recycled content of the plastics in the product and 100% recycled materials (cardboard and PE) for the packaging. The product weight (bare) is 7.09 kg, which is at the level of the base case. On sound power, the score is 67 dB(A), comparable to e.g. the Rowenta Silence Force Compact 4A[286], but less quiet than the Miele C3 Silence EcoLine - SGSK3 at 64 dB(A) and the Bosch In'genius Prosilence [287] at 59 dB(A). Handstick models perform better on material consumption than the larger mains-operated types (cylinder and uprights) due to the lower product weight of around 3 kg[288].

BNAT

The Best Not yet Available Technology (BNAT) is a vacuum cleaner in the highest label performance class for all aspects, i.e. a model with A+++, A, A, A (according to the annulled Energy Labelling Regulation) and a sound power of 59 dB(A) or lower. As indicated above, there are models that are almost there, but turning the energy class A++[289] into an A+++[289] or achieving an A in carpet cleaning performance at energy class A+++[289]

[283] https://www.electrolux.ch/de-ch/vacuums-home-comfort/vacuum-cleaners/vacuum-cleaners/vacuum-cleaner/pd91-green/
[284] https://www.electrolux.fr/vacuums-home-comfort/vacuum-cleaners/vacuum-cleaners/vacuum-cleaner/pd91-8ssm/
[285] But streetprice will usually drop after the novelty wears off.
[286] https://www.rowenta.be/nl/Schoonmaken/Stofzuigers-met-zak/SILENCE-FORCE-COMPACT-4A%2B-RO6371EA/p/2211400326?gclid=CjwKCAjworfdBRA7EiwAKX9HeC_jr_gRPP_8hP367723L78YGdKhxjGDp8zzsM8ESoQ9iPBceOhsOBoCVGwQAvD_BwE
[287] https://www.coolblue.be/nl/product/772255/bosch-in-genius-prosilence-bgb8a32w.html?ref=410179&gclid=CjwKCAjworfdBRA7EiwAKX9HeBXPT7GQPoPfmqyO5gk4RCxFrNPW_z9toOtCArfOtJxifzXHs6KP_hoCKGsQAvD_BwE#product_specifications
[288] E.g. Kärcher VC5
[289] According to the previous, annulled Energy Labelling Regulation

might turn out to be very difficult, especially - depending on the final decision making - if the testing becomes more realistic and more challenging, e.g. including debris pick-up for hard-floor and fibre pick-up for carpet cleaning.

As regards circular economy there is a matter of opinion: are lightweight, compact solutions that use fewer virgin plastics and metals to begin with to be preferred, or is a current weight vacuum cleaner with high recycled content considered better? In the first case, building on the corded handstick of 3 kg, of which e.g. 2 kg of virgin plastics, is probably the way forward. In the second case, a 7 kg cylinder type with 70% recycled content of the 5 kg of plastics is setting apart only 1.5 kg of virgin plastics. Or are both strategies equally valid?

Table 71. Base case 1: Household mains-operated vacuum cleaners' energy, performance, price

	BAU				BAT	BNAT
	2016	2018	2025	2030		
Rated power	900	900	900	900	300	300
dpu_c	0.81	0.81	0.81	0.81	0.81	0.91
dpu_{hf}	1.08	1.08	1.08	1.08	1.11	1.11
AE (kWh/year)	33.6	33.7	37.0	36.6	9.9	9.5
Price incl. VAT, €	123	123	115	113	380	430

Table 72. Base Case 1: Household mains-operated vacuum cleaners' materials (product life 8 years, package 0.08 m³)

Life Cycle materials	Production		Use	End of life		
Impacts per product	Virgin + recycled	Only recycled		Disposal	Recycle	Recover
Materials	g	g	g	g	g	g
Bulk Plastics	3,643	911	36	1,129	1,093	1,457
TecPlastics	638	0	6	198	192	255
Ferro	863	345	9	52	820	0
Non-ferro	850	340	9	51	808	0
Electronics	55	14	1	28	28	0
Misc.	734	661	7	255	479	7
Auxiliaries	0	0	640	640	0	0
Total weight[290]	**6,784**	**2,271**	**708**	**2,353**	**3,419**	**1,720**

10.3.2 Commercial vacuum cleaners

Commercial dry vacuum cleaners are typically used for cleaning offices, shops, restaurants and hotels. They are not of the wet & dry barrel type, excluded from the scope of the

[290] Average weight of one appliance

regulation, that is typically used to clean workshops and industrial premises and is able to pick up liquids when necessary.

Commercial dry vacuum cleaners are generally not very different from household vacuum cleaners, except that they usually have a sturdier construction and larger receptacle (8-15 litres) allowing them to operate for 300 hours per year, i.e. 6 times more than household vacuum cleaners.

Having said that, there are some exceptions, such as the Nilfisk that is a cordless 10 kg cylinder vacuum cleaner primarily designed for commercial purposes. It comes with 2 battery-packs. Each pack, recharges in only a few hours and allows the vacuum cleaner to operate for 40 minutes at 600 W. Thus, in practice, an operator can operate at least for 80 minutes without interruption at maximum power, take a short break and start again. There are also commercial vacuum cleaners with a backpack, corded and cordless.

The table hereafter shows two canister type models (VP930, VP300), one backpack vacuum cleaner (GD10 BACK corded, but 'backvacs' are also available as cordless) and a very efficient cylinder model VP600 that is also available in a cordless version[291]. It shows performance and energy values comparable (or better) than the household types.

Figure 51. Commercial, cordless, backpack vacuum cleaner (source: Hoover)

Table 73. Nilfisk commercial cylinder vacuum cleaner examples (source: Nilfisk.com, Sept. 2018)

Product NILFISK	VP930 ECO HEPA A++	VP300	GD10 BACK	VP600 ECO HEPA	VP600 BATTERY
price (Nilfisk-shop.nl, sept. 2018)	299 euro	189 euro	659 euro	469 euro	~1000 euro
power (W) in 2 settings battery					190/465
Rated power (W)	400	600	780	330/550	650

[291] Commercial cordless VCs are not proposed to be in scope here, but shown for information

Airflow (l/sec.)	26	25.5	33	24/28	21.7/26.7
Weight (kg)	7.9	5.2	5	7	10
Vacuum at nozzle (kPa)	16	13.4	22	15/18	?
Dust bag capacity (l)	15	10	10	8	10
Main filter area (cm²)	2400	1250	2400	2400	2400
Suction power end of tube (W)	120	112	225	75/155	45/116
Length x width x height (mm)	440x390x330	395x340x390	380x260x570	480x300x270	480x300x270
Cable length (m)/ plug type	15/EU	10/EU	10/EU	15/EU	
Sound pressure (dB(A) BS 5415)		47			
Sound power (dB(A) IEC 704)		65.5			
Protection class / ip protection	II / IP20	IP20	II / IP20	II / IP20	II / IP20
Main filter type	HEPA 13	-	HEPA 13	HEPA 13	HEPA 13
Energy efficiency class	A++	A	B	A++	
Dust pick up on carpet	C	E	D	C	
Dust pick up on hard floor	B	E	D	C	
Dust re-emission class	A	G	B	A	
Sound power dB(A) IEC/EN 60335-2-69	66	65.5	76	70/74	
Annual energy consumption (kWh/year)	14	21	33	11	
Cable length (m)	15	10			
Number of filters	4	N/A		2	
Hose length (m)	1.9	N/A			
Hose diameter Ø (mm)	32	N/A			
Sound pressure DB(A) IEC/EN 60335-2-69	53	N/A	64	58/62	56/61 (@1.5m ISO 11203)
Hepa filtration	□	□	□	□	
H13 Exhaust filter	□	□	□	□	
Two speed	N/A	N/A	yes	yes	
*=With battery :Li-ion, 36V, 7.8 Ah (-->280 Wh), 2.8 kg, charge time <40minutes					

Table 74. Base case 2: Commercial mains-operated vacuum cleaners (BC2)

	BAU				BAT	BNAT
Rated power	900	900	900	900	300	300
dpu_c	0.81	0.81	0.81	0.81	0.81	0.91
dpu_{hf}	1.08	1.08	1.08	1.08	1.11	1.11
AE (kWh/year)	43.90	30.73	35.60	34.76	12.71	11.63
Price incl. VAT, €	331				380	430

The sturdy construction also is evident from the bill-of-materials as seen in Table 75.

Table 75. Base Case 2: Commercial mains-operated vacuum cleaner materials (product-life 5 years, package 0.1 m³)

Life Cycle materials	PRODUCE		USE	END OF LIFE		
Materials	g	g	g	g	g	g
Bulk Plastics	5,795	1,449	58	1,796	1,739	2,318
TecPlastics	144	0	1	45	43	58
Ferro	1,436	574	14	86	1,364	0
Non-ferro	2,102	841	21	126	1,997	0
Electronics	2	1	0	1	1	0
Misc.	1,631	1,468	16	571	1,060	16
Auxiliaries	0	0	1,000	1,000	0	0
Total weight	**11,110**	**4,332**	**1,111**	**3,625**	**6,204**	**2,392**

10.3.3 Cordless handstick vacuum cleaners

Manually-operated household cordless vacuum cleaners are assumed to be used for the same amount of total cleaning as mains-operated household vacuum cleaners However, most cordless vacuums often would not have sufficient run time to be used for as long as the mains-operated household vacuum cleaners, as most cordless vacuum cleaners have a run time of 15-40 minutes while only a few can run for up to 60 minutes at the lowest power setting[292].

The capacity of a cordless is also smaller than that of a normal vacuum cleaner, i.e. in the range of 0.2-0.8 litres compared with around 2-3 litres for an average-sized standard vacuum cleaner according to Which?[293]. The same source also finds that, while a carpet dust pick-up of 79% is average for a cylinder vacuum cleaner, the cordless vacuum cleaner only reaches 47%. In other words, the average cordless would not meet the 2017 Ecodesign requirements for carpet cleaning (minimum dpu_c 75%) and possibly could only enter as a hard-floor only model (minimum dpu_{hf} 98%).

Especially over the last 5 years there has been a lot of progress in performance, battery capacity and lifespan for cordless vacuum cleaners. Belgian consumer association Test-Achats[294] tested 10 cordless handstick vacuum cleaners in 2013 and largely confirmed the findings of Which?: Lower suction power, overall lower performance, limited battery autonomy (between 9 and 33 minutes), recharging times between 3 and 17 hours depending on the model. The overall conclusion was that the average cordless vacuum cleaner has a lower performance than equivalent corded models. However, it should be noted that the performance of the best cordless vacuum cleaners (only a few models) is

[292] http://www.which.co.uk/reviews/cordless-vacuum-cleaners/article/corded-vs-cordless-vacuum-cleaners
[293] https://www.which.co.uk/
[294] Test-Achats 575, Aspirateurs Balais, Mai 2013, p. 38-39.

close to the performance of corded models. Finally, with a price varying between 118 and 380 € (average 196 €) Test-Achats found the product to be expensive. Weight of the tested products varied between 2.4 and 3.9 kg (2.9 kg on average).

Five years later, published in Feb. 2018, the Stiftung Warentest (StiWa) again tested 10 cordless vacuum cleaners and found 2 models, Bosch Athlete and Dyson V8, to currently have a 'satisfactory' cleaning performance compared to corded alternative. Stiwa does not specify a virtual (because not compulsory) label classes, but a carpet cleaning performance class of at least 'C' for these two models is not unlikely. The other 8 of 10 models were still judged to be disappointing. See Annex E. There is also more variation in form factors than 5 years ago. There are now models where the motor (and receptacle) is in the middle, at floor level and at the top (hand-level), as shown in Figure 52).

Figure 52. Examples of form factors for cordless stick models

(a) (b) (c)

(a) Hoover FE144LG011, 14.4 V NiMH-battery (estimated capacity study team 32Wh), runtime 25 minutes (estimated motor power input 76W), charges in 12h, bagless (cyclone technology), 2 speed sections, bin 0.6 L. Street price (BE) 119 €[295]*.*

(b) Gtech AirRam MK2,'upright', 22V, 2Ah (44Wh--> estimate study team 60-70W motor input), 3h loading, 3.2 kg, uses washable filter box (reusable), telescope handle, www.gtech.co.uk

(c) Dyson V10, Dyson V10 Absolute, 25.4-29V, 525 'Watt' reported capacity (NCA Li-ion), 151 airwatts output (max. setting), 3.5h loading, 2.68kg product weight, bin 0.76 L, runtime 7(at max power)-60(at minimum power) minutes, street price 629 €[296]

Recently a cordless cylinder model from Nilfisk, designed both for the household ('Family') and commercial sector, has also entered the market. The aim is to achieve a long run time at high suction power without the user having to drag the full extra weight of 2-3 kg batteries around.

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[295] https://www.unigro.be/nl/elektro-en-huishouden/stofzuigen-en-reinigen/stofzuigers/snoerloze-steelstofzuiger-hoover-fe144lg011/1003079?channable=e50079.MTAwMzA3OS0tLU5M&gclid=Cj0KCQjw6MHdBRCtARIsAEigMxF1B17W6hQyzfcHFgb66vYLUOxdR1Wn089vS9b__n7e21E6g79jwtIaAoLjEALw_wcB

[296] https://www.dyson.be/nl-BE/stofzuigers/snoerloze-stofzuigers/dyson-v10/techniek.aspx

Note that the above models are all advertised (also) for carpet cleaning, i.e. as 'general purpose'. But there are also typical 'sweepers' and 'electric broom' types, with a form factor as (b) in the figure above, i.e. a rotating brush without filtration and a 10-15 W suction power[297] that is just enough to keep the dust from falling out of the small bin next to the brush. If their performance allow, they could be in scope of a revised regulation as 'hard-floor only'. More sophisticated 'hard floor only' products are certain types that combine the dry vacuum cleaning with a humid mop.

As the APPLIA database did not distinguish cordless vacuum cleaners specifically, data was collected from retailers online for 27 cordless models from 16 different brands, which are shown in Table 76. Note that not all data points were available at all retailers.

Table 76: Average data for cordless handstick cleaners collected from online retailers for 27 models from 16 brands.

Cordless vacuum cleaners	Average data
Max run time	34 min
Charging time	248 min
Motor power	241 W
Suction power	79 W
Battery voltage	30 V
Price	221 €
Bagless share	99%

Note that there is at least one manufacturer that offers a bagged cordless stick model[298].

Table 77. Base case 3: Cordless vacuum cleaners' energy, performance, price, 2018 data

Characteristics	BAU	BAT	BNAT
Maintenance consumption, charged and docked [W]	2.6	1.0	0.5
Standby dock, when cleaning [W]	1.7	0.5	0.5
dpu_c	0.63	0.75	0.80
dpu_{hf}	0.45	0.98	0.98
ASEc [Wh/m2]	0.59	0.56	0.56
ASEhf [Wh/m2]	0.57	0.56	0.56
AE [kWh/year]	21.88	20.14	19.55
Consumer price incl. VAT, €	221	500	630

The materials cycle is given in Table 78.

Table 78. Base Case 3: Cordless vacuum cleaners' materials (product-life 6 years, package 0.05 m³, dock/charger included)

Life Cycle materials	PRODUCE	USE	END OF LIFE

[297] E.g. https://www.gtech.co.uk/cordless-vacuum-cleaners/sw20-premium-cordless-floor-sweeper.html, featuring 7.2V battery and a 60 minutes runtime.
[298] https://www.gtech.co.uk/gtech-pro.html

Impacts per product	Virgin + recycled	Only recycled		Disposal	Recycle	Recover
Materials	g	g	g	g	g	g
Bulk Plastics	1,624	406	16	503	487	649
TecPlastics	287	0	3	89	86	115
Ferro	400	160	4	24	380	0
Non-ferro	835	334	8	50	793	0
Electronics	295	74	3	148	150	0
Misc.	0	0	0	0	0	0
Total weight	**3,440**	**974**	**34**	**814**	**1,897**	**764**

10.3.4 Robot vacuum cleaners

A robot vacuum cleaner is a self-propelling, cordless floor cleaning device capable of determining its own trajectory in cleaning and in tracking its power-charger/docking station. Consumer prices range from less than 100 Euro for models with low-end cleaning and battery performance to 700-1000 Euros for models with best cleaning and battery performance.

Manufacturers include:

- US robotics specialists such as iRobot (Roomba brand) and Neato[299] (Botvac, Connected)
- European vacuum cleaner manufacturers such as Vorwerk (DE, e.g. VR200, also owns Neato), Dyson (UK, 360 eye), Bosch (DE, Roxxter), Miele (DE, Scout)
- Asian vacuum cleaner manufacturers Samsung (Powerbot, Navibot), LG (Hombot), Techtronics industries TTI (Dirt Devil, VAX, Hoover brands), Chiuwi (ILIFE)
- Chinese smartphone manufacturer Xiaomi

Figure 53 illustrates a typical high-end robot vacuum cleaner[300]. The geometry is typically cylinder or D-shaped, diameter 34-36 cm, height 9-10 cm and includes a ‘bag-less' dustbin, 0.4 – 0.7 litre, HEPA filter, battery pack and the following active components[301]:

Motors

- 2 large drive wheels, independently driven (2xDC motor+gearbox), also drives main brushes, spring-hinged (vertical object detection+ switch) and controlled (tachometer for position feedback)
- 1 castor wheel, positioned through small DC motor (belt drive)
- 2 side-brushes each with DC motor

[299] Recently acquired by Vorwerk
[300] Note that the illustration is not an existing model but merely an illustrative drawing by VHK
[301] Note that the list only present possible component and not a complete list. Robot vacuum cleaners may have less components.

- 1 centrifugal backwards-curved fan, DC-motor driven (compare: PC cooling fan for graphics card); turbo-compressor type and cyclonic dust separation is also found.

Sensors (optional)

- IR sensors (LED + receiver), side and cliff detection
- IR receivers for tracking docking station and/or virtual wall[302]
- sensor to detect magnetic tape
- mechanical bumper ('keypad') sensors for collision detection
- piezo-electric sensor for dirt-detection
- tachometer for drive wheels
- drop sensor for drive wheels
- laser distance sensor or camera
- ultrasonic sensor
- gyroscope
- electronic compass
- fan speed control, including sensor

Printed circuit board

The Printed Circuit Board (PCB) of a high-end robot vacuum cleaner is similar to that of a low-end laptop or smartphone. The latest model from Xiaomi contains a central processing unit (CPU) in the form of an Allwinner R16 quad-core System-on-Chip (SoC), 512 Mb RAM (Random Access Memory), 4 Gb flash memory (eMMC, embedded MultiMediaCard) controlled by a 32-bit microcontroller unit (STM32 MCU) and a wireless (WiFi) module. The SoC and STM are equipped with an UART (universal asynchronous receiver-transmitter) for communication through a serial port. Also there is an UART for the LIDAR laser rangefinder.

Other models, e.g. of the Roomba 650, also feature a PCB with a large inductor and big capacitors. All other components on the PCB are small SMDs (surface mounted transistors, diodes, etc.) and connectors for wiring to and from the active components.

Communication *(optional)*:

- Remote control (battery driven controller)
- One or two push-buttons
- Display: LED-lit segments or LED-display
- Voice control
- Smart phone control: through WiFi (in HomeLAN) and/or Bluetooth

Peripherals *(optional)*:

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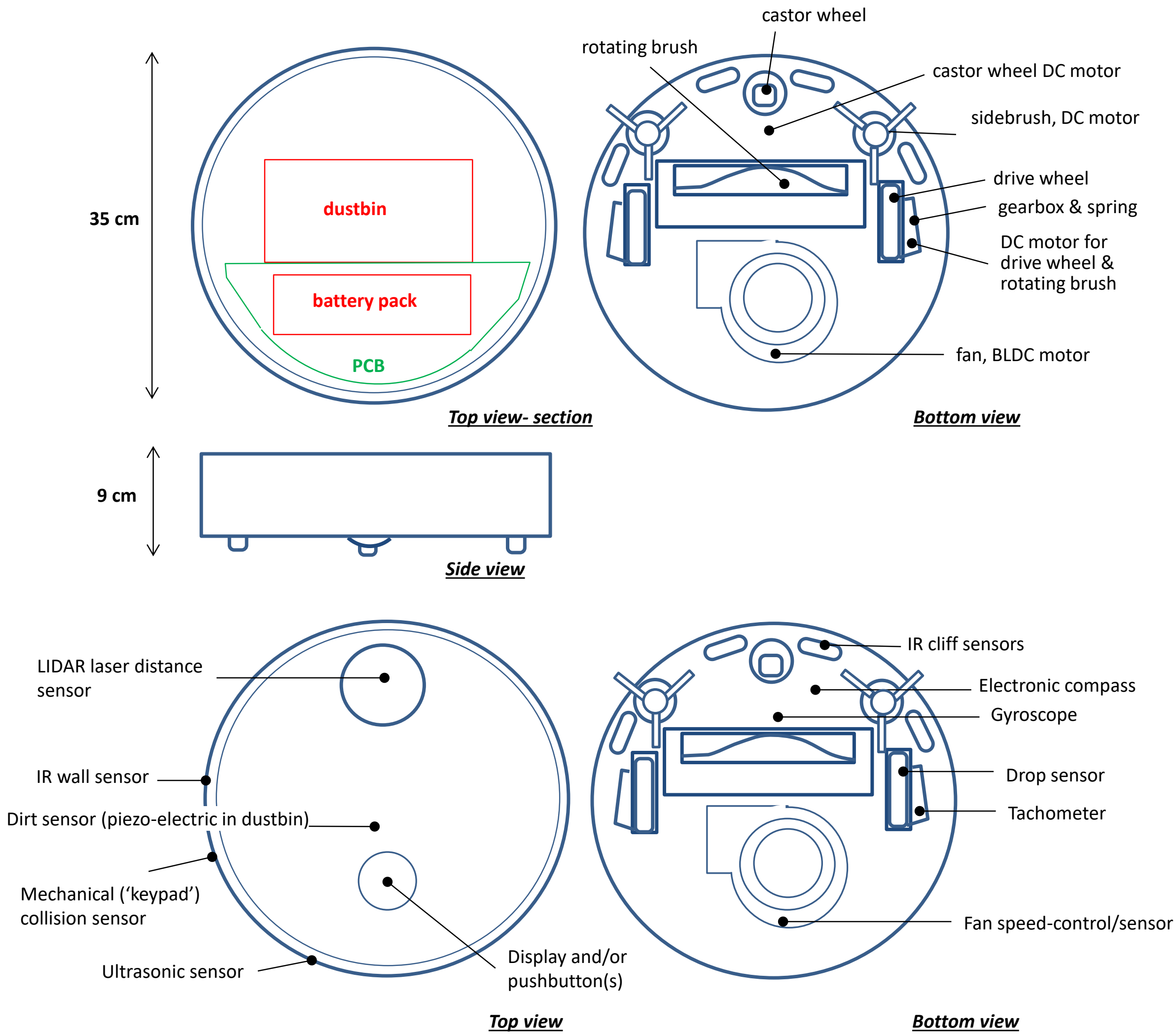
[302] Virtual wall: Active perimeter control through battery-driven IR signal, e.g. between two 'towers' (3 x 1.5V alkaline batteries, 6 months life); alternative is magnetic tape (passive control)

- Docking station with battery charger, IR transmitter (for the VC to find the way home) and possibly electromagnetics to facilitate docking.
- Virtual walls and/or magnetic tape
- Additional cleaning aids (e.g. mops)

More information on the construction and reparability of robot vacuum cleaners can be found on so-called 'teardown' and test sites[303,304].

Figure 53: Robot vacuum cleaner (illustrative only, VHK 2018)



The cleaning algorithm, i.e. the pattern in which the robot moves across the floor, varies from brand to brand and model to model. The pattern can be random or mapped following a zig-zag, crisscross, or spiralling pattern[305], or it can be controlled by simultaneous

[303] https://robomow.jimdo.com/xiaomi-mi-robot-vacuum-saugroboter-test/
[304] https://www.fictiv.com/blog/posts/the-great-robotic-vacuum-showdown-part-2-neato-xv-21
https://www.fictiv.com/blog/posts/the-great-robotic-vacuum-showdown-part-1-roomba-650-navigation-system
https://www.fictiv.com/blog/posts/the-great-robotic-vacuum-showdown-part-1-roomba-650-mechanical-system
[305] https://www.vacuumcleanerbuzz.com/articles/how-does-a-robot-vacuum-cleaner-work/

localisation and mapping (SLAM), which requires more processing power (Figure 54 to Figure 56).

For instance, the early Roomba models followed a combination of a "wall following" pattern, where it drives along walls and a "random bounce" pattern, where it crosses the floor in a straight line until it hits an obstacle and then moves away in a random direction. Newer models use the SLAM technology, which uses slightly more power due to increased processing power, but on the other hand has a much lower coverage time[306]. The algorithms, no matter which model, should all ensure that every part of the floor is covered, but it cannot be guaranteed depending on the shape and size of the room, and some places might be covered multiple times. It is therefore not comparable to the 2 double strokes assumed for manual vacuum cleaners[307].

Figure 54: Robot cleaner using a random bounce pattern to cover the surface

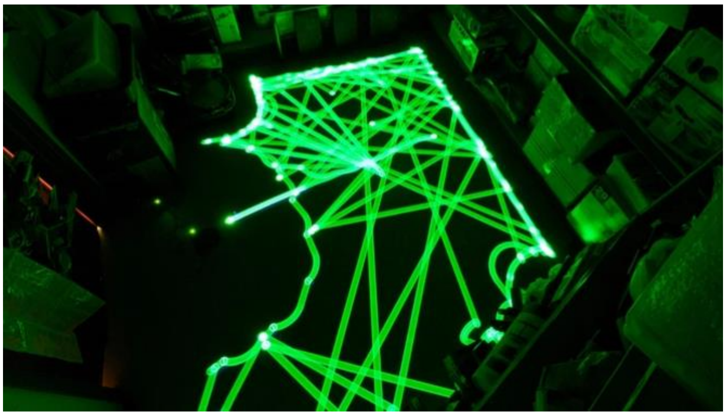
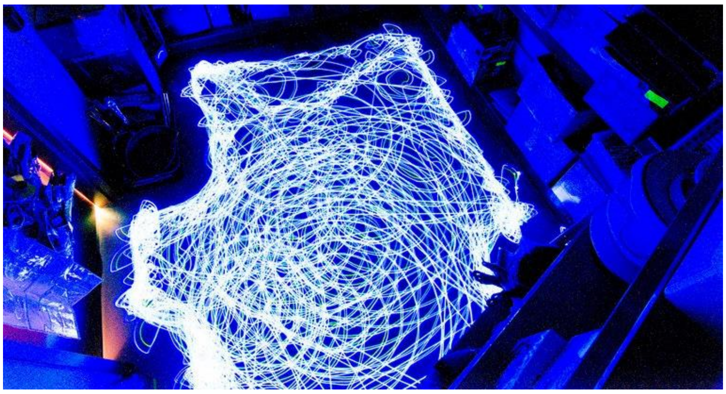


Figure 55: Robot cleaner using a random + spiralling pattern to cover the surface[308]



[306] https://infoscience.epfl.ch/record/177726/files/vacuum-taros2012-camera-ready.pdf (same as https://link.springer.com/chapter/10.1007/978-3-642-32527-4_12)
[307] https://www.cooksillustrated.com/articles/182-testing-robot-vacuums?incode=MCSCD00L0&ref=new_search_experience_3
[308] Pictures from https://www.cooksillustrated.com/articles/182-testing-robot-vacuums

Figure 56: Robot cleaner using SLAM technology to map the room

No sources have indicated any use of bags for collecting dust in the robot vacuum cleaners. Instead robot vacuums have a bin that must be emptied regularly: some suggest after every run[309], but it depends on the amount of dirt collected. Most robot cleaners have changeable filters and moving brushes that should be cleaned regularly and changed (often brush sets are available) when worn. It has not been possible to find any solid evidence of how often brushes need to be changed, but based on anecdotal evidence, once a year was assumed.

The top-three robot models in a recent German consumer test reveal a hard floor cleaning performance almost as good as that of an average (150-200 Euro) cylinder vacuum cleaner[310], while carpet cleaning performance is only half as good in comparison (Figure 57). The dust-retention of a robot cleaners is considerably worse than that of a standard vacuum cleaner. However, it should be noted that there is a difference in the standards used for robot and for a standard cylinder vacuum cleaner, so the performance is not directly comparable. Table 79 gives some general characteristics from a 2017 test by Stiftung Warentest of 6 robot models.

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309 https://taenk.dk/test-og-forbrugerliv/hus-og-have/robotstoevsugere/robotstoevsugere-fordele-og-ulemper

310 Note that the performance cannot be directly compared as there is no crevice test on hard floor for robots.

Figure 57: Dust pick-up for an average cylinder cleaner and the three best robot cleaners on flat floor without crevice (source: Stiftung Warentest 2017).

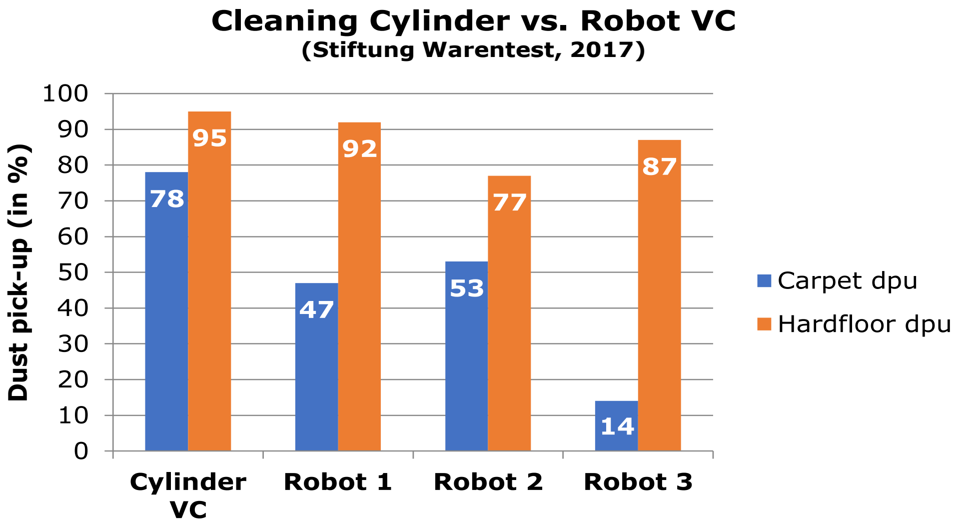


Table 79: characteristics of 6 robot vacuum cleaner models (source Stiftung Warentest 2017)

Feature	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	Average
Price in EUR	725	980	495	545	360	525	605
W declared	70	33	36	80	33	11	44
Weight (kg)	4.2	3.9	4.1	4.4	3.5	2.9	3.83
Height (cm)	9	9	10	14	9	9	10
Width (cm)	34	35	34	36	34	40	36
Time programming	Y	Y	Y	N	N	Y	
Boundary-limit	Magnet	Dual Mode	Magnet	No	Optional	Magnet	
Charging station	Y	Y	Y	Y	Y	Y & cable	
Charging time (from empty) in min	143	146	88	114	144	73	118
Operational when charged in min	47	76	63	27	90	103	68
Price of battery in EUR	99	120	50	160	90	93.5	102
Price of main brushes* or set in EUR	25*	70	50	na	50	19.9*	57
Price of filter in EUR	15	na	15	na	25	9.9	16

The high-end robot vacuum cleaners advertise 20 'Airwatts' suction power (*qv* 5-13 dm^3/min and *dP* 1-1.8 kPa), which is only 5-18% of that of an average cylinder vacuum cleaner (see Task 3). The relatively limited suction power is a key factor in the relatively low dust retention performance.

Cleaning performance not only depends on suction power. Whereas most of the cylinder vacuum cleaners have a 'passive nozzle', robot vacuum cleaners heavily rely on the use of rotating brushes and other 'active' devices to pick up dust and fibres. Consumer association tests show that many robot cleaners have problems cleaning tight corners and that especially low-end models skip parts of the designated floor area. In those cases, secondary (vacuum) cleaning will be needed. In any case, many manufacturers indicate that their robot cleaners are only suitable for hard-floor and low-pile (<1 cm) carpet cleaning.

Privacy and security aspects are important: robot vacuum cleaners are often linked to the Internet, either via WiFi and/or via smartphone. They store the complete lay-out of the home. Some types are even equipped with cameras. In short, there are many ways that privacy can be invaded if proper security measures are not taken. More information can be found in the media[311].

Energy aspects

As regards the energy consumption of robot vacuum cleaners, the winner of the 2017 German test requires around 84 Wh for one recharge. A recharge takes about 3 hours, so average power input is 28 W. At 200 cleaning cycles per year (see Task 3) this means 13.75 kWh/year. It depends on the mode, floor type and floor geometry, but for now it is assumed that this gives 1 hour of operation. The manufacturer gives an average power consumption during cleaning of 70 W[312], which suggests a recharge efficiency of 80%. This is in line with results from Vaussard et al. for Li-ion batteries, presented in Table 80 and Table 81.

The off mode is when the switch is turned off, and the cleaner is not connected to power[313]. The idle mode is when the robot is turned on, but not moving or vacuuming. The results cannot be used directly in the energy consumption analysis as it measures energy drawn from the battery, however, it does provide some valuable insights of the technologies used in each of the robot cleaners.

In order to calculate the overall energy consumption of the robot vacuum cleaners, the measurements of electricity supplied from the grid are used. Here three power modes are identified: (1) the consumption of the base station only, which corresponds to when the robot is vacuuming or otherwise away from the charging station while the power is still plugged in. (2) the station + robot idle mode, which is when the robot is placed in the charging station, but is fully charged. (3) Recharging mode, which is when the robot

[311] http://www.zeit.de/digital/datenschutz/2017-12/34c3-hack-staubsauger-iot
[312] The manufacturer indicates between 60 and 90 minutes operating time. Average power is 70W (50-60W fan, 10W brush, 2.5 W standby) in normal mode; 50W in Eco-mode (30-35W fan, 7W brush, 2.5W standby). The 70W during 1h versus the 84Wh re-charge energy suggests a recharge efficiency of 80%. The Stiftung Warentest 2017 test indicates 47 minutes operation, presumably at normal (non-ECO) mode.
[313] No switch was available for robot 7.

returns from a cleaning task and the battery is charging. No wattage was stated for the recharging mode, but the total recharging energy in kWh was given.

Table 80: Measurements of robot vacuum cleaner energy consumption when in use[314], energy from battery

Mode:	Unit	Robot 1	Robot 2	Robot 3	Robot 4	Robot 5	Robot 6	Robot 7
Off	[W]	0.0068	0.0087	0.064	0	0	0.0075	1.47
Idle	[W]	1.09	2.4	2.93	3.9	2.99	3.85	1.97
Cleaning concrete	[W]	15.6	20.5	13.03	19.98	12.9	23.2	29.95
Cleaning carpet	[W]	16.6	24.5	15.25	22.9	13.7	27.8	30.19
Recharge efficiency		0.64	0.33	0.65	0.57	0.71	0.84	0.37
Battery		Ni-MH	Ni-MH	Ni-MH	Ni-MH	Li-ion	Li-ion	Ni-MH
Mapping		Random	Random	Random	CV-SLAM	CV-SLAM	CV-SLAM	Laser SLAM

Table 81: Measurements of energy consumption from electricity grid[315]

Power mode:	Unit:	Robot 1	Robot 2	Robot 3	Robot 4	Robot 5	Robot 6	Robot 7
Base station only	[W]	1.2	3.51	1.23	1.94	0.94	0.66	0.4
Station + robot	[W]	6.13	5.95	4.32	8.06	3.19	3.61	4.63
Recharge energy	[kWh]	0.06	0.07	0.07	0.06	0.03	0.05	0.07
Cleaning time	[min]	158	63	202	104	107	102	48

The robot vacuum cleaners were not previously covered by the Standby Regulation, since many models have maintenance charging in the Station + Robot mode, which could be considered a primary function[316]. However, from January 2019 robot vacuum cleaners will be subject to the networked standby requirements. The Base station only-mode could be considered as a sort of standby, but since this might include energy for communicating with the robot, neither this state is in scope of the Standby regulation. As seen from the measurements big

differences exist for both modes and there is thus a large room for improvement. The lowest consuming "base station only" mode is below the Standby Regulation requirement of 0.5 W (robot 7), whereas the highest is 3.5 W (robot 2), which is a difference of a factor 7. For the station + robot mode (i.e. maintenance charging), the lowest consumption is

[314] https://infoscience.epfl.ch/record/206269/files/EPFL_TH6522.pdf
[315] https://link.springer.com/chapter/10.1007/978-3-642-32527-4_12
[316] FAQ for the Standby Regulation

Robot 5 and 6, which were both equipped with Li-ion batteries. All other investigated models had +4 W consumption in this mode, the highest being robot 4 with a consumption of 8 W, more than double of the Li-ion models.

Manufacturer Vorwerk[317] measured the energy consumption of 6 robot types and confirms the often high energy consumption when the robot is charged and docked. The graph below compares daily energy consumption (in Wh) during charging after one cleaning cycle in the IEC navigation room (see section 7) versus energy consumption during the time the robot is charged and docked. The least energy efficient model (RUT3) consumed 90-95 Wh for charging after a runtime of 23 minutes (implying power use during cleaning operation of around 25 W[318]) and 195 Wh for 24 h at the docking station (8 W). The least energy consuming models feature only ~50Wh for a day at the docking station (2W).

The following energy consumption is defined for the average Base Case and Best Available Technology for robot vacuum cleaner[319]. Note that the AE calculation is based the calculation method presented in task 3, and the dpu factors are based on test according to the draft standard for robots, thus not directly comparable to dpu of mains operated vacuum cleaners. In addition, the current performance is based on consumer test organisations, products for sale online and inputs from stakeholders.

Table 82. Base Case 4: Robot vacuum cleaners' Energy and performance

	BAU	BAT	BNAT
Maintenance mode consumption, charged and docked [W]	3.7	2.0	0.5
Standby consumption, dock, when cleaning [W]	0.99	0.50	0.50
dpu_c first pass	0.13	0.36	0.50
dpu_{hf} first pass	0.60	0.95	1.00
Cleaning cycle energy, carpet [Wh/cycle]	42.50	26.00	33.00
Cleaning cycle energy, hard floor [Wh/cycle]	42.50	26.00	33.00
Room coverage factor	83%	95%	95%
Average AE (Kwh/y) – Based on test room	42.43	16.94	4.27
Average AE (Kwh/y) - no carpet	42.43	17.74	5.39

Table 83. Base Case 4: Robot vacuum cleaner materials (product-life 6 years, package 0.05 m³, dock/charger included)

Life Cycle materials	PRODUCE		USE	END OF LIFE		
Materials	g	g	g	g	g	g
Bulk Plastics	2,657	664	27	824	797	1,063

[317] Presentation on energy consumption by Maike Brede (Vorwerk) at Suzhou IEC meeting, Oct. 2017. pers. comm. Vorwerk.
[318] At recharging efficiency assumned 85% (typical LI-ion, for NiMH would be lower) plus docing station/charger use during assumed 3h charging
[319] Based on inputs from stakeholders

TecPlastics	337	0	3	104	101	135
Ferro	823	329	8	49	781	0
Non-ferro	568	227	6	34	539	0
Electronics	607	152	6	304	310	0
Misc.	0	0	0	0	0	0
Total weight	**4,991**	**1,372**	**50**	**1,315**	**2,529**	**1,198**

11. Task 5: Environmental and economic impact

In accordance with the MEErP methodology task 5 identifies the relevant base cases and quantifies the current baselines in terms of economic and environmental impact for each of the base cases. The economic impact is calculated as the life cycle costs of products for the end-user, while the environmental impact is quantified in terms of energy and resource aspects. The inputs for the calculations consist of the data presented in the previous tasks.

The calculations are performed with the ErP EcoReport tool, which is an Excel sheet developed specifically to aid in the impact analysis of Energy-related Products[320]. All calculations in this task is based on the year 2016, which is the latest year with sufficient available data. The EcoReport tool includes a range of background data for calculating impacts of different materials, distribution, and disposal methods.

The calculations in EcoReport tool are made for each of the following four base cases identified for the purpose of this study:

Base case 1 (BC1): Mains-operated household vacuum cleaners

Mains-operated household vacuum cleaners are in principle the household products already covered by the regulations, including cylinder, uprights and mains-operated handstick vacuum cleaners.

Base case 2 (BC2): Commercial vacuum cleaners

Commercial vacuum cleaners are also covered by the current regulations, and are all assumed to be mains-operated.

Base case 3 (BC3): Cordless

Cordless vacuum cleaners, as defined in task 1, are battery driven, manually handled vacuum cleaners intended for floor cleaning, and are all assumed to be household.

Base case 4 (BC4): Robot vacuum cleaners

Robot vacuum cleaners are also battery driven, but can clean autonomously, not needing the interference of a human being.

5.1 Inputs for baseline calculations

The inputs needed from the previous tasks to establish a baseline scenario for each base case, is summarised in the following.

320 https://www.eup-network.de/fileadmin/user_upload/Produktgruppen/Methodology_prep_study/MEErP_study_by_vhk/20110819_Ecoreport_2011_MEErP.xls

Sales, stock and economic base data is all found in task 2, and is summarised in Table 84.

Table 84: Base case economic and market data for EcoReport, from task 2. All data is for 2016.

Description	Unit	Household mains-operated	Commercial	Cordless	Robot	From section
Product Life	years	8	5	6	6	8.3
Annual sales	mln. Units/ year	27.69	3.27	7.39	2.00	8.2
EU Stock	mln. Units	248.74	18.43	28.01	9.48	8.4
Product price	€ / unit	122.53	306.71	220.86	344.99	8.7.2
Electricity rate	€ / kWh	0.196	0.163	0.196	0.196	8.7.3
Repair and maintenance costs	€ / unit	21	31	45	74	8.7.4
Bags and filters[321]	€ / unit	65	169	40	48	
Discount rate (interest minus inflation)	%	4%	4%	4%	4%	8.7.1
Escalation rate (projected annual growth of running costs)	%	1%	1%	1%	1%	8.7.1
Present Worth Factor (PWF)	(years)	7.03	4.58	5.42	5.42	Automatically calculated in EcoReport

The present worth factor, which are automatically calculated in EcoReport is calculated by the following formula:

$$PWF = \{1 - 1/(1 + r)^N \}/r$$

Where:

- *N* is the product life

r is the discount rate minus the growth rate of running cost components (e.g. energy and water rates)

The energy consumption inputs are derived from the use patterns and formulas in task 3 and the technical product data from task 4. For all calculations the data purchased from

[321] Based on the use of 2 bags and 0.5 filter per year over the lifetime for domestic mains operated vacuum cleaners and commercial vacuum cleaner. Cordless and robots are assumed to use two filters over their lifetime.

GfK is used. The derived average energy consumption for each base case 2016 is shown in Table 85.

Table 85: Average annual energy consumption (based on AE values) for each base case in 2016.

Description	Average AE value, 2016	Presented in section:
Household mains-operated	33.66 kWh/year	10.3.1
Commercial	184.33 kWh/year	10.3.2
Cordless	21.88 kWh/year	10.3.4
Robot	42.43 kWh/year	10.3.4

In addition to the energy consumption during the use phase, the materials in the product itself contain a considerable amount of embedded energy e.g. the energy used to mine the raw materials and produce the finished materials. Some of this energy can be recovered at end of life when products are either reused, recycled, or burned. When products are landfilled this energy is lost. The necessary inputs are presented in Table 86.

Table 86: Inputs to calculate the environmental impacts and where they are presented

Description	Presented in section:
The material composition and weight of the materials for the different vacuum cleaners	10.2.1, Table 69
Description of the manufacturing process and the values used in the EcoReport tool	10.2.3 (description) and below in this section (value used in EcoReport tool)
The distribution phase and values used in the EcoReport tool (Volume of package during transportation.	Below in this section
Share and weight of materials send to re-use, recycling, incineration and landfill at End of life	9.13.1, Table 64
The environmental impacts and commodity prices of gold, copper and cobalt are:	Below in this section

The manufacturing process is assumed to be negligible or at least small compared to other impacts. Furthermore, it is not possible to add or adjust values for the manufacturing process itself. The only adjustable input in EcoReport regarding manufacturing is the percentage of sheet metal scrap. The default value is 25%, which is kept. Changing this value will only have a very limited impact on results, since this is not a widely used material in vacuum cleaners.

The distribution phase is included in the calculations but have a very limited impact on the overall analysis. This phase comprises the distribution of the packaged product and covers all activities from OEM (Original Equipment Manufacturer) components to the final customer. However, the only parameter that can be changed in EcoReport is the volume of the final package. The volume of the packaged product from the preparatory study is used in the current study. The volumes of the package for the different base cases are assumed to be:

- Mains-operated household vacuum cleaners: 0.08 m^3
- Commercial vacuum cleaners: 0.1 m^3
- Cordless vacuum cleaners: 0.05 m^3
- Robot vacuum cleaners: 0.05 m^3

In addition to the impacts calculated with EcoReport, the economic value and environmental impacts of selected raw materials are investigated. The needed inputs are:

- Gold: 250 GJ/kg, 22500 CO_2-eq/kg[322] and 35150 euro/kg[323]
- Copper: 50.9 MJ/kg, 2.7 CO_2-eq/kg[324] and 5.9 euro/kg[325]
- Cobalt: 130 MJ/kg, 100 CO_2-eq/kg[326] and 5.9 euro/kg[327]

11.1 Outputs from baseline calculations

For each base case the following environmental and economic impacts are calculated:

- Life cycle Impacts per product over its lifetime – one product
- Impacts of all appliances sold in 2016 over their lifetime – the sales in 2016 multiplied with the impacts of one product
- Impacts of all appliances in stock in 2016

All impacts are divided into five different life cycle phases[328]:

- The material phase: in this phase the weight of the materials is multiplied with the LCA Unit Indicators[329] so the impacts of using the different materials can be calculated.
- The manufacturing phase: the manufacturing phase describes the (OEM) manufacturing of metals and plastics materials. The specific weights per process are calculated automatically from the material phase.
- The distribution phase: this phase covers all distributing activities from OEM components to the final customer.

322 http://ec.europa.eu/environment/integration/research/newsalert/pdf/302na5_en.pdf
323 Price assessed in November 2017 at: http://www.infomine.com/investment/metal-prices/gold/1-day-spot/
324 EcoReport tool
325 Price assessed in November 2017 at: http://www.infomine.com/investment/metal-prices/copper/1-year/
326 http://www.iaeng.org/publication/WCE2015/WCE2015_pp863-865.pdf
327 Price assessed in September 2018 at: http://www.infomine.com/investment/metal-prices/cobalt/1-week/
328 The lifetime and life cycle are different parameters. However, the lifetime of vacuum cleaners is included in the use phase of the life cycle
329 see MEErP 2011 Methodology, Part 2

- The use phase: for the use phase, the average product life in years and the annual energy consumption are multiplied with each other to calculate the energy consumption during the whole lifetime.
- The disposal and recycling phase: these phases deal with the impacts of end of life. In the recycling phase, the recycling of the different materials is credited, and a negative value can appear (due to avoiding the production of new materials).

In addition to total energy consumption and greenhouse gas emissions, other impacts are calculated in the EcoReport Tool. All the impacts over the product life cycle are presented in Annex F for the different base cases. The impact categories are:

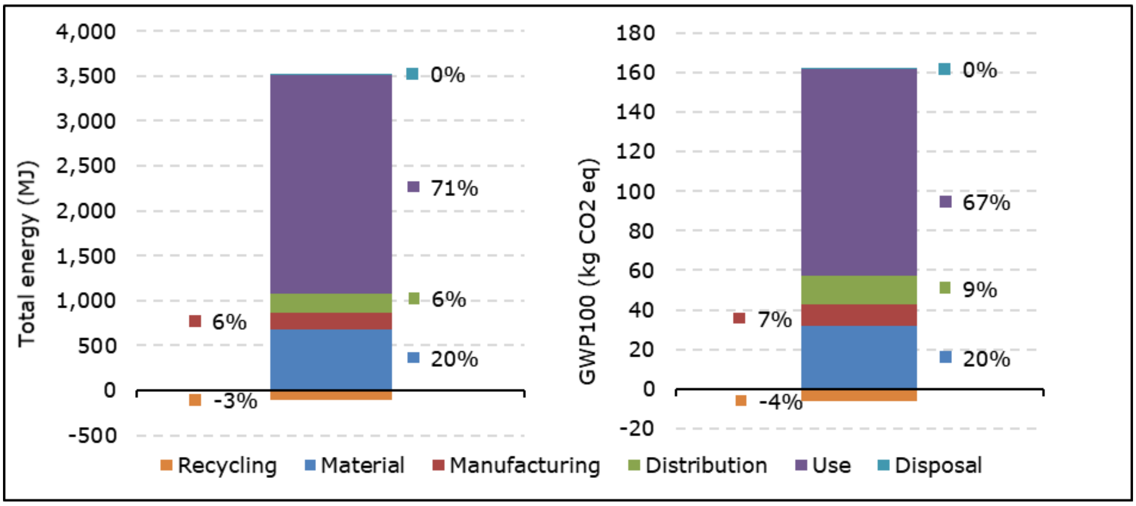
- Other Resources & Waste
    - Total Energy (MJ)
        - of which, electricity (MJ)
    - Water – process (litre)
    - Water – cooling (litre)
    - Waste, non-hazardous/ landfill (g)
    - Waste, hazardous/ incinerated (g)
- Emissions (air)
    - GWP100 (kg CO_2-eq.)
    - Acidification (g SO_2-eq.)
    - Volatile Organic Compounds (VOC) (g)
    - Persistent Organic Pollutants (ng i-Teq)
    - Heavy Metals (mg Ni eq.)
    - PAHs (mg Ni eq.)
    - Particulate Matter (g)
- Emissions (Water)
    - Heavy Metals (mg Hg/20)
    - Eutrophication (g PO_4)

All impacts are further divided in the different life phases of the product which are the material phase, manufacturing phase, distribution phase, use phase, disposal phase and the recycling phase.

11.1.1 Mains-operated household vacuum cleaners

The energy and global warming (GWP) impacts of mains-operated household vacuum cleaners over a lifetime (8 years) are presented in Figure 58.

Figure 58: Total energy consumption and emission of CO_2-eq of mains-operated vacuum cleaners – the impact of one vacuum cleaner over a lifetime



The energy consumption in the use phase of mains-operated household vacuum cleaners has decreased over the past years, but is still the greatest share of the energy consumption in the life cycle with 71% of total energy consumption. The material phase is responsible for 20% of the energy consumption. It should be noted, that if the lifetime of vacuum cleaners decreases, the importance of the material phase will increase.

The energy consumption and greenhouse gas emissions are closely connected and there is a high correlation between the parameters. For energy consumption in the use phase there is a clear correlation between energy used and CO_2 emitted. However, for materials the total energy consumption and emitted CO_2 differs depending on the material. For household mains-operated vacuum cleaner, the use phase is responsible for 67% of the global warming potential (GWP) due to emission of greenhouse gasses.

Some of the use phase impacts are caused by the use of bags. For mains-operated household vacuum cleaners the impact of the bags over a lifetime is based on the use of 2 bags[330] and 0.5 filter per year over the lifetime of 8 years, and an average weight of each bag of 0.04 kg and each filter of 0.0017 kg, which gives approximately:

- 11 MJ of total energy consumption, responsible for approximately 0.3% of the energy used
- 0.6 kg CO_2-eq emitted, responsible for approximately 0.4% of the emitted CO_2-eq

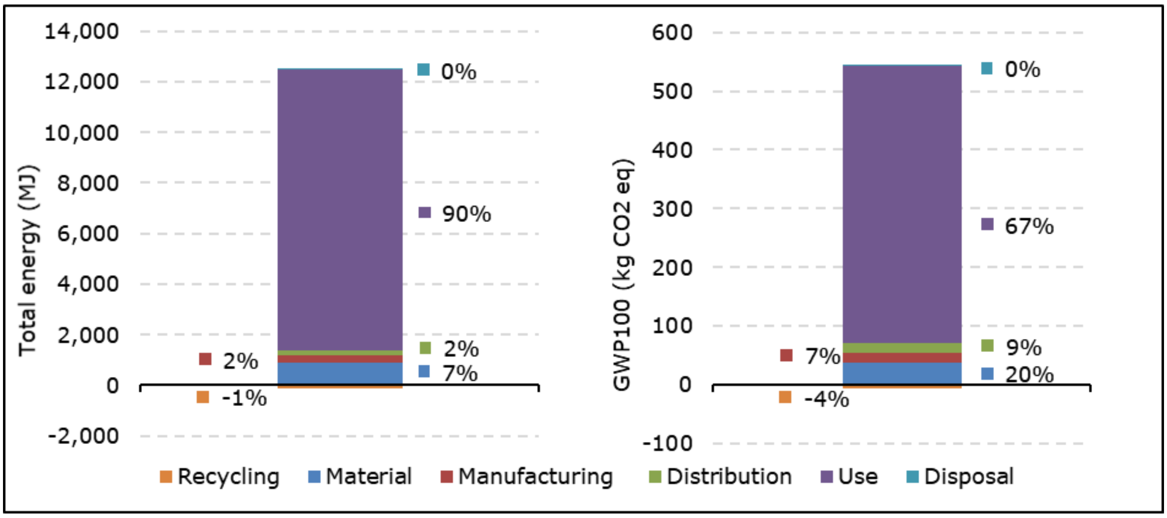
Besides total energy consumption and emission of CO_2-eq, other impacts are calculated in the EcoReport Tool. All the impacts over the life cycle are presented in Annex F. Here it is visible that the use phase has the highest impact in 6 out of the 15 impact categories, and the material phase has the highest impact in 8 of the impact categories.

[330] For the average domestic mains operated vacuum cleaner

11.1.2 Commercial vacuum cleaners

The environmental impacts of commercial vacuum cleaners over a lifetime (5 years) are presented in Figure 59.

Figure 59: Total energy consumption and emission of CO_2-eq of commercial vacuum cleaners – the impact of one vacuum cleaner over a lifetime



Commercial vaccum cleaners have a shorter lifetime than household vacuum cleaners, but commercial vaccum cleaners are used for more hours. This means the the use phase is connected with the highest energy consumption in the life cycle of commercial vacuum cleaners. The use phase is responsible for 90% of the total energy consumption in the life cycle. The material phase is responsible for 7% of the energy consumption.

The energy consumption and the emission of CO_2-eq are closely connected. For commercial vacuum cleaner, the use phase is responsible for 88% of the emission of CO_2-eq. The material phase is responsible for 7% of the emission of CO_2-eq.

Some of these impacts are caused by the use of bags. For commercial vacuum cleaners the impact of the bags over a vacuum cleaner's lifetime is based on 10 bags[331] and 0.5 filter per year over the lifetime of 5 years, and an average weight of each bag of 0.04 kg and each filter of 0.0017kg, which gives approximately:

- 14 MJ of total energy consumption, responsible for approximately 0.1% of the energy used
- 0.8 kg CO_2-eq emitted, responsible for approximately 0.2% of the emitted CO_2-eq

Besides total energy consumption and emission of CO_2-eq, other impacts are calculated in the EcoReport Tool. All the impacts over the life cycle are presented in Annex F. Here it is

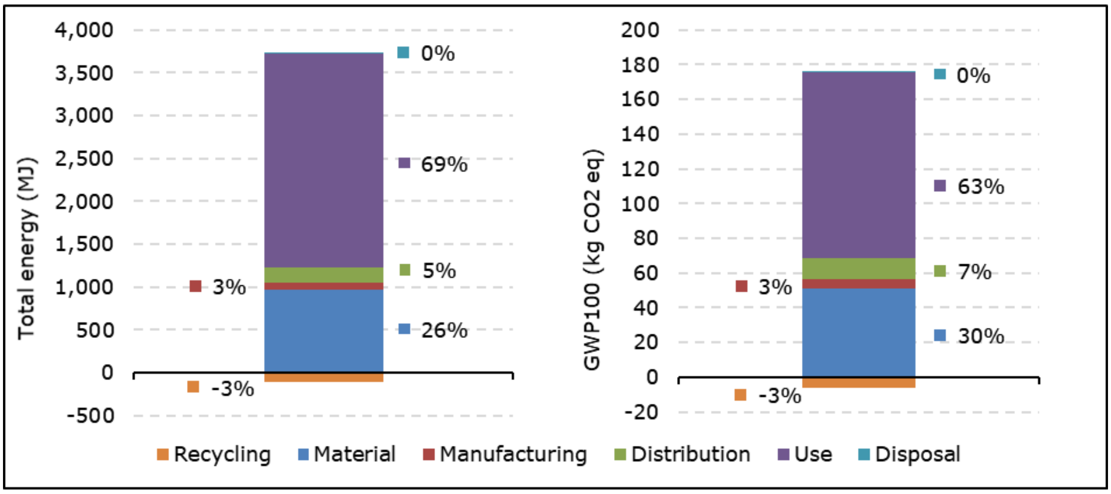
[331] For the average commercial vacuum cleaner (50% bagged)

visible that the use phase has the highest impact in 8 out of the 15 impact categories, and the material phase has the highest impact in 6 of the impact categories.

11.1.3 Cordless vacuum cleaners

The environmental impacts of commercial vacuum cleaners over a lifetime (6 years) are presented in Figure 60.

Figure 60: Total energy consumption and emission of CO_2-eq of cordless vacuum cleaners – the impact of one vacuum cleaner over a lifetime



Cordless vaccum cleaners have the second lowest overall impacts of all vacuum cleaners, as most cordless vacuum cleaners are lightweight (few materials) and have a lower energy consumption in the use phase. However, cordless have a high energy consumption in maintenance mode. The use phase of cordless vacuum cleaners is connected with the highest consumption of energy in the life cycle. The use phase is responsible for 69% of the total energy consumption in the life cycle. The material phase is responsible for 26% of the energy consumption.

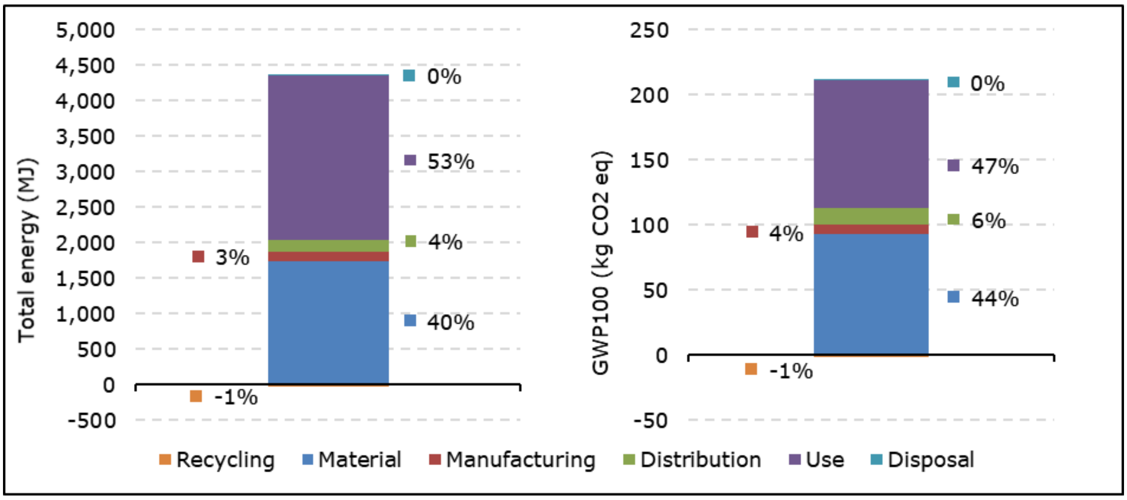
The energy consumption and the emission of CO_2-eq are closely connected. For cordless vacuum cleaners, the use phase is responsible for 63% of the emission of CO_2-eq. The material phase is responsible for 30% of the emission of CO_2-eq.

Besides total energy consumption and emission of CO_2-eq, other impacts are calculated in the EcoReport Tool. All the impacts over the life cycle are presented in Annex F. Here it is visible that the use phase has the highest impact in 5 out of the 15 impact categories, and the material phase has the highest impact in 10 of the impact categories.

11.1.4 Robot vacuum cleaners

The environmental impacts of commercial vacuum cleaners over a lifetime (6 years) are presented in Figure 61.

Figure 61: Total energy consumption and emission of CO2-eq of robot vacuum cleaners – the impact of one vacuum cleaner over a lifetime



Robot vaccum cleaners have the second highest life cycle impacts of all vacuum cleaners, as robot vacuum cleaners use a high amount of energy in the maintenance mode and also contains a high amount of PCBs. The use phase of robot cleaners is connected with the highest consumption of energy in the life cycle. The use phase is responsible for 53% of the total energy consumption in the life cycle. The material phase is responsible for 40% of the energy consumption.

For robot vacuum cleaners, the use phase is responsible for 47% of the emission of CO_2-eq. The material phase is responsible for 44% of the emission of CO_2-eq.

Besides total energy consumption and emission of CO_2-eq, other impacts are calculated in the EcoReport Tool. All the impacts over the life cycle are presented in Annex F. Here it is visible that the use phase has the highest impact in 4 out of the 15 impact categories, and the material phase has the highest impact in 11 of the impact categories.

11.1.5 EU Totals – Environmental impacts

The EU totals are the environmental impacts aggregated to EU-28 level. For the EU totals the following is calculated:

- Environmental impacts during the entire life cycle of vacuum cleaners sold in 2016 is calculated by multiplying the annual sales with the impacts of each of the base cases and presented in Table 87.
- Environmental impacts of vacuum cleaners (EU-28 stock) is calculated by multiplying the current stock with the impacts of each of the base cases and presented in Table 88.

Table 87: Environmental impacts during the entire lifetime of vacuum cleaners sold in 2016

Materials	Household mains-operated	Commercial	Cordless	Robot	Total

Bulk Plastics (kt)	32	5	2	0	39
TecPlastics (kt)	6	0	0	0	6
Ferro (kt)	1	0	0	0	2
Non-ferro (kt)	1	0	0	0	2
Electronics (kt)	1	0	1	0	1
Misc. (kt)	7	2	0	0	9
Total weight (kt)	58	9	5	0	73
Total Energy (PJ)	95	31	27	9	162
of which, electricity (PJ)	73	28	22	7	131
Water (process) (mln.m^3)	2	0	1	1	3
Water (cooling) (mln.m^3)	24	5	3	1	34
Waste, non-haz./ landfill* (kt)	80	22	20	7	130
Waste, hazardous/ incinerated* (kt)	3	1	1	0	4
GWP100 (mt CO_2-eq.)	4	1	1	0	7
Acidifying agents (AP) (kt SO_2-eq.)	20	6	6	2	35
Volatile Org. Compounds (kt)	2	1	0	0	3
Persistent Org. Pollutants (g i-Teq.)	0	0	0	0	1
Heavy Metals (ton Ni eq.)	2	0	1	1	4
PAHs (ton Ni eq.)	2	0	0	0	3
Particulate Matter (kt)	10	1	3	1	16
Heavy Metals (ton Hg/20)	2	0	1	0	3
Eutrophication (kt PO_4)	0	0	0	0	0

‘The combined energy consumption of all vacuum cleaners sold in 2016 will amount to 162 PJ during their lifetime resulting in 7 Mt CO_2-eq emitted. The highest impacts are connected with mains-operated household vacuum cleaners as they have the highest annual sales.

In Table 88 the annual impact of all vacuum cleaners (impacts by the stock for one year) is calculated which allows for comparison with the EU totals from all energy-related products (values for EU is a part of the EcoReport Tool).

Table 88: Annual environmental impacts of vacuum cleaners (EU-28 stock)

Materials	Household mains-operated	Commercial	Cordless	Robot	EU totals
Plastics (Mt)	0.120	0.020	0.014	0.006	48
Ferrous metals (Mt)	0.024	0.005	0.003	0.002	206

Non-ferrous metals (Mt)	0.024	0.007	0.006	0.001	20
Other resources & waste					
Total Energy (PJ)	159	45	21	8	75697
of which, electricity (TWh)	15	5	2	1	2800
Water (process)* (mln.m^3)	2	0	1	1	247000
Waste, non-haz./ landfill* (Mt)	0.12	0.03	0.02	0.01	2947
Waste, hazardous/ incinerated* (kton)	0.00	0.00	0.00	0.00	89
Emissions (Air)					
GWP100 (mt CO2-eq.)	7	2	1	0	5054
Acidifying agents (AP) (kt SO2eq.)	33	9	6	2	22432
Volatile Org. Compounds (kt)	3	1	0	0	8951
Persistent Org. Pollutants (g i-Teq.)	1	0	0	0	2212
Heavy Metals (ton Ni eq.)	3	1	1	1	5903
PAHs (ton Ni eq.)	2	1	1	0	1369
Particulate Matter (kt)	11	2	3	1	3522
Emissions (Water)					
Heavy Metals (ton Hg/20)	3	0	1	0	12853
Eutrophication (kt PO_4)	0	0	0	0	900

The annual energy consumption of all vacuum cleaners (in the stock in 2016) in EU-28 is calculated at 233 PJ which leads to 10.5 Mt CO_2-eq released to the atmosphere. This means that vacuum cleaners are responsible for 0.3% of the energy consumption (0.79% of the electricity consumption) and 0.21% of the CO_2-eq in the EU.

11.2 Consumption of critical raw materials and other materials of high importance

The consumption of critical raw materials (cobalt) and the consumption of other materials with high importance (gold and copper) are determined for each of the base cases. The amount of cobalt, gold and copper are calculated and the derived impacts regarding energy, emission of CO_2-eq and market value in euros are presented in Table 89.

Table 89: The amount of cobalt, gold and copper and the derived impacts regarding energy, emission of CO2-eq and market value in euros per product

Base case	Resource	g	MJ	Kg CO_2-eq	Euro
BC 1	Gold	0.02	4.13	0.37	0.58

	Copper	307.00	15.63	0.83	1.81
	Cobalt	-			
BC 2	Gold	0.001	0	0	0
	Copper	766.00	38.99	2.07	4.52
	Cobalt	-			
BC 3	Gold	0.09	22	2	3
	Copper	354.50	18.04	0.96	2.09
	Cobalt	12.00	1.56	1.20	0.61
BC 4	Gold	0.18	45.53	4.10	6.40
	Copper	224.00	11.40	0.60	1.32
	Cobalt	20.00	2.60	2.00	1.02

Cobalt, copper and gold have limited impacts compared with the impacts of the use phase of vacuum cleaners. Copper is responsible for less than 1 % of the emission of CO_2-eq over a lifetime and gold and cobalt has an even lower impact. The robotic vacuum cleaner has the highest contest of printed circuit boards, the biggest battery and thus the highest content of gold and cobalt. Even the "high" content, the combined value of the gold and cobalt in the robotic vacuum cleaner, is limited.

The impacts of the mentioned raw materials are also aggregated to EU-28 level. For the EU totals the following is calculated:

- The EU consumption of critical raw materials in vacuum cleaners is calculated by multiplying the current stock with the amount of cobalt, gold and copper in each of the base cases and presented in Table 90.

Table 90: The amount of cobalt, gold and copper and the derived impacts regarding energy, emission of CO2-eq and market value in euros for the total stock of vacuum cleaners

Base case	Resource	Tonne	PJ	Tonne	Million euros
BC 1	Gold	4	1.05	94136	147
	Copper	77845	3.96	210180	459
	Cobalt	0	0.00	0	0
BC 2	Gold	0.01	0.00	286	0
	Copper	16237	0.83	43840	96
	Cobalt	0	0.00	0	0
BC 3	Gold	2	0.44	39260	61
	Copper	6989	0.36	18871	41
	Cobalt	237	0.03	23659	12
BC 4	Gold	1	0.29	25755	40
	Copper	1408	0.07	3802	8
	Cobalt	126	0.02	12572	6

The impacts of the raw materials are limited[332] compared to the other impacts imposed by vacuum cleaners in the use phase. However, the value for the amount of cobalt, gold and copper present in the EU stock are significant. The combined impact and the value of gold and copper in all vacuum cleaners (stock) are presented in Table 91.

Table 91: The combined impact and value of gold and copper in all air conditioners (stock)

	Total Energy (PJ)	GWP100 (t CO_2-eq.)	Total (mln. €)
Gold	1.8	159437	249
Copper	5.2	276694	605
Cobalt	0.0	36231	18
Total	7.0	472362	872

Cobalt, gold and copper are accountable for an energy consumption of 7.0 PJ and an emission of 0.47 Mt of CO2-eq. The combined value of copper, gold in the EU stock amounts to 0.87 billion euros.

11.3 Life cycle cost

Based on these inputs EcoReport automatically calculates the Life cycle costs (LCC) with the following formula:

$$LCC = PP + PWF \times OE + EoL$$

Where:

- LCC is Life Cycle Costs
- PP is the purchase price of the vacuum cleaner
- OE is the operating expense and are the combined costs of electricity[333], bags, filters and the repair and maintenance.
- PWF (Present Worth Factor) is a formula described below and is based on the concept of time value of money[334].
- EoL is End of life costs (disposal costs, recycling charge) or benefit (resale) which are assumed to be negligible.

The life cycle cost is thus the cost experienced by the user, when purchasing a vacuum cleaner in 2016, with discounted energy prices throughout the lifetime of the product. The life cycle costs of the four different base cases is calculated in the EcoReport tool and presented in Table 92.

[332] Taking environmental impacts beyond energy and GWP into account, raw materials are connected to very severe environmental and health issues (gold: use of mercury; copper: acid mine drainage, water contamination in mining etc.) though these aspects are difficult to assess with MEErP methodology.
[333] The service rate is solely used for the commercial vacuum cleaners; thus, it is assumed that all household vacuum cleaners are used in households and all commercial vacuum cleaners are used at service premises.

[334] Time value of money is the idea that an amount received today is worth more than if the same amount was received at a future date.

Table 92: Life cycle costs of the three base cases (VAT included)

	Household mains-operated	Commercial	Cordless	Robot
Product price (€)	123	307	221	345
Electricity (€)	46	137	49	45
Repair & maintenance costs (€)	19	28	41	67
Bags and filters	57	96	36	44
Total (€)	244	568	347	501

For all base cases the highest expenses are connected with the purchase of the vacuum cleaner. Commercial vacuum cleaners have the highest expenses in the use phase, which is due to the extensive use of these vacuum cleaners. Cordless vacuum cleaners have the second highest expenses in the use phase, however it is approximately on par with household mains-operated vacuum cleaners and robots. Over a lifetime the mains-operated household vacuum cleaner has the lowest cost followed by cordless vacuum cleaners. The life cycle cost for each of the base cases is also aggregated to EU-28 level. For the EU totals the following is calculated:

- Annual consumer expenditure in EU-28 is calculated based on the life cycle costs per product multiplied by the annual sales and presented in Table 93.

The annual consumer expenditures in EU-28 of the different base cases are presented in Table 93. The product price and installation costs per product is multiplied by annual EU sales to arrive at the annual consumer expenditure for EU28. The lifetime electricity costs per product multiplied by the annual EU stock and divided by the lifetime to arrive at the annual consumer expenditures for electricity in the EU-28, the same is done for repair & maintenance costs.

Table 93: Annual consumer expenditure in EU28

	Household mains-operated	Commercial	Cordless	Robot	Total
Product price (mln. €)	3393	1003	1632	690	6718
Electricity (mln. €)	1667	552	254	78	2551
Repair & maintenance costs (mln. €)	656	113	211	117	1097
Bags and filters	2012	386	188	76	2662
Total (mln. €)	7728	2054	2285	961	13028

The highest costs are related to mains-operated household vacuum cleaners which have the highest annual sales. As the table above shows, every year EU consumers are spending almost 13 billion euros on purchase and operation of vacuum cleaners. Approximately 20 % (2.6 billion euros) are related to electricity expenses.

12. Task 6: Design options

According to the MEErP, Task 6 builds on the Base Case models described in Task 5 to identify design options, assess their costs and benefits, determine the combined impact of clusters of options that give the Least Life Cycle Costs (LLCC), the Best Available Technology (BAT) and the Best Not yet Available Technology (BNAT). Note that there is not enough information on commercial vacuum cleaners to make an independent cost-analysis. Hence, we will assume similar costs as for the household models, but with a higher mark-up for extra sturdiness and higher retail costs.

For materials efficiency we will, in line with the Waste Directive hierarchy, look at cost-effective individual options to *Reduce, Re-use, Recycle, Recover* and *Remove* (the 5Rs), which (under *Reduce*) includes durability aspects.

According to Article 15(6) of the Ecodesign Directive 2009/125/EC, and also taking into account the boundary conditions stipulated in Article 15 (5), the Task 6 assessments are a basis for possibly setting more stringent and/or new Ecodesign requirements. Furthermore it will be the basefor rescaling the energy label classes in accordance with the Energy Label Framework Regulation, Regulation (EU) 2017/1369.

In section 10 the various technologies and design options for components were presented in section 10.1, including possibilities to improve the circular economy aspects in section 10.2. In section 10.3 the energy, performance and price characteristics were given for BAU (Business as Usual, starting from current average), Best Available Technology (BAT) and Best Not yet Available Technology (BNAT) relating to four Base Cases:

- Household mains-operated vacuum cleaners (BC1)
- Commercial vacuum cleaners (BC2)
- Cordless vacuum cleaners (BC3)
- Robot vacuum cleaners (BC4).

The current state of the material flow over the life cycle was given in section 10.

As such, most of the quantitative basis for the design options in Task 6 is available. This section will be limited to identifying/describing the design options, present additional information where information is lacking and facilitate the impact assessment for Task 7. The design options will be presented per Base Case.

12.1 Household mains-operated vacuum cleaners (BC1)

The following design options for this category were identified and investigated:

12.1.1 Option 1: More stringent energy requirements

Investigating more stringent Ecodesign requirements on energy and more ambitious energy class categorisation is the default first step with the review of the regulations. However, while the energy consumption during the use phase is still the most important impact for most environmental impact categories (global warming, acidification, etc., see section 11), the current Ecodesign and Energy Labelling Regulations for vacuum cleaners have been very effective in reducing the average power from around 2200 W before the 2014 measures, to 900 W or less since the second tier in 2017. The Dutch consumer association *Consumentenbond* mentions that replacing an average 2013 model (at 165 kWh/year) by a new 2018 model (at just below the limit of 900W or 43 kWh/year) saves as much as 26 €/year on the electricity bill[335].

As mentioned in section 10, the average power input is now as low as 700 W. Section 8.5.1 indicates that only 7.5% of 2018 models has a rating between 800 W and 900 W. Assuming that these models would, once eliminated, 'return' to the population at just below the limit, a limit at 800 W gives EU energy savings in 2030 of lower than 0.1 TWh[336]. The extra product price that the 7.5% of current consumers would have to pay to get this 11% saving can be estimated from the difference between BAU 2016 (900W, 38 kWh, 122 €) and BAU 2018 (700 W, 30 kWh, 170 €). This comes down to a difference 48 € for a saving of 200W or 8.6 kWh/year. At 100 W these figures halve, so the consumer pays 24 € to get a 4.3 kWh/year saving during a product life of 8 years. This is a saving of 34.4 kWh over life; at an electricity rate of 0.2 €/kWh in 2015 prices, this comes down to almost 7 € saving. Net costs of this measure for the consumer are thus 24 €−7 €=17 €. For the EU, i.e. 7.5% of the estimated 200 million households owning a mains-operated vacuum cleaner (15 million), the extra cost for those households would be 255 € million in around 2030 if the measure is implemented in 2021-2022. Setting the level at a more ambitious level, e.g. at 750 W leading to a cut-off rate of around 30%, will only aggravate the situation.

In task 7 these projections will be elaborated with proper discounting, but it is easy to see that from the perspective of Life Cycle Costs there is no monetary gain in setting more stringent Ecodesign requirements for mains-operated vacuum cleaners.

12.1.2 Option 2: More realistic performance, indirectly better energy efficiency

This option aims at (indirectly) achieving better energy efficiency and functionality by prescribing more realistic and challenging performance tests. As the dust pick-up (dpu_c and dpu_{hf}) in those tests are a part of the formula for the annual energy consumption AE,

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335 'Strengere regels voor stofzuigers', Consumentengids, July/Aug. 2018, p.26-29.

336 5 kWh/annually per unit for 7,5% of ca. 30 million sales accumulating over 8 years stock life→ 5kWh x 0,075 x 30 x 8 mln.= 90 mln. kWh=0,09 TWh electricity

tougher performance tests will increase the ambition level of the Ecodesign energy limits, even if they are nominally kept at the same level.

It is proposed to add a debris test to the hard floor test, in addition to the current crevice test, to seek more differentiation. Results from Round-Robin Tests are not yet available, but it is assumed that this will lower the current dpu_{hf} values by at least 10 percentage-points (0.1), because the nozzles have to be opened more up. It will prohibit some manufacturers to continue to use special test-nozzles with full enclosure of the suction area, just to get a better crevice performance, because such a nozzle would not work for debris pick-up.

Likewise, it is proposed to add a debris pick-up test to the dust pick-up test for carpets. Debris pick-up test is also being developed for carpet, but no results are ready yet. It is important that such a test and test-conditions are formulated carefully so as not to have unwanted side-effects. It is a known phenomenon that active nozzles have a superior performance in that test over passive nozzles. On the other hand, active nozzles cost energy and for people not having pet hair in their home, passive nozzles are seen as quite sufficient for good cleaning. Hence, the requirement should not lead to additional production and use of active nozzles.

In order to compensate for the negative impact on the cleaning performance, the products need to be at least 10% more efficient, i.e. 'virtually' the power has to go from 700 W to 630 W. To go from 900 to 700 W (minus 22%) made the VC around 40% more expensive. Assuming the same proportionality, to go from 700 to 630 W (minus 10%) makes the vacuum cleaner 18% more expensive. Instead of 170 € the new average price would become 200 €. Having said that, it also has to be taken into account that timing plays a role, because price are decreasing –on average at 1% per year—due to learning effect, larger production volumes, competition, etc. So, for a new measure to be implemented in e.g. 2022, 5 years from now, the price impact is expected to be 10 € less: new price 190 € in 2022.

Please note that, as an outcome of the extensive RR Tests, the industry is currently undertaking in the context of standardisation activities, it is possible that a more real-life dimension could be added with testing of several types of carpets. However, given the large deviations in intermediate results between the different laboratories that the study team has witnessed thus far, it is not very likely that this could be implemented in a legal context of accuracy, reliability and repeatability.

12.1.3 Option 3: Recycled content and/or light-weighting

As mentioned in section 10, for a balanced circular economy it is important to address both sides of the recycling balance: increased recycled content of materials in production and increased recycling at the product's end of life. Given that already a few manufacturers are reaching a high recycled content of up to 70% for their plastics parts, demonstrating that it is economical, it is plausible that Ecodesign measures set targets for a minimum recycled content for the plastic parts, and/or that it could be included as a parameter on the energy label. As discussed in section 10.2, for metals and electronics it is functionally unacceptable to have contaminations that go with post-consumer recycled materials (even when small) or the recycled content is either already very high (e.g. 85% for most die-casts).

There are a few problems to solve: first of all, how can the legislator implement and execute control over any requirement on recycled content? The dispute has always been that either there is a burdensome administrative route with a disproportionate burden for all concerned or there should be very sophisticated lab-tests to track to contaminations and loss of properties due to recycled content. And even then, there is the problem of estimating a percentage of recycled content. Another option is to do a visual inspection of vacuum cleaners, as recycled plastics, that can withstand mechanical loads often are through-and-through black[337]. However, recycled plastic can be a mix of colours and virgin plastic can be black. Hence, it is not possibly to rely on a simple visible inspection. A practical solution could simply be statements (proof of paper) and calculations on the content of recycled plastic according to the standard under development prEN 45557:2019, however, this cannot used to ascertain the content.

A second factor is that it is not economically advantageous to circumvent a requirement to use a reasonable fraction of recycled plastics: the pellets cost around half of pellets from virgin material. The two plastics that constitute most of the plastics in vacuum cleaners are PP and ABS.

In this case, and probably in more cases where injection moulded parts are used nowadays, the solution might be simple for two reasons: first, and different from a few years ago, recycled plastics have considerably lower costs than virgin material. Second, recycled plastic granulates for injection moulding are almost without exception black. This does not mean that the vacuum cleaners need to be black, using techniques such as in-mould decoration (IMD, similar to in-mould labelling IML) the colour comes from a very thin but scratch-resistant foil that forms an outer layer. Other, less frequently used, possibilities are thermoformed inlays in injection-moulds or 2K (2-component) injection moulding.

[337] For ejection moulded plastic which often are used for vacuum cleaner.

The table below shows that currently (September 2018), the recycled ABS and PP pellets cost around half of the virgin material pellets. So even with the extra costs of colouring techniques as described above and with possibly a bit more material due to differences in mechanical properties, the use of recycled materials is economical and does not have to lead to a higher cost.

Table 94 . Prices of plastic injection moulding grades

Material	Recycled	Virgin	Difference
ABS pellets 2018	1.46	2.60	-78%
PP pellets 2018	0.89	1.77	-99%
PP pellets 2015 plastic recyclers Europe	0.90-0.95	1.43-1.50	-73%
source 2018: www.plasticsnews.com; conversion 1 lbs=0.4535 kg, 1 US $= 0.86 EUR			
prices at annual volumes of 2 to 5 million lbs.			
injection moulding grade pellets, typically colour black			
source 2015: Plastics Recyclers Europe, Increased EU Plastic recyling targets: Environmental, Economic and Social Impact Assessment, prepared by BIO, 2015			

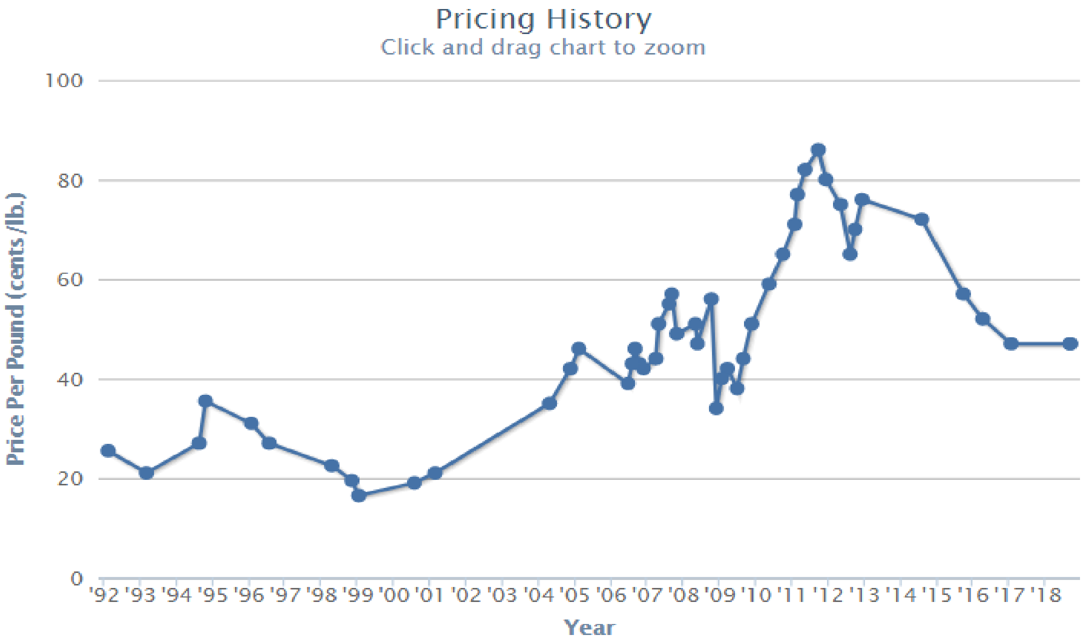
The graphs Figure 62 show that this was not always the case. In the period 2012-2015 the price difference of the raw materials was only 25%.

Figure 62: Pricing history of recycled injection grade PP (above) versus virgin PP (below). Source: www.plasticsnews.com , extract 2018)

Recycled Plastics

RESIN: PP

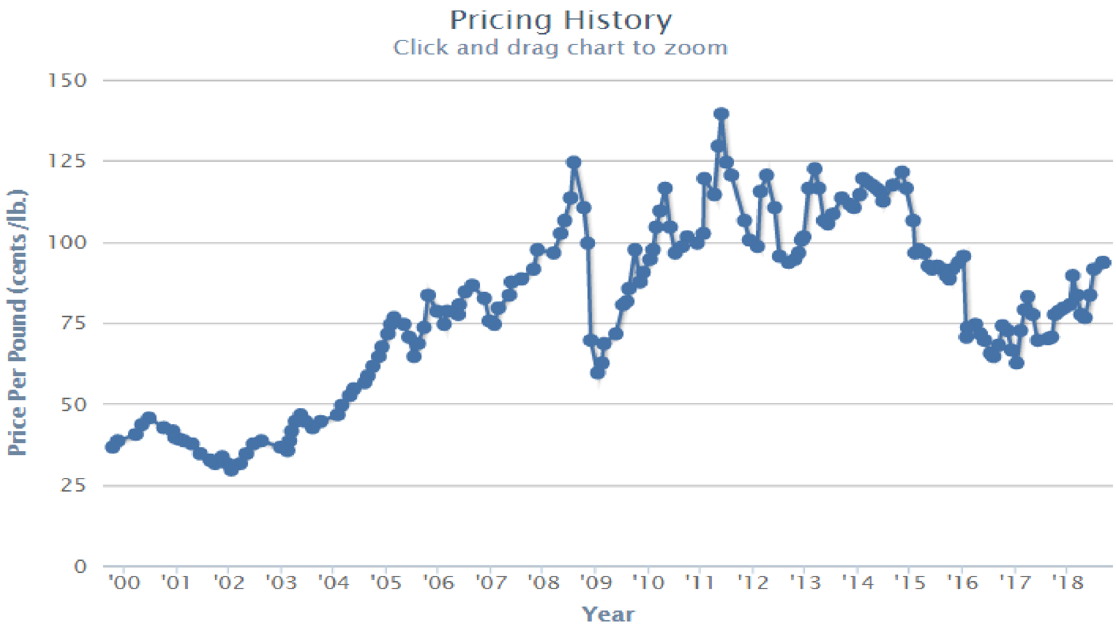
RESIN GRADE: Industrial pellets



RESIN: PP

RESIN GRADE: Homopolymer Injection GP

VOLUME: Annual volumes of about 2 million to 5 million pounds.



Recycled plastics in acceptable quality are currently available only for bulk-plastics like PE, PP, PS and ABS. This covers 90% of the plastics used in the average vacuum cleaner, but of course elastomers (rubbers) and thermosets (e.g. polyester in the motor housing) cannot be covered by recycled plastic. Also, the availability of recycled plastic is currently high, but recycled plastic is somehow a limited resource. If the demand increases the availability might decrease, but on the contrary, the economy of recycling may be improved so more plastic is recycled. Currently, a share of 60-70% seems technically feasible also for various form factors.

However, setting a simple percentage might be counter-productive, as it could lead to industry making heavier products for no other reason than to meet the percentage. In addition, it might penalize manufacturers that choose a different strategy to avoid using virgin material, i.e. to use much less to make the products lighter. For instance, at the moment 4.3 kg (3.6 kg bulk- and 0.6 technical) of plastics are used, of which 0.9 kg (22%) are assumed to come from recycled plastics. Setting a recycled content target of 70% for plastics would increase that number to 3.0 kg. So only 1.3 kg of virgin plastics will be used. Together with the recycled content of metals and packaging (1.9 kg) this means that two-thirds (66%) of the 6.8 kg product is made of recycled materials. It also means that 2.3 kg of virgin material is still required. If a 2.3 kg product, e.g. a corded stick, can achieve the same energy efficiency and performance as a 7.1 kg product than this is not just equal in avoiding environmental performance, but actually superior because also at the end of life, there is only 2.3 kg to worry about in terms of disposal, recycling, etc. Achieving a weight of only 2.3 kg probably requires the best possible material properties and might be impossible to reach with a 70% recycled content target.

Rather than setting the requirement for a share of recycled content, it is technically better to set a maximum target for the assumed virgin material, i.e. product weight minus recycled content, and give a credit for the fact that there is no material loss for the avoided kilos at end of life.

A monetary LCC calculation for this option is not necessary, because manufacturers are assumed not to encounter extra costs when setting the target for plastics only. As a positive impact it is assumed that per vacuum cleaner 2 kg extra of bulk plastics (assumed PP) will come from recycled content. The recycled PP will also have its impact for collection and recycling, as is calculated in the EcoReport, but much less.

Another option is to inform the consumers of the content of recycled plastic on the label. However, recycled plastic can both be pre- and post-consumer recycled. It is assumed that most plastic used in vacuum cleaners is pre-consumer recycled plastic as this fraction is available in a higher quality. Post-consumer recycled plastic is more difficult to use in consumer products as the quality is lower, and the risk of unwanted contaminants is higher. This means that the general application of post-consumer plastic is limited and therefore, it should be valued if manufacturers are able to include post-consumer recycled plastic in their products. Based on the prEN 45557:2019 the following calculation method could be used for calculating the content of pre- and postconsumer recycled plastic:

$$R_{content(pre-cons),t} = \left(\frac{sum\ of\ pre - consumer\ recycled\ contene\ of\ materials}{sum\ of\ materials'\ mass}\right) * 100\%$$

$$R_{content(post-cons),t} = \left(\frac{sum\ of\ post - consumer\ recycled\ contene\ of\ materials}{sum\ of\ materials'\ mass}\right) * 100\%$$

To value the greater challenge by using post-consumer recycled plastic and the environmental benefits by avoiding downgrading or incineration of plastic it is suggested to calculate a combined indication of the amount of content of recycled plastic with the following weighing and formula:

$$R_{content} = \frac{R_{content(pre-cons),t}}{2} + R_{content(post-cons),t}$$

This means that a product made of 100% pre-consumer recycled plastic obtains a mark of 50%, and a product made of 100% postconsumer plastic obtains a mark of 100%. However, although the annulled label contained a lot of information already, it is assumed that most consumers are familiar with the sign for recycling. A conceptual drawing of the mark is presented in Figure 63 below.

Figure 63: Conceptual drawing of a recycling sign

12.1.4 Option 4: Increase product life

Increasing product life is an option in the circular economy concept that aims to slow down the materials cycle of products. For instance, if the lifetime of mains household vacuum cleaners goes from 8 to 10 years, it is assumed that 25% less material resources will be needed. That is to say, if there are no negative repercussions. They can become less efficient due to wear and tear. Slowing down the introduction of new products in the market will also slow down possible energy efficiency improvements and possible savings on auxiliary materials. If the increase in product life requires the use of extra materials and/or materials that represent an extra environmental burden, that has to be taken into account in calculating the benefits.

At the moment, product life of household mains-operated vacuum cleaners is in the order of 8 years. For commercial vacuum cleaners the expected life is 5 years and for cordless and robots a life of 6 years is assumed.

There are a number of options to prolong the average product life:

- Increase the technical product-life of critical components such as the motor and hose;
- Facilitate reparability by ensuring that spare parts are available for a sufficient time after the production of a model stops (Blue Angel suggests 8 years) and that critical parts are easy to replace;
- If possible through the design, promote re-use in the sense of refurbishing[338], to give the products a second life.

The options are described in more detail hereafter, but the estimated impact of the measures would indeed increase the product life from 8 to 10 years. This means that consumers holding on to their product for 2 years more will miss out on two years of energy savings, compared to buying a more efficient product earlier.

But they will also postpone an investment decision of around 170 € for 2 years. At a going rate of 5% for consumer loans and at current inflation of 1%, the interest on such a loan would be 7 € per year. So the consumer is saving 13.20 € net by increasing product life by two years. The monetary situation may change if the product life increase involves the costs of a repair. However, in the 2016 JRC study discussed hereafter calculates that even a repair of 22 € to prolong the product life can be economical, also taking into account the technical impact.

As regards promoting re-use of the whole product, the possibilities of the regulator are limited. What can be addressed is the re-usability of filters, as will be elaborated hereafter.

Increasing technical life

As discussed in the 2016 special review study there seems to be an opportunity for increasing the durability of the motor to 550 hours without much extra costs, i.e. merely a few euros to increase the size of the carbon brushes, while optimising also thermal and mechanical design of the universal motor. The extra cost, in consumer prices is estimated at around 2 €.

[338] As mentioned in section 4, the fraction of VCs given away, or even sold for a small amount, to family, friends and charity is not included in the definition of 're-use'. Refurbishing means checking/repairing/replacing all components and ensure a full second life fort he product.

For the primary hose of a cylinder vacuum cleaner the 40,000 flexes in the current test seems adequate, as only 7.7% of consumers experience technical issues with the hose[339]. The hose is both an important and exposed part of the vacuum cleaner, subject to a lot of wear and tear directly imposed by consumers and consumers have a large influence on the durability of the hose. This means that if the requirements increase the consumers might still experience faults on the hose due to mishandling. However, the hose should be available as a spare part.

For the secondary hose of an upright vacuum cleaner it was agreed that a new test procedure would be elaborated in the standard, but no concrete proposals are on the table right now.

For cordless and robots, the battery lifetime has a great influence on the overall lifetime of these appliances. However, no official measure for battery lifetime exists, but the computer Ecodesign Regulation[340] has an information requirement of battery lifetime based on the number of charging cycles it can last. The battery capacity falls over time with the number of charging cycles, and the share of power drawn from the battery out of its total rated capacity (also called Depth of Discharge, DoD) is crucial for the lifetime in terms of the capacity left after a number of cycles. It is therefore recommended to set the requirement according to a definition including DoD and threshold for remaining capacity, for example 'after 600 charging cycles with 90% discharge in each cycle, 75% of the battery capacity should remain'[341]. This means that cordless and robots will need 2 batteries on average in their lifetime of 6 years, since they are used 200 times a year. Setting stricter requirements for the batteries may lead to oversized batteries which challenge both the comfort level for the consumer and the resource efficiency of the battery. Instead batteries should be available as a spare part.

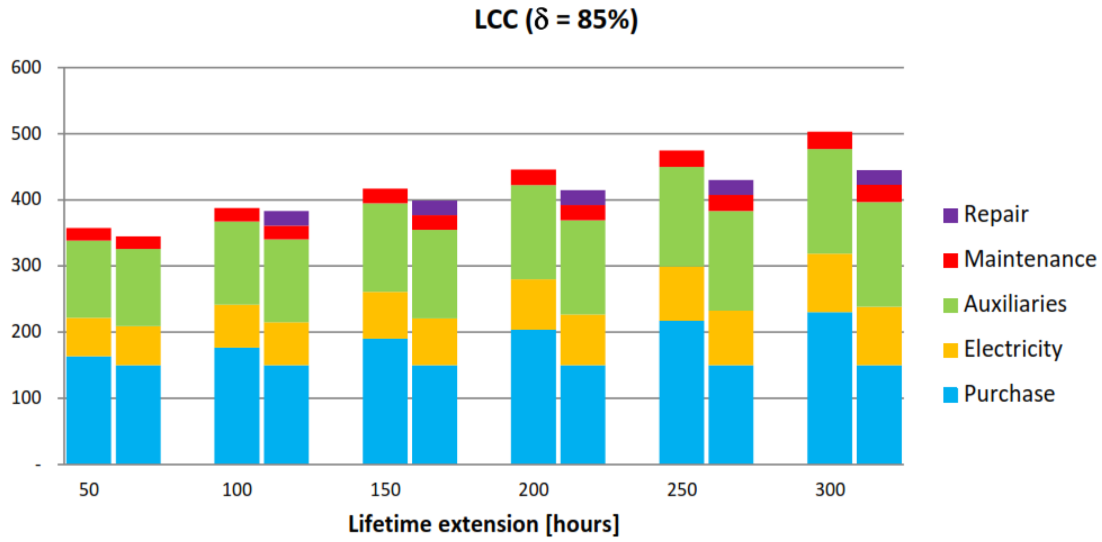
Better reparability

The 2015 JRC-IES study on durability of vacuum cleaners has calculated the life cycle costs for a better reparability of vacuum cleaners. They follow the MEErP and the Ecoreport for important parts of the study. As regards the LCC, the study assumes a base purchase price of 150 €, a repair cost of 20% of the discounted original purchase price (22 €), electricity consumption of 25 kWh/year an electricity rate of 0.205 €, an improvement multiplier (δ=85%) for the energy use of the new product that replaces the broken-down product,

339 https://www.vhk.nl/downloads/Reports/2016/VHK%20546%20FINAL%20REPORT%20VC%20Durability%20Test%2020160623.pdf
340 Commission Regulation (EU) No 617/2013 of 26 June 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for computers and computer servers. OJ L 175, 27.6.2013, p. 13–33
341 EN 61960:2011 could be used for measuring battery endurance in cycles (part 7.6.2 or 7.6.3 in the standard)

etc. For various scenarios of lifetime extension the results are shown in the figure below. It shows that for this product in all cases the Life Cycle Costs with the repair are lower.

Figure 64: LCC of the base-case (first column) and the durable scenario (second column) (source: JRC-IES 2015)



One of the conditions for these repair-scenarios is of course that the repair is feasible because the spare part is still available. For other Ecodesign products the availability of spare parts, after the model has seized to be produced, is to be guaranteed for up to 7 years. Also in this case, a period of 7 or 8 years, 8 years being a condition in the Blue Angel environmental mark, seem reasonable.

Another condition is that the labour cost will be limited or at least a part of the repairs can be done by the consumer/user of the product. In that sense, it seems reasonable to demand that the most repair-prone products, like hoses, must be replaceable without special tools.

Re-use

Studies on the re-use of small household appliances are scarce. Prakash et al. (2016)[342] discusses the product life and grounds for discarding hand mixers (first-hand service life 10-11 years) and electric kettles (first-hand service life 5-7 years). 63% of discarded mixers and 71% of discarded kettles were fully functional, 22% of mixers and 11% of kettles showed defects but still worked and 11-13% didn't work. As method of discarding these small appliances 7.8% of respondents mentioned re-use (sold or given away).

[342] Prakash, S., Stamminger, R. et al., Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz", Umweltbundesamt Texte, 11/2016.

In the 2016 preparatory Ecodesign study on washing machines[343] the authors found two references for what was called 're-use' (sold or given away) of large household appliances: Magalani et al. 2012[344] found that in Italy 8% of discarded products were re-used. A WRAP 2011 study for the UK estimates that 3% of large household appliances are re-used, after discounting for the fact that 25% of products offered for re-use are unrepairable[345].

Based on this (scarce) information, it is estimated that for 7 to 8% of smaller appliances like vacuum cleaners there is a second owner. Like with large household appliances there are no studies that regard how long the average second-hand life of a vacuum cleaner in the EU actually is. The study team assumes that the second owner should be able to use the vacuum cleaner at least 2-3 years[346]. As mentioned before, in the context of this preparatory study for Ecodesign and Energy Labelling measures for new products, giving away old vacuum cleaners is not relevant, because it cannot be changed through regulation. What could be relevant is where re-use of the whole product requires a full refurbishing, preparing the product for a true second life. Such an activity could not be identified, but because we cannot exclude it, the EcoReport assumes that full refurbishment applies to 1%.

What is relevant is the re-usability of filters, e.g. at least the HEPA and motor filter. The current cost of a HEPA filter is in the range of 10-35 €, depending on brand and type. The motor filter is normally washable but a new one costs 5-15 €. Manufacturers would recommend replacing at least the HEPA filter annually or bi-annually, so making them re-usable saves on monetary costs, but also on materials and energy as clogged filters have a higher air resistance (up to 2% energy savings is expected). The latter energy saving is especially true for the many users that never change their HEPA filter[347]. As regards the bag versus bagless discussion, the past years have taught that there is a market for both and that the regulator should not interfere. What can be done is giving the information to the consumer, e.g. via the energy label, whether a product is bagged or bagless, however, this information is often very easily accessible for the consumer already.

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[343] Boyano Larriba, A., Cordella, M., Espinosa Martinez, M., Villanueva Krzyzaniak, A., Graulich, K., Rüdinauer, I., Alborzi, F., Hook, I. and Stamminger, R., Ecodesign and Energy Label for household washing machines and washer dryers, EUR 28809 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 97892-79-74183-8, doi:10.2760/029939, JRC109033

[344] Magalani, F.; Huisman, J. & Wang, F. (2012). Household WEEE generated in Italy: Analysis on volumes & consumer disposal behaviour for waste electrical and electronic equipment.
Available at http://www.weeeforum.org/system/files/2012_ecodom_weee_arising_in_italy_en.pdf.

[345] WRAP (ed.). Benefits of Reuse: Case Study: Electrical Items, 2011. Available at http://www.wrap.org.uk/sites/files/wrap/Electricals%20reuse_final.pdf.

[346] This implies the 8 years product life for the cylinder VC is composed of 93% at a service life of 7.85 years plus 7 % at a service life (first- and second-hand) of 10 years.

[347] Stakeholder feedback in first stakeholder meeting 2018.

12.1.5 Option 5: Recycling

The technical recycling options have been discussed extensively in section 10.2. Currently 48% of the product and use phase waste of BC1 is recycled (4.1 of 8.7 kg), of which one third of the plastics and auxiliaries (filters and filter bags), most of the metals and cardboard packaging, very little of the electronics (just the precious and critical materials if present).

The main challenge for BC1 is increasing the recycled fraction of the 4.3 kg plastics in the product and 1.5 kg (also mainly plastic) auxiliaries. Of this total 5.8 kg plastic fraction in the disposed product, 1.7 kg (30%) goes to recycling, 1.8 kg (32%) to heat recovery, 2.1 kg (38%) goes to landfill or incineration without heat recovery. The policy objective in the WEEE will be to achieve 65% recycling of small appliances like the vacuum cleaner. The waste policy objective is to abolish landfill in the EU (although there might always be a small fraction of illegal dumping). Putting this all together means that 3.64 kg (65%), almost 2 kg extra should go to recycling and the rest to heat recovery[348].

In the Ecoreport tool the credit for recycling is 40% of all impacts. In this case it is proposed to take PP as the reference plastic[349]. With over 30 million sales and 8 years lifetime (in 2022) the saved impacts from 2022 until 2030 would be 40% of the impacts of 240 million kg PP, i.e. amongst others 7 PJ primary energy and 192 million kg CO_2 equivalent.

Recover means that the product is incinerated with waste heat recovery. Most vacuum cleaners, without batteries, do not contain toxic materials and can safely follow that route, even if the vacuum cleaners are not collected separately as WEEE this will happen. For discarded PP the combustion value is still some 75-80% of the combustion value of the oil feedstock that was needed for its production. For ABS this is around 50-60%. The metals, if not removed beforehand, can still be found in the remains and ashes and thus will always be used for recycling.

At the moment, 40% of plastics is incinerated with heat recovery. To ensure that heat recovery can take place and products don't go to landfill or non-recovery (hazardous) incineration it is important that no hazardous materials such as those mentioned in RoHS and REACH are included (see Blue Angel requirements). Also halogenated flame retardants should be avoided. Once the Member States have met the waste target of abolishing landfill, the share of incineration with heat recovery versus the landfill will not decrease.

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348 Of course, in combination with the previous design option of re-using the filters it might not be 2 kg but less, but for a first calculation 2 kg is taken.

349 Main impacts Ecoreport per kg PP: 73 MJ primary energy of which 7 MJ electric and 53 MJ feedstock, 4 g hazardous waste, 28 g non-hazardous waste, 2kg CO2 eq. (GWP), 6 g SO2 eq. (Acidification), 1 g particulates (PM), 165 g phosphate eq. (eutrophication).

12.2 Commercial mains-operated vacuum cleaners (BC2)

For commercial mains-operated vacuum cleaners, Base Case 2, the same options and considerations apply as for Base Case 1. But the absolute numbers of the impacts will be different, in accordance with the data supplied in section 10.3.2.

12.3 Cordless vacuum cleaners (BC3)

The most important design option is whether or not to include cordless vacuum cleaners in the scope. This adds to the energy and material consumption in the scope and thus the energy and material saving potentials. At the moment they are the fastest growing segment in the vacuum cleaner market. Most models have a performance that would qualify them as 'hard floor only', because they do not meet the performance requirements for carpet cleaning, but there are now a few models that would qualify as 'general purpose' and at least one leading manufacturer, Dyson, who claims to no longer invest in new corded machines but only develop cordless vacuum cleaners. These are all important reasons to take the cordless vacuum cleaners on board.

Option 1: Power limits for maintenance mode

The most important energy saving option for cordless vacuum cleaners is the maintenance mode power consumption, i.e. when the battery is fully charged and in a docking station. According to section 10, the power consumption in this mode varies between less than 1 W and 8 W, depending on the model. The estimated market average is 2.6W or rather 50% of the total energy consumption of the vacuum cleaner (21 kWh on 41 kWh/year total). As discussed in section 10, there is no technical reason for this. For Li-ion batteries there is no 'trickle charge' and even for NiHM its merits from a long-life point of view are questionable. This option entails to bring down the maintenance mode (charged and docked) power to 0.5-1 W. Thus saving 8 kWh/year (13 € over product life in energy) at no cost at all.

Options 2 and 3

Options and considerations under option 2 to 3 of BC1 apply, albeit with different figures.

Option 4

As regards option 4, the increase of product life, the battery is a highly relevant additional issue on top of what is mentioned with BC1. The battery life of cordless and robot models is relevant for the lifetime and thus the resource efficiency. Given a motor life of 550 hours for cordless vacuum cleaners, 550 hours battery life under normal usage conditions also seems reasonable. At the moment this is only feasible with a Li-ion battery (500-1000 cycles, no memory effect[350]). A battery-life to match a 1200 hour robot motor life is not technically feasible at the moment; 600 hours is probably all that can be achieved at a

[350] Memory effect relates to a diminished battery capacity in time, as a result of supoptimal (incomplete, or too soon) charging

reasonable size of the battery of around 0.5 kg. Potential buyers will have to be made aware that the battery will have to be replaced every 2-3 years, probably at a cost of around 80-100 € for Li-ion. NiMH may have to be replaced twice as much for the same lifetime, but it also costs half.

Option 5

Option 5, recycling, could be extended with considerations regarding batteries:

In addition to what was said with BC1, the batteries are a separate issue for recycling. Li-ion is now the most common type. The challenge is to recover the cobalt, typically 10-20%, from the battery. This is technically difficult[351], but cobalt is rare and much in demand. This rising demand made its price triple in recent years to currently 30 $/lbs (57 €/kg). With a typical vacuum cleaner battery weighing 0.5 kg and thus cobalt 0.05-0.1 kg this means that there is 2.85 € to 5.70 € to gain there[352]. Another possibility is to use Li-ion batteries with lower share of cobalt, i.e. NCA (2-4% Co) instead of NMC (4--8% Co).

The second most common battery type is NiMH (Nickel Metal Hydride), which contains typically 35% of nickel and possibly up to 15% of cobalt. Also here the recycling process is challenging but worthwhile[353]. It is possible to set a limit of e.g. 20% cobalt on the battery. This would merely be pre-emptive, i.e. to avoid that certain Li-ion batteries such as LCO (Lithium Cobalt Oxide) types would ever be used. At the moment there would be no impact from such a measure.

According to the Battery Directive 2006/66/EC the EU Member States should, from 2016, collect 45% of the batteries in the waste stream and of this 50% should be recycled. Note that from 1.1.2017 it is forbidden to use Ni-Cd batteries or other types containing lead, mercury and cadmium for vacuum cleaners. Apart from helping Member States to meet Battery Directive targets the Ecodesign measures could also aid the WEEE targets by prescribing easy dismounting of batteries and easy disassembly of the PCBs of robot vacuum cleaners.

12.4 Household robot vacuum cleaners

All the options and considerations of BC3 apply, but with different impacts. These impacts can be seen in section 10.3. Only as regards option 1 a small modification is proposed: As many robot vacuum cleaners should be able to wake up on a signal of their Local Area Network (WOL=Wake-up On LAN) it is reasonable to set the maintenance mode limit at 2 W instead of 0.5 W, in accordance with the 2019 networked standby requirements.

[351]https://www.researchgate.net/publication/259645071_Recycling_of_Spent_Lithium-Ion_Battery_A_Critical_Review
[352] https://www.bloomberg.com/news/articles/2017-12-01/the-cobalt-crunch-for-electric-cars-could-be-solved-in-suburbia
[353] Also see https://csm.umicore.com/en/recycling/battery-recycling/our-recycling-process

13. Task 7: Scenarios

This chapter consists of two main parts, one retrospective and one forward-looking:

- Evaluation of the existing regulations in accordance with the Better Regulation parameters efficiency, effectiveness and relevance
- Scenarios and recommendations for amending and improving the regulations. Scenarios for both energy and resource efficiency are included in this section.

Evaluation is a tool to help the Commission learn about the functioning of EU interventions and to assess their actual performance compared to initial expectations. By evaluating, the Commission takes a critical look at whether EU activities are fit for purpose and deliver their intended objectives at minimum cost (i.e. avoiding unnecessary costs or burdens). Since the evaluation is retrospective and based on collected market data, it includes the previous, annulled Energy Labelling Regulation and the effect it had on the market.

The scenario section presents the options for how the Regulations can be further improved and how they can aid in better environmental performance of vacuum cleaners. Options are presented for two different aspects separately: energy efficiency and resource efficiency. These aspects are analysed separately, and in the end, recommendations are given as to what combination of energy and resource requirements are favourable based on both cost and environmental impact.

13.1 Better Regulation evaluation

The purpose of this section is to evaluate the effect of the current Ecodesign Regulation and the annulled Energy Labelling Regulation for vacuum cleaners, and compare the results obtained so far with the expectations in the impact assessment. In addition, it analyses how well the regulations have been able to solve the market failures identified in the impact assessment.

The evaluation will focus on answering questions regarding:

- Effectiveness of the regulations. What has been the impact of the regulations so far and have the objectives of the policy measures been achieved?
- Efficiency of the regulations. Have the regulations been cost effective and are the costs justified?
- Relevance of the regulation. Are the regulations still relevant and have the original objectives been appropriate?

These questions are based on the official template[354] and the Better Regulation Toolbox[355],

[354] https://ec.europa.eu/info/sites/info/files/file_import/better-regulation-toolbox-47_en_0.pdf
[355] https://ec.europa.eu/info/files/better-regulation-toolbox-47_en

and the specific questions answered in each of the following sections, are the questions from these sources.

The existing regulations are the Ecodesign Regulation and the annulled Energy Labelling Regulation for vacuum cleaners Regulation EU 666/2013 and regulation EU 665/2013 respectively. The aim of the regulations was to provide dynamic incentives for suppliers to improve the energy efficiency of vacuum cleaner for household and professional use and to accelerate market transformation towards energy-efficient technologies.

According to the current Ecodesign Regulation the annual electricity consumption of vacuum cleaners covered by the regulation was 18 TWh in the Union in 2005. Without the regulations the annual electricity consumption was predicted to be 34 TWh in 2020. In addition, the preparatory study showed that it is possible to significantly reduce the electricity consumption of vacuum cleaners.

13.1.1 Description of the current regulations and their objectives

The Ecodesign Regulation and the annulled Energy Labelling Regulation have been prepared in a parallel process with the aim to assess the possibilities of implementing Ecodesign and Energy Labelling requirements for vacuum cleaners.

The two regulations are intended to work in synergy; the Ecodesign Regulation pushing the market towards higher energy efficiency by removing the least efficient vacuum cleaners from the market, and the energy label pulling the market towards even higher energy efficiency by providing consumers with the necessary information to identify the most energy efficient vacuum cleaners on the market.

The Ecodesign Regulation for vacuum cleaners entered into force in 2013 and sets maximum limits for annual energy consumption in two tiers from respectively 1 September 2014 and 1 September 2017. In addition, the two tiers include maximum limit for rated input power, and minimum levels for dust pick-up. The second tier also include requirements regarding dust re-emission, sound power level, durability of the hose and operational motor lifetime.

The annulled Energy Labelling Regulation also entered into force in 2013. According to the Energy Labelling Regulation vacuum cleaners should have, when displayed for sale, from 1 September 2015 bear an energy label with an A-G scale and from 1 September 2017 an energy label with three more ambitious energy classes on top of the A-class (i.e. A+, A++, and A+++). From 18 January 2019 the energy label may no longer be displayed on vacuum cleaners.

See a more detailed description of the current regulations in section 7.2.1.

The objectives of the current regulations are:

- Correcting the identified market failures in the preparatory study and impact assessment
- Reducing energy consumption and related co_2 and pollutant emissions due to vacuum cleaners following Community environmental priorities, such as those set out in decision 1600/2002/EC or in the Commission's European climate change programme (ECCP)
- Promoting energy efficiency hence contribute to security of supply in the framework of the community objective of saving 20% of the EU's energy consumption by 2020.

More specifically, the objectives of the current regulations were to reduce the energy consumption of vacuum cleaners by 20% (from 34 to 19 TWh/year in 2020) and CO_2-emissions from 11 to 7 Mt/year.

According to the Impact Assessment[356] the main market failure related to vacuum cleaners was the lack of consumer information on energy use and cleaning performance. As a result, most consumers took the electric power input (in W) as a proxy for cleaning performance.

The power consumption of vacuum cleaners had been rising from 1275 W in 1990 to around 1500 W in 2005 and was expected to reach 2300 W in 2020 (without measures). Non-household 'professional' vacuum cleaners were more efficient (30% less power for a better performance) but still had a potential for energy savings. At the same time a decrease in the energy efficiency was seen, which meant the higher power ratings were not justified by better cleaning performance. High power rating was actually a sales argument in itself.

Over the past decades this led to low price, high-power but low-performance vacuum cleaners, mainly from China, flooding the EU market and more than doubling the societal energy consumption of vacuum cleaners. Vacuum cleaners were therefore a significant contributor to household's energy consumption and a candidate for Ecodesign measures.

13.1.2 Baseline and point of comparison

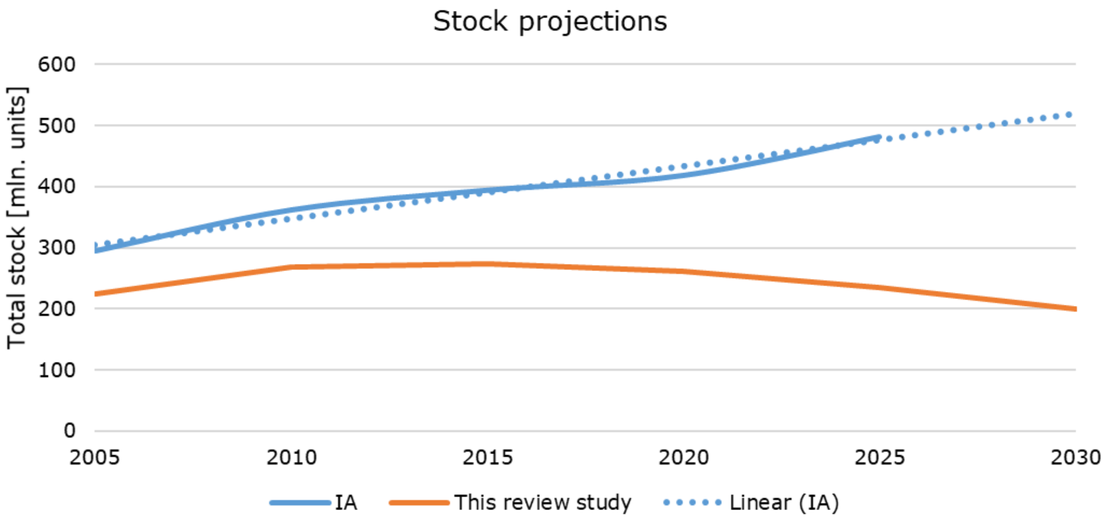
The baseline for the evaluation is the market without the implementation of the current Ecodesign Regulation and the annulled Energy Labelling Regulation. The Impact Assessment accompanying the actual regulations is normally an important data source for determination of the baseline. However, the stock and sales figures used in the 2013 Impact Assessment for vacuum cleaners is generally very high compared to the newest available data. Therefore, the stock model from this review study is used as a baseline for

[356] Executive summary of the Impact assessment accompanying the documents Commission Regulation with regard to Ecodesign requirements for vacuum cleaners and Commission Delegated Regulation with regard to Energy Labelling of vacuum cleaners http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2013/swd_2013_0241_en.pdf

the evaluation in this section, and the data from the 2013 Impact Assessment is scaled to match. Only vacuum cleaner types in scope of the current regulation is evaluated, and cordless and robot vacuums are thus excluded from all analysis.

The projected stock reduction post-2015 is not due to a decrease in overall vacuum sales, but because a larger percentage of the total sales is moved to robots and cordless. The stock data appear from Figure 65.

Figure 65: Comparison of stock in 2013 Impact Assessment (IA) and the stock estimates used in this study



One of the objectives of the evaluation is to compare the effect of the current regulations with the foreseen effects when the regulations were adopted, which means the result of the 2013 Impact Assessment. The estimations in the Impact Assessment are generally good, but difficult to use for comparison, as none of the policy options included in the Impact Assessment are used in the regulations. The policy options used as for comparison is PO 5, Sub-option 1, which is the most ambitious option addressed in the Impact Assessment[357].

Furthermore, no unit prices were reported in the Impact Assessment, which only reports total user expenditure for the stock. Since other sales and stock numbers are used in the Impact Assessment, the results can therefore not be compared directly. Instead data from this review study was used and scaled with the data in the Impact Assessment.

The following terminology is used in the following analysis and figures:

- BAU0 = scenario without the current regulation,
- BAU = scenario with the current regulation,
- IA SO1 = scenario predicted in the 2013 Impact Assessment PO 5, sub-option 1.

[357] This sup-options includes power caps of 1350 W in the first tier and 1050 in the second tier which is less ambitious than the actual requirements in the regulation

13.1.3 Effectiveness

Evaluation question 1: What have been the effects of the regulations?

Energy savings and reduction of CO_2-emissions

The regulations have transformed the market towards a higher energy efficiency and have resulted in electricity savings and reduction of CO_2-emissions. Compared to the expectations in the Impact Assessment this study shows for key parameters very similar results, however for a lower stock. Comparison of results appears in Table 95 and Figure 66 and Figure 67.

Table 95: Comparison of results of this study to results from the 2013 Impact Assessment regarding cumulative savings of key parameters

Study	Parameter	2015	2020	2025	2030
This review study	Electric savings [TWh]	36	138	276	384
	GHG emissions [Mt CO_2-eq]	15	54	105	151
	User expenditure [bln. €]	7	28	57	85
IA	Electric savings [TWh]	47	153	280	377
	GHG emissions [Mt CO_2-eq]	19	60	107	148

Regarding the development of the total annual energy consumption and CO_2-emissions the current regulations have already resulted in significant savings and further savings is expected in the coming years. The savings of the regulations are very much in line with the expectations in the 2013 Impact Assessment with a tendency that the regulations could achieve more savings in the longer-term than estimated in the Impact Assessment.

Figure 66: Total energy consumption for various scenarios (based on stock)

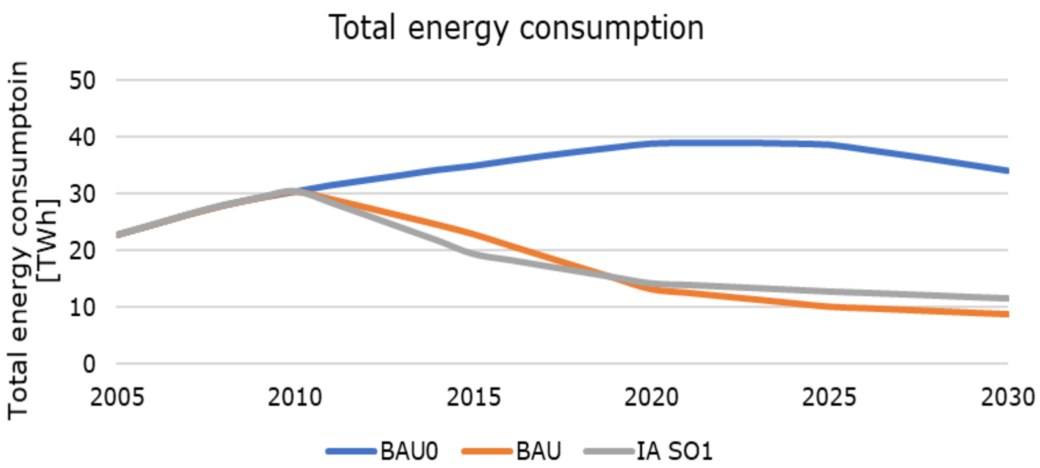
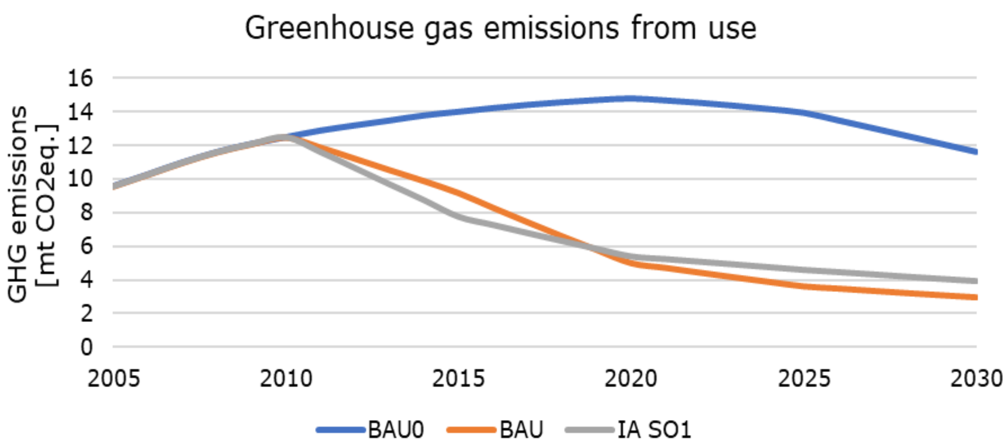


Figure 67: Greenhouse gas emissions related to electricity consumption in the use phase



<u>Annual energy consumption (stock)</u>

The power limits in the second tier of the Ecodesign Regulation have reduced the rated input power of vacuum cleaners. This has contributed to a large decrease in the annual energy consumption of the vacuum cleaners in scope of the regulations.

In the period from 2010-2016 the annual energy consumption of vacuum cleaners on the market shows a declining trend as seen Figure 68. This is the case for all types of vacuum cleaners covered by the regulations. Based on the market average, the annual energy consumption decreased from around 78 kWh/year in 2010 for household cylinder vacuum cleaners to 34 kWh/year in 2016. For upright vacuums, it declined from around 74 to 29 kWh/year. For handstick mains it decreased from 44 to 30 kWh/year. This means that the energy consumption of the vacuum cleaners in scope declined by more than 50% on average[358] in just 6 years.

[358] Based on market data from GfK

The impact of the current regulations on energy consumption must be attributed to both the Ecodesign power limit and the annulled Energy Labelling Regulation.

The Ecodesign power limit has resulted in a decrease of the annual energy consumption from the 2010 values down to the limit values of 62 kWh/year by 2030 and 43 kWh/year by 2017. However, the annual energy consumption for all vacuum cleaner types covered by the Regulations have decreased further than this limit as shown in Figure 68. This illustrates that the annulled Energy Labelling Regulation has created a market pull beyond the Ecodesign power limits, and approximately 20% of the savings over the years are expected to be attributed to the annulled Energy Labelling Regulation as illustrated in Figure 69. This is based on the assumption that all savings beyond ecodesign are a result of the label market pull. The dotted line in the graph illustrates the Ecodesign limits. All savings from the previous BAU0 graph down to the dotted line are expected to be the result of ecodesign, while the savings from the dotted line down to the BAU graph are expected to be the result of the energy label.

Figure 68: Average annual energy consumption of household VC in stock and impact of Ecodesign and Energy Labelling Regulations

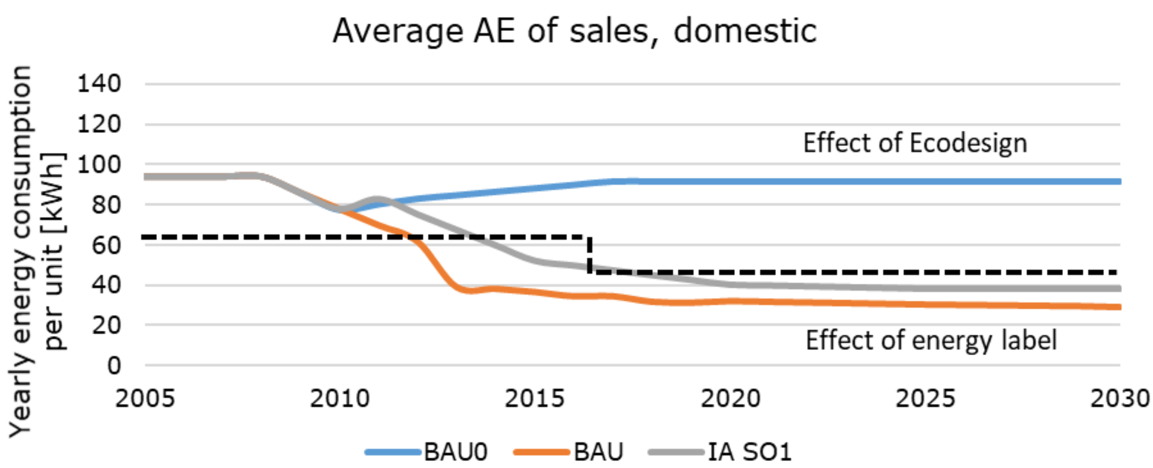
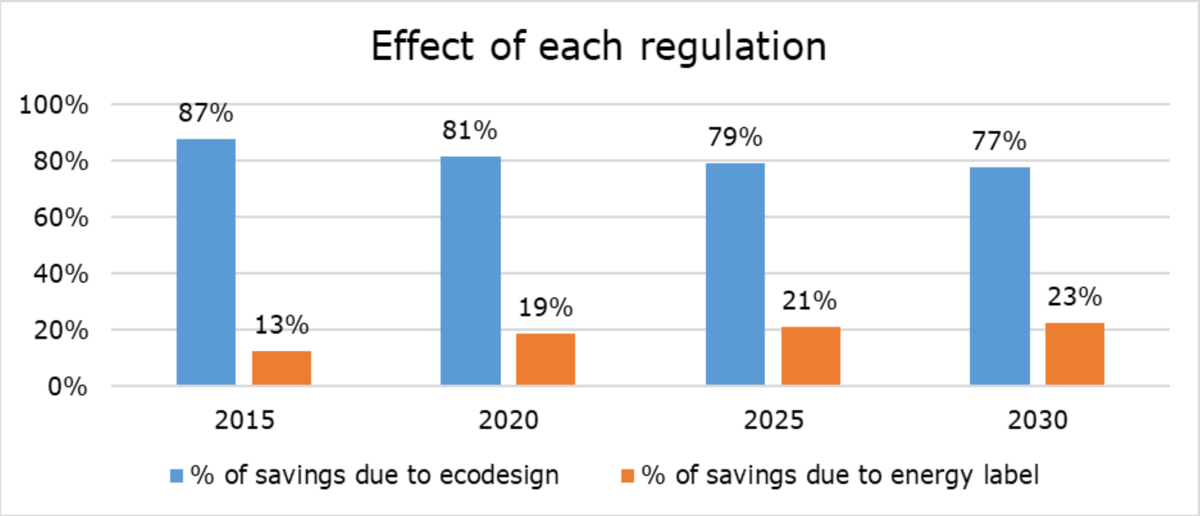


Figure 69: Share of energy savings due to the Ecodesign regulation and the previous, annulled Energy Labelling Regulation, based on average AE value of sales each year



<u>Distribution of energy classes</u>

Looking at the distribution of vacuum cleaners in the annulled energy classes, the data analysis is difficult because useful data is only available for two years. Before implementation of the regulations, information about energy and performance classes was only available for a small share of the market. Even though the annulled Energy Labelling Regulation entered into force in 2013 the labelling requirement was not mandatory before 1 September 2014. In 2014 information about the parameters on the label was only available for 6% of vacuum cleaners on the market as seen in Table 96. The share of vacuum cleaners bearing the label information increased to 77% in 2015 and 85% in 2016 on average for all types covered by the annulled Energy Labelling Regulation. The average value is close to value for cylinder vacuum cleaners as they constitute 85% of the EU vacuum market.

Table 96: Coverage of the previous, annulled energy label data for each vacuum cleaner type in scope of the regulations

	2013	2014	2015	2016
Cylinder	5%	19%	79%	86%
Upright	16%	23%	67%	75%
Handstick mains	2%	13%	73%	77%
Total	6%	19%	77%	85%

Looking only at the share of vacuum cleaners provided with the annulled energy label, the share of vacuum cleaners in energy class A increased from 47% in 2013 to 59% in 2016. The share of A labelled vacuum cleaners was higher for uprights and handsticks than for cylinder vacuums in 2016, but for all three types the shares of A and B labelled vacuum cleaners dominate the market compared to the situation in 2013 (Figure 70 and Figure 71). At the same time the share of vacuums with C, D, and E energy classes has decreased and the share of cylinder vacuums in energy class F and G has also decreased, while for handstick and upright cleaners these were almost non-existent already in 2013.

Figure 70: percentage distribution of energy classes for each vacuum cleaner type in 2013, label coverage 6%

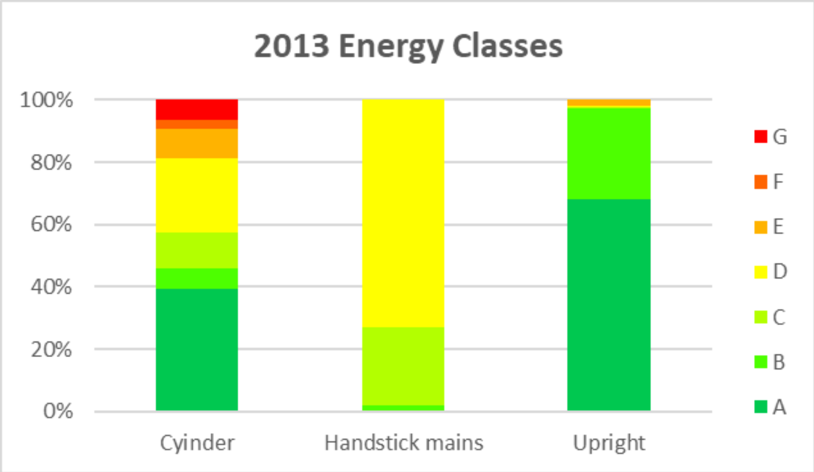
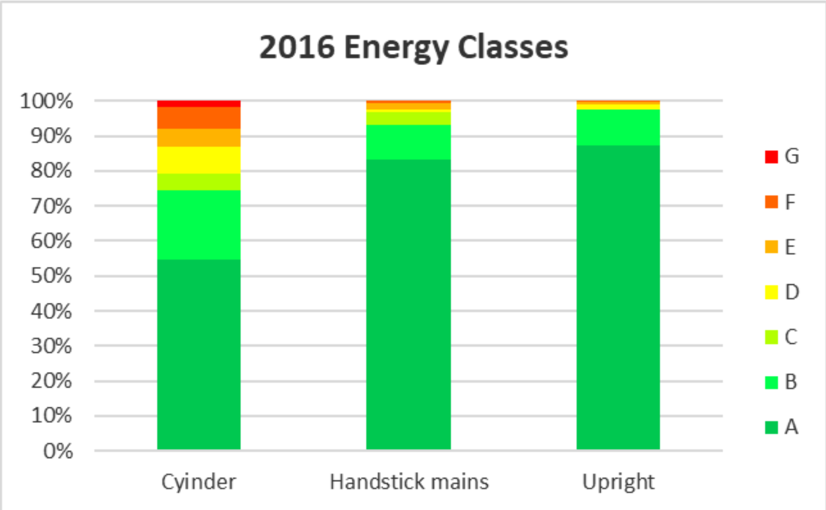


Figure 71: Percentage distribution of energy classes for each vacuum cleaner type in 2016, label coverage 85%



Dust pick-up and dust re-emission

The majority of vacuum cleaners sold in the EU are considered 'general purpose', meaning they are intended for use on both hard floor and carpet, and the dust pick-up class should be shown on the label for both. In addition, the dust re-emission class should be shown on the label. The existing data regarding the development of the market share of vacuum cleaners in the various dust pick-up and dust re-emissions classes is very uncertain[359], and it is not at the current stage possible to evaluate the impact of the regulations on these

[359] GfK data coverage is less than 20% for the years 2013 and 2014 on these parameters, hence only 2015 and 2016 data is available, which is not sufficient to draw any conclusion on trendlines.

parameters. Furthermore the parameters were not quantified for the market in the Impact Assessment. See section 8.5 of this report regarding the current market distributions.

Evaluation question 2: To what extent do the observed effects link to the regulations?

The observed market change towards more energy efficient vacuum cleaners is likely to be largely linked to the regulations, where the Ecodesign Regulation removed the most energy consuming models from the market, and the annulled Energy Labelling Regulation created further market pull beyond the power caps.

It is unlikely that the effects are in part due to other factors such as general innovation and market trends towards more energy efficient vacuum cleaners as this is not line with the development for vacuum cleaners seen during the last decades. Especially for household vacuum cleaners the regulations have been able to turn the market trend from rising rated input power, because high input power was the most important assessment parameter for the consumers, to reduced rated input power and higher energy efficiency.

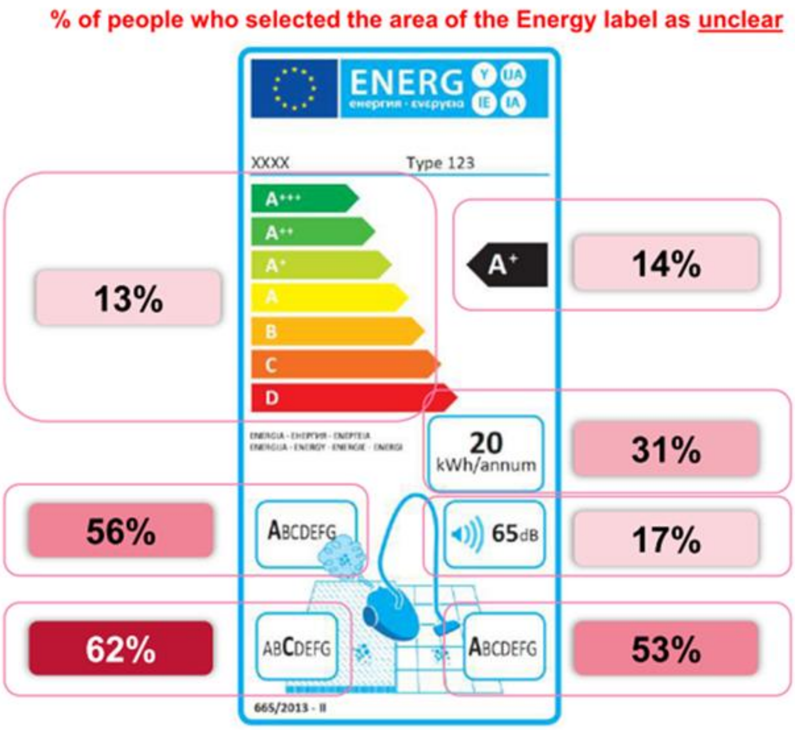
Evaluation question 3: To what extent can these changes/effects be credited to the intervention?

Before implementation of the regulations there was no available information about energy efficiency and cleaning performance of vacuum cleaners. The only available information was the rated input power. Without the regulations this would still have been the case and the consumers would still buy vacuum cleaners with the highest rated input power, considering vacuum cleaners with high rated input power to have the best cleaning performance. Therefore, the observed impact can to a very large extent be credited to the regulations. If the regulations were not implemented the rated input power would probably have increased to an even higher level leading to a further increase in the annual energy consumption for especially household vacuum cleaners.

Evaluation question 4: To what extent can factors influencing the observed achievements be linked to the EU intervention?

Some factors have reduced the achievements of the regulations. This is mainly a slow implementation of the label (low coverage), lack of consumer awareness and around 70% of consumers finding one or more parts of the information on the label unclear. Figure 72 shows the share of the 70% finding each label information unclear. It appears that more than half of the consumers who find some of the label information unclear, find cleaning performance and dust re-emission information particularly difficult to understand.

Figure 72: Share of people finding areas of the annulled label unclear, out of the 70% finding at least one parameter unclear (source: APPLiA 2018 consumer survey)



Another factor that could have reduced the market pull effect of the label towards higher energy efficiency is that consumers consider cleaning performance more important than energy efficiency. As seen in Table 97, 90% of consumers consider cleaning performance very important or important while only 67% of consumers consider energy efficiency very important or important. This is in line with the consumers' preference before the implementation of the annulled energy label where the consumers chose vacuum cleaners with high rated input power considering that high power was similar with high cleaning performance. High cleaning performance is still the most important performance parameter for the consumers.

Table 97: Percentage of consumers rating parameters important/very important in a purchase situation (Source: APPLiA 2018 consumer survey)

Parameter	Percentage answering "very important" or "important"
I expect it to last a long time	91%
Its performance	90%
The ease of use	89%
The price	87%
The ease of maintenance	86%
The type /stick, robot, canister etc.)	80%
A good filtration of the dust (allergies)	79%
The time spend cleaning	77%

The noise level	67%
The energy efficiency	67%
Having/not having a bag	66%

In addition, uncertainty about the cleaning performance information on the label probably has a negative impact on the achievements. Not because it affects the end-user understanding of the label, but because some might experience buying a label A vacuum cleaner and not getting the expected performance.

Only the factor dealing with unclear information on the label is directly linked to the Regulation. The other factors are more related to enforcement, consumer awareness and preferences when purchasing vacuum cleaners, measurement standards and the consumers' confidence in the information on the label.

The scope of the current Regulations also reduces the achievements because not all types of vacuum cleaners are included in the scope, such as robot and cordless vacuum cleaners. Extension of the scope to cover (both or one of) these types of vacuum cleaners is assessed in the second part (the scenario part) of this task.

Conclusion effectiveness

The current regulations have been very effective in reducing the electric consumption, and GHG emission of vacuum cleaners. The Ecodesign Regulation so far seems to have been more influential than the annulled energy label, resulting in around 80% of the total savings.

The energy savings has also led to monetary savings for end-users, due to the savings in electricity costs and despite the increased purchase price. However, unclear information on the label and uncertainty about measurement standards probably reduces the achievements of the regulations.

Also, the trend that more and more of the sale of vacuum cleaners moves towards robot and cordless vacuum cleaners reduces the effectiveness of the Regulations because these types of vacuum cleaners are not included in the scope.

13.1.4 Efficiency

Evaluation question 1: To what extent has the intervention been cost-effective?

The average price of vacuum cleaners increased from 2013 to 2016 for all the vacuum cleaner types in scope of the regulations; cylinder prices increased from 109 EUR to 119 EUR, uprights from 168 EUR to 179 EUR, and mains handstick from 90EUR to 95 EUR[360].

[360] These prices are not corrected for inflation.

This indicates that the manufacturers have passed on the extra costs for innovation and improvements of vacuum cleaners to the end-users and that the end-users are willing to pay a higher price for more efficient vacuum cleaners.

With the annulled Energy Labelling Regulation manufacturers had the possibility to improve the performance of their products and achieve a price premium because it is possible to make higher performing products identifiable by the label. This is contradictory to the situation before energy labelling where the only sales argument and consumer information was the rated input power.

Even though the vacuum cleaner purchase price has increased the total cost of ownership (i.e. costs for purchase and use) have decreased due to the regulations. This is the case both for household and commercial products.

The figures below show the development in the total costs of ownership for an average vacuum cleaner for respectively household and commercial vacuum cleaners.

As the manufacturers are able getting a higher price (increased turnover) and the total costs of owner ship has decreased for the end-users the regulations seem to be cost-effective.

Figure 73: Average total costs of ownership for household users

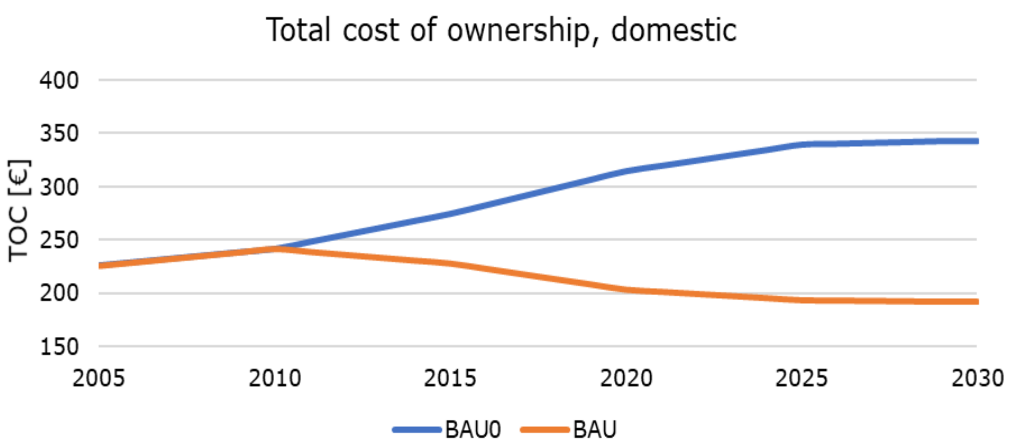
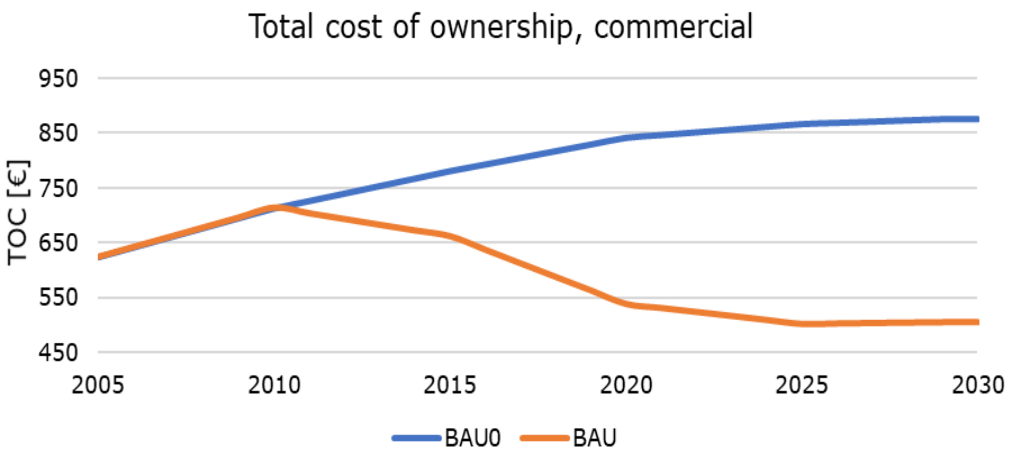


Figure 74: Average total costs of ownership for commercial users



The regulations apply some extra costs for testing on the manufacturers. However, as both regulations are based on self-declaration, no excessive testing costs are put on the manufacturers. In addition, experiences from the annulled EU energy labelling scheme show strong evidence that manufacturers have reacted positively to the EU energy labelling and consider the label as an important instrument to differentiate their products. This also suggests that the extra investments needed to achieve higher efficiency levels have generally been outweighed by the benefits[361].

Dealers must ensure that vacuum cleaners bear the label at the point of sale and they will have to cover the administrative costs for this activity. Although no quantitative data is available, costs for dealers to show the label on displayed products is widely accepted within the framework of the EU energy labelling scheme for energy-related products. In addition, the dealers will benefit from higher turnover due to increased sales of better performing and more expensive vacuum cleaners. As dealers of household vacuum cleaners usually display other energy labelled products, and in the past vacuum cleaners with labels, they are already familiar with the procedures and they will easily could transfer their experiences to the re-introduced product group.

Member States need to bear the costs for market surveillance, but they will also benefit from the energy savings and the reduction of emissions. In addition, EU wide legislation will be more cost effective from a Member State perspective compared to national legislation, because the costs of developing the regulation, test methods and conducting pre-regulatory studies are shared instead of conducted for each country separately.

The costs for market surveillance vary between Member States. Some carrying out almost no activities while others undertake both shop inspections, inspection of documentation,

[361] Ecofys, Evaluation of the Energy Labelling Directive and specific aspects of the Ecodesign Directive, June 2014.

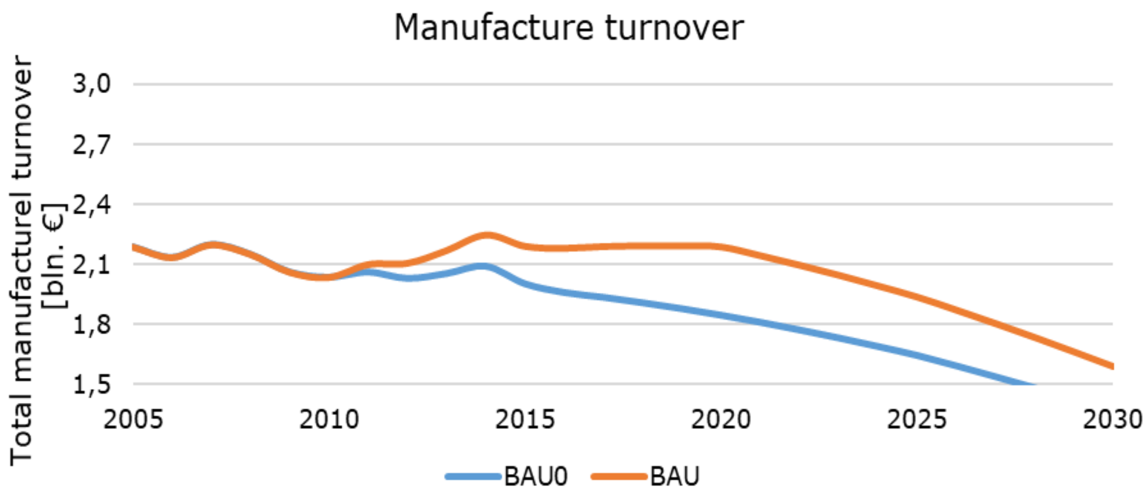
and testing. No EU-wide data regarding Member States costs for market surveillance with regard to vacuum cleaners is available.

Evaluation question 2: To what extent are the costs of the intervention justified, given the changes/effects it has achieved?

The current Regulations have resulted in substantial savings for end-users and society, without excessive costs for manufacturers, other market actors or Member States. In total the regulation will in 2020 have saved 116 TWh of electricity, corresponding to 45 Mt CO_2-eq, and users will in total have saved 19 bln. EUR.

Manufacturers have been able to pass on the extra cost for development of better performing vacuum cleaners to end-uses, and both manufacturer and retailers have benefitted from increased turnover compared to the situation without regulations. Both with and without the regulations the turnover is foreseen to decrease due to the expected sales of mains-operated household vacuum cleaners[362]. But the turnover is estimated to be higher with the regulations than without[363], as shown in Figure 75 and Figure 76.

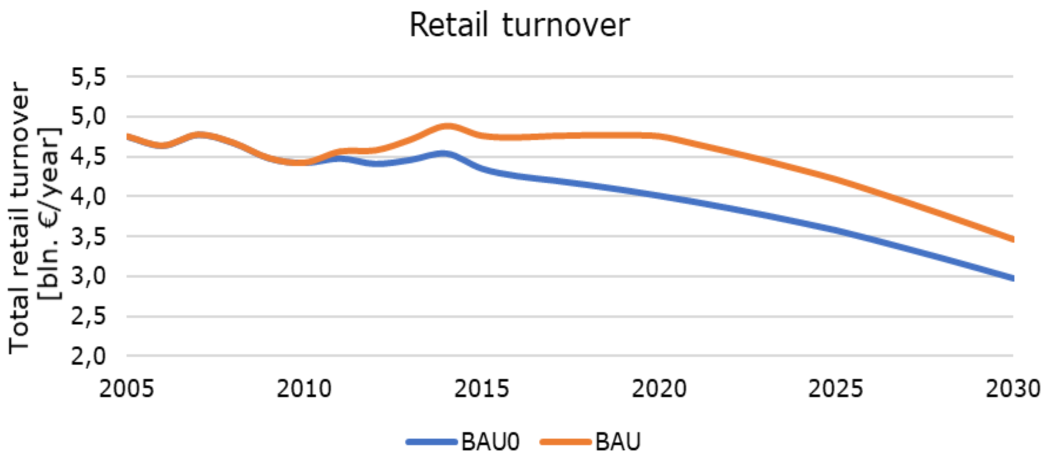
Figure 75: Manufacturers turnover without regulations (BAU0) and with the current regulations (BAU).



[362] This decrease was not expected by the Impact Assessment, but is shown by the newest market data

[363] Calculation of turnover in the BAU scenario is based on sales prices from GfK. Manufacturer turnover estimated by using

Figure 76: Retailers turnover without regulations (BAU0) and with the current regulations (BAU).



Member States need to bear the costs for market surveillance, but they will also benefit from the energy savings and reduced emissions due to the Regulations. In addition, an EU wide legislation will be more cost effective from a Member State perspective compared to national legislation. Therefore, the intervention costs seem justified given the improved performance of vacuum cleaners and the associated benefits.

Evaluation question 3: To what extent are the costs associated with the intervention proportionate to the benefits it has generated? What factors are influencing any particular discrepancies? How do these factors link to the intervention?

Due to the benefits illustrated above and the low costs for implementation of the regulations, the intervention is considered proportionate. The fact that the Ecodesign Regulation and the annulled Energy Labelling Regulation are implemented in a parallel process and with use of the same test procedures and calculations methods for proving compliance (for annual energy consumption and cleaning performance) makes the regulations more cost efficient for manufacturers.

No particular discrepancy has been identified so far.

Evaluation question 4: To what extent do the factors linked to the intervention influence the efficiency with which the observed achievements were attained? What other factors influence the costs and benefits?

Since the efficiency to some extent depends on the effectiveness of the Regulations, the same factors as mentioned above also influence the efficiency.

If consumers are not aware enough of the label and/or find label information unclear vacuum cleaners with high performance according to the label parameters will probably not have a market advantage, but rather the opposite since they are often also sold at higher prices.

In addition, the lack of reproducibility of the measurement method and the on-going work to develop new standards probably at least in a short-term perspective decrease the manufacturers' incentive to develop even better performing products, until it is determined exactly how measurements will be performed. Increasing consumer relevance of the test methods will also increase manufacturer incentive to produce better performing vacuum cleaners that reduce the life cycle costs of the product, both on the label and in real life.

Evaluation question 5: How proportionate were the costs of the intervention borne by different stakeholder groups taking into account the distribution of the associated costs?

Manufacturers of vacuum cleaners bear the largest share of the costs, but they have so far been able to pass the extra costs on to end-users, without increasing the total costs for end-users over the lifetime of the vacuum cleaners. As shown above the total costs of ownership have decreased significantly due to the current regulation.

End-users bear the costs for more expensive vacuum cleaners, but they will be compensated by saved electricity costs over the lifetime of the vacuum cleaners and increased performance.

Member States bear the costs for market surveillance for energy related products and in general vacuum cleaners is only a small part of that.

In addition, it is important to bear in mind that it is voluntary for manufacturers to improve the performance of vacuum cleaners beyond the Ecodesign requirements and for end-users to purchase the products with high energy classes.

Evaluation question 6: Are there opportunities to simplify the legislation or reduce unnecessary regulatory costs without undermining the intended objectives of the intervention?

One opportunity for reduction of the regulatory costs is establishment of a product registration database. This is already decided for products covered by Energy Labelling Regulations and implemented via the Energy Labelling Framework Regulation (EU) 2017/1369. However, further reduction of the administrative costs for Member States could be achieved if the database is extended to cover also Ecodesign Regulations (i.e. the manufacturers should have an obligation to enter technical documentation and other relevant documents proving compliance with relevant Ecodesign Regulations in the product registration database). This is relevant because the Ecodesign Regulation includes various requirement that is not included in the Energy Labelling Regulation, and the technical documentation for proving compliance with energy labelling not is sufficient to prove compliance with Ecodesign.

This would save the MSAs a lot of time in the process of first identifying the economic operator in each country (manufacture or their representative) and retrieve the correct documents before they can start verifying them. While document control is not considered as important as testing, it is the step that goes before the testing, and saving time on document control will leave more time and resources to perform actual tests. The market surveillance could improve even more if Member States collaborated across borders to check products, and the database is the first step in the direction of such a collaboration.

If all the necessary documentation is available in a data base the burden for Member States' MSAs to obtain the documentation will be reduced, and the burden for manufacturers to send documentation to each MSA, likewise.

As the Commission is already obliged to set up the database for energy-related products covered by Energy Labelling Regulations, the extra costs for inclusion of products covered by Ecodesign Regulations would most likely be marginal.

Another opportunity for simplification of the regulations is to differentiate which parameters are covered by ecodesign requirements and which are covered in the energy label. Some ecodesign limits might be set so high/low that there is no room for differentiating the remaining products into different label classes within the frames of the test uncertainties. In that case these parameters could be removed from the label. The same is true the other way around, especially for requirements for new parameters, where it might be a good solution to start with a label regulation before setting strict ecodesign limits.

Evaluation question 7: If there are significant differences in costs (or benefits) between Member States, what is causing them? How do these differences link to the intervention?

Member State costs associated with the current regulations are primarily related to market surveillance.

Even though all Member States have the same the obligation to perform market surveillance of compliance with the Regulations, the actual level of market surveillance varies between Member States. However, market surveillance for vacuum cleaners is probably not a high priority for any Member State. The differences in market surveillance costs are not linked to the interventions rather to the Member State priorities and limited budget for market surveillance.

Conclusions on efficiency

The evaluation assessment has shown that the benefits of the regulations seem to outweigh its costs, both for business, end-users and for society as a whole.

The manufacturers have invested in improvements of the products, but they have been able to pass the costs on to the end-users. In addition, the manufacturers have benefitted from an increased turnover compared to the situation without the regulations.

The increased performance has resulted in increased purchase prices for end-users, but this is offset by the energy savings, which results in larger savings over the lifetime of the vacuum cleaner i.e. lower total costs of ownership.

Member State costs associated with the regulation are primarily related to market surveillance. These costs should be reduced, to incentivise market surveillance in all Member States at a sufficient level. In addition, the market surveillance costs will be reduced by establishing of the product registration database for energy related products covered by Energy Labelling Regulations[364].

13.1.5 Relevance

Evaluation question 1: To what extent is the intervention still relevant?

The objective of the regulations was to reduce the energy consumption of vacuum cleaners and to provide consumers with reliable information about relevant performance parameters for vacuum cleaners allowing them to make a better-informed choice. In addition, the objective was to address the identified market failure i.e. that consumers buy vacuum cleaners according to the rated input power, without necessarily getting the assumed cleaning performance. This had resulted during the last 10-20 years in design of vacuum cleaners with a much higher input power than required.

The objectives have to a large extent been met, but the regulations are still considered relevant. The second power cap only entered into force in September 2017 and the vast majority of the saving related to this requirement (and the regulation) have still not been achieved. The same is the case for the labelling where the more ambitious energy classes A+, A++ and A+++ was introduced on the label in September 2017.

Furthermore, it is most likely that without the Energy Labelling and Ecodesign Regulations consumers will again buy vacuum cleaners according to the rated input power and that manufacturers will be influenced to place vacuum cleaners on the marked with still increasing power.

[364] According the Energy Labelling Framework Regulation (EU) 2017/1369

Consumers are buying more and more vacuum cleaners of the types not covered by the regulations (robot and cordless vacuum cleaners). For these types a tendency to have excessive power consumption when standing still has been observed, often exceeding the annual energy of mains-operated vacuum cleaners. This consumption has not been decreased based on the Standby Regulation, which also shows the relevance of the regulations for these products. Furthermore, it shows that robot and cordless vacuum cleaners should be included in the scope of the regulations to avoid unnecessary standstill energy consumption and low cleaning performance in these vacuum cleaner types.

Evaluation question 2: To what extent have the (original) objectives proven to have been appropriate for the intervention in question?

The original objectives have been appropriate and have resulted in better designed products without unreasonably high input power of vacuum cleaners on the market. In addition, the marked failure has been corrected for vacuum cleaner types included in the scope of the regulations.

Evaluation question 3: How well do the (original) objectives of the intervention (still) correspond to the needs within the EU?

The objectives regarding energy savings and increased energy efficiency are in line with European policies such as the 2030 Climate and Energy Policy Framework, that sets targets for greenhouse gas emissions and improvement of energy efficiency at European level for the year 2030 (at least 40% cuts in greenhouse gas emissions, and at least 32.5% improvement in energy efficiency)[365].

Evaluation question 4: How well adapted is the intervention to subsequent technological or scientific advances?

A significant market trend for vacuum cleaners is a technology shift to more and more robot and cordless vacuum cleaners. However, these types of vacuum cleaners are not covered by the current Regulations. This undermines the Regulations' achievements and create inadequate market conditions.

The fact that robot and cordless vacuum cleaners are not in the scope of the current Regulations mean that there is no EU system of information to end-users for these types of vacuum cleaners, and the end-users will probably make their purchase decision according to the power as was previous the case for the types of vacuum cleaners now covered by the regulations, and not be aware of their hidden energy consumption, such as in standstill. Advertisement with words such as "equally powerful to a corded vacuum cleaner" or similar are seen more and more for cordless cleaners, but without specifics of

[365] 2030 Climate and energy policy framework. Conclusion – 23/24 October 2014. EUCO 169/14. https://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf

what “powerful” means. Furthermore the advertised runtimes and suction power are rarely correlated for cordless cleaners with more than 1 power mode[366]. Hence, the regulations are not very well suited for the different functionality of cordless vacuum cleaners.

Furthermore, for both robot and cordless vacuum cleaners, there are currently no durability or dust re-emission requirements, and especially dust re-emission is very high, up to almost 7% for some models[367].

Only a very small share of vacuum cleaners are in the top energy classes of the label (A++ and A++). This means that the energy scale is still able to differentiate new and innovative solutions with regard to energy efficiency. However, the review study will propose a rescaling of the current A+++ to D scale to an A-G scale in order to align with the Framework Energy Labelling Regulation.

Evaluation question 5: How relevant is the EU intervention to EU citizens

According to the consumer survey conducted by APPLiA in 2018, the energy label is of relevance for a large share of consumers purchasing vacuum cleaners. A share of 25 % anticipate that the label will be a crucial consideration next time they will buy a vacuum cleaner, while 50 % anticipate that the label will be considered among other important items, as shown in Figure 77.

Since this reflects only how important the label as whole is to end-users, and not the importance of each of the parameters included in the label, it is not possible to say exactly which of the parameters that end-users look for or how important each of them are in a purchase situation.

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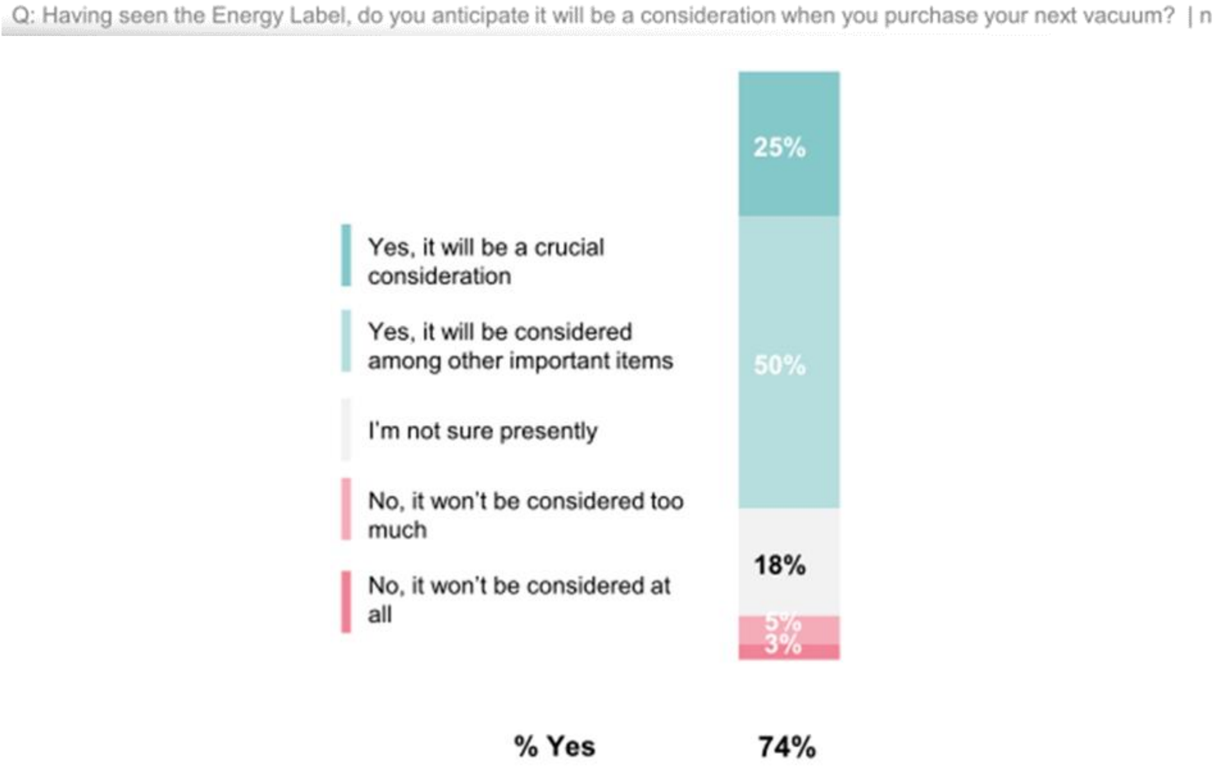
[366] See for example the comparison between measured and advertised runtime in the test by the Danish testing organization TÆNK: https://taenk.dk/test/ledningsfrie-stoevsugere/testede-produkter

[367] Test data provided by the GTT laboratories

Figure 77: Importance of the energy label for future vacuum cleaner purchases



Conclusion on relevance

The regulations continue to be relevant for reducing the energy consumption of vacuum cleaners and contributes to achieve the targets in the EU 2030 Climate and Energy Policy Framework[368].

The Ecodesign Regulation prevents placing on the market of vacuum cleaners with too high rated input power and the energy labelling creates further market pull and functions as a comparable information source to compare products for end-users. Together the regulations have resulted in better designed products being placed on the market.

However, a large share of the potential savings has not been achieved yet because the second power cap and the energy label with A+++, A++ and A+ was not introduced before late in 2017.

The consumers that participated in the APPLiA survey find the label relevant and a large share anticipate that they will consider the information on the label next time they would buy a vacuum cleaner.

[368] 2030 Climate and energy policy framework. Conclusion – 23/24 October 2014. EUCO 169/14. https://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf

13.2 Policy analysis

13.2.1 Stakeholders consultation

During the entire study, the study team has maintained a dialog with different stakeholders.

A first stakeholder meeting was held on the 27th of June 2018 where representatives from Member States, testing facilities, consumer organisations and manufacturers provided input to the first four tasks. A second stakeholder meeting was held on the 5th of December 2018 where inputs were given to the complete draft report including all tasks. Comments and inputs were taken into account in the report.

Telephone and face-to-face meetings have taken place with some individual manufacturers who have provided input to the first four tasks, including among others APPLiA Nilfisk, iRobot, BSH Hausgeräte, Bissel, Dyson, Groupe SEB and th CENELEC T59X WG6.

Furthermore data was received from several stakeholders, as well as collected by the study team from especially consumer test organisations.

13.2.2 Policy measures

The following policy options have been considered for the policy scenarios:

- No action ('Business-as-Usual', BAU)
- Self-regulation
- Energy labelling
- Ecodesign measures

No action ('Business-as-Usual', BAU)

If no new action is taken, the existing Ecodesign Regulation 666/2013 for vacuum cleaners remains in force. The Energy Labelling Regulation 665/2013 was annulled, and the savings related to this Regulation will therefore not be achieved.

Tasks 1 to 6 of this review study show that the two regulations in force have worked on pushing the EU market towards more efficient vacuum cleaners. However, further improvement opportunities exist offered by existing BAT. Moreover, the scope limitation to only mains operated vacuum cleaners leaves unutilised potential for energy and performance improvements.

Overall, it is recommended to take action and review the existing ecodesign regulation in force and investigate whether a new energy label could be beneficial. BAU is used as a baseline to establish the potential savings, costs and impacts on consumers, industry and employment.

Self-regulation

In Art. 15.3 b) of the Ecodesign Directive 2009/125/EC self-regulation, including voluntary agreements offered as unilateral commitments by industry, is indicated as a preferred option. However, this is subject to certain conditions stipulated in Article 17 and Annex VIII to the Directive (e.g. market coverage by signatories, ambition level, etc.).

These conditions are not fulfilled for vacuum cleaners: none of the relevant stakeholders expressed interest in self-regulation because the risk of 'free-riders'.

Consequently, self-regulation has not been further considered as a policy option.

Ecodesign

The Ecodesign Regulation 666/2013 in force has made a positive impact as presented in section 13.1. However, further improvement opportunities exist as presented in previous tasks, especially for an expanded scope.

While the Ecodesign Regulation has removed the far majority of inefficient vacuum cleaner from the market, there is still a large variety in products on the market, especially when it comes to cleaning performance. Cleaning performance is currently represented by dust pick up from a crevice in hard floor and embedded dust from a plush carpet. This is not necessarily the situation consumers meet in real life, and it is therefore proposed to review the current ecodesign requirements to reflect more consumer relevant performance and possibly expand the scope. This review could also take the opportunity to introduce resource efficiency requirements as discussed in previous tasks.

Details about proposed ecodesign policy options are presented in section 13.4.

Energy Labelling

The previous Energy Labelling Regulation 665/2012 that has been annulled also made a positive impact while it was in force as presented in section 13.1.

The distribution of the energy label classes of the old energy label showed that there is still potential for improving a large share of the market towards simultaneous better cleaning performance and lower energy consumption.

Due to the result of the Dyson vs. European Commission court case, any new energy label regulation would need to consider part load testing of the vacuum cleaner. This will most likely lead to an increased uncertainty of measurements. Using the opportunity of instating a new Energy Label Regulation, energy and performance classes could be adjusted to reflect the actual uncertainty of the measurements, by making them wider than the measurement uncertainties.

Moreover, other aspects related to consumer understanding can be incorporated to make the label easier to understand by the consumer at the time of purchase. Finally, some aspects about resource efficiency could also be integrated, as discussed in task 6.

The effect of the energy labelling regulation on performance and annual energy consumption is clear, and it is therefore proposed to review the current energy label to reflect the current and future technological progress and market trends. Details about proposed energy labelling policy options are presented in section 13.4.

13.3 Baseline scenario - BAU

In order to estimate the effect of any changes of the regulations, a base line scenario with the current regulations was established. The baseline scenario, or Business As Usual (BAU), reflects the market development, energy consumption and resource consumption of vacuum cleaners if no changes are implemented to the current Ecodesign Regulation. The BAU is used to compare the effect of the policy option scenarios presented in the next sections. All scenarios are modelled from 2015 to 2030, including the BAU scenario.

The BAU scenario is built on the data presented in task 2-5 of the current market and product characteristics. The following assumptions are made regarding the development from 2018-2030:

- Sales (and thus stock) will follow the trends presented in task 2
- Robot vacuum cleaners are sold as hard floor vacuum cleaners only
- The average AE values for the various types of vacuum cleaners will develop as shown in Table 98

Table 98: Development of average AE values for household mains-operated and commercial vacuum cleaners 2020-2030

Product type	2020	2025	2030
Cylinder household	32	30	29
Upright household	28	28	28
Handstick mains-operated	29	28	28
Weighted average mains (base case 1)	31	30	29
Commercial (base case 2)	30	30	29
Cordless (base case 3)	43	49	52
Robots (hard floor only) (base case 4)	71	71	71

The annual energy consumptions in Table 98 are all based on the formulas given in chapter 3, which includes corrections for the performance. For both robot and cordless vacuum cleaners, the maintenance mode consumption makes up around half of the annual energy consumption. Even though the poor carpet performance is removed from the robot calculation (because they are assumed to be sold as hard floor only), the generally high energy consumption while cleaning (around 40 Wh in the 20 m^2 test room), gives rise to high energy consumption[369].

The total annual energy consumption for the entire stock in the BAU scenario can be seen in Figure 78. The line depicting the total, takes into account only the four base cases and not the dotted line for robot cleaners including carpet performance, which is also shown in Figure 78. It should be noted that the energy consumption for commercial cleaners is based on the actual use pattern (300 cleaning cycles per year), as described in task 3, rather than the label AE value, which is based on around 50 hours per year, as explained in task 3.

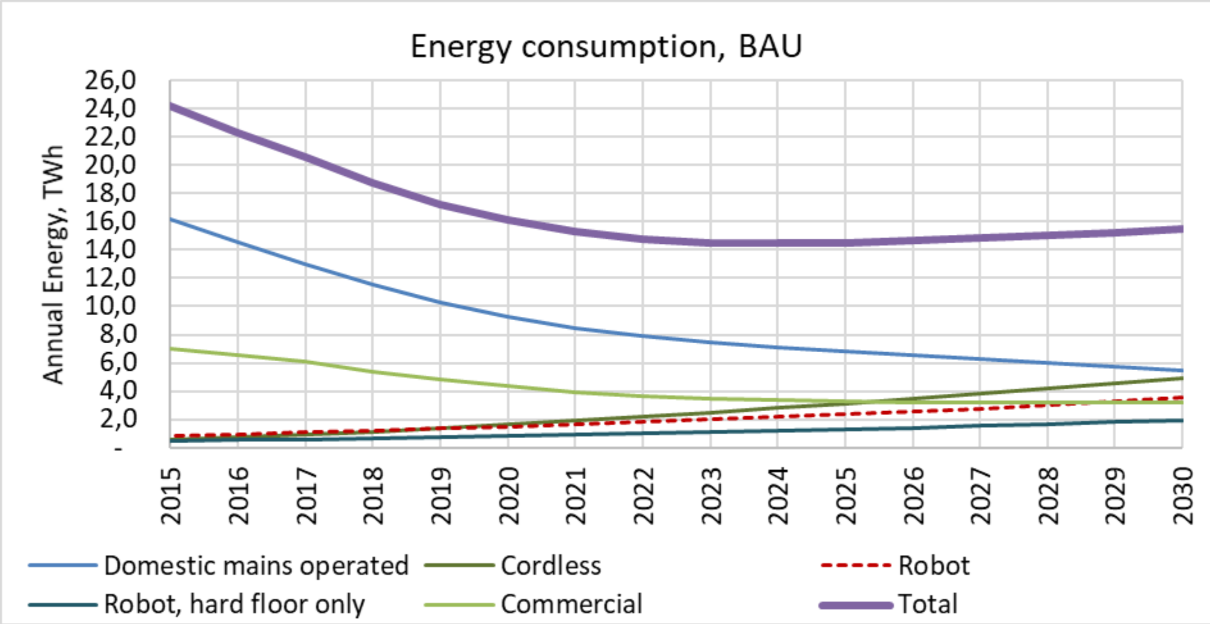
As seen from the BAU scenario of the energy consumption, the household mains-operated vacuum cleaners are by far the type of vacuum that gives rise to the largest energy consumption in the EU28, which is due to the large stock of these products. However, when going towards 2030, the stock is slowly shifted towards cordless and robot vacuum cleaners. With the simultaneous increasing battery size of cordless products, the energy consumption of the cordless stock is expected to be close to that of the mains-operated stock by 2030, partly because end-users exchange their corded vacuum cleaner with a cordless one.

This also results in an increase of the overall energy consumption in EU28 (i.e. the purple line showing the total consumption of the entire stock), both because of an increase of the total stock increases and because the energy consumption of the cordless and robot products is not covered by the current Regulations.

The energy consumption of commercial vacuum cleaners decreases only very slowly, and is more or less linear until 2030 due to the assumed constant sales and slowly decreasing AE values.

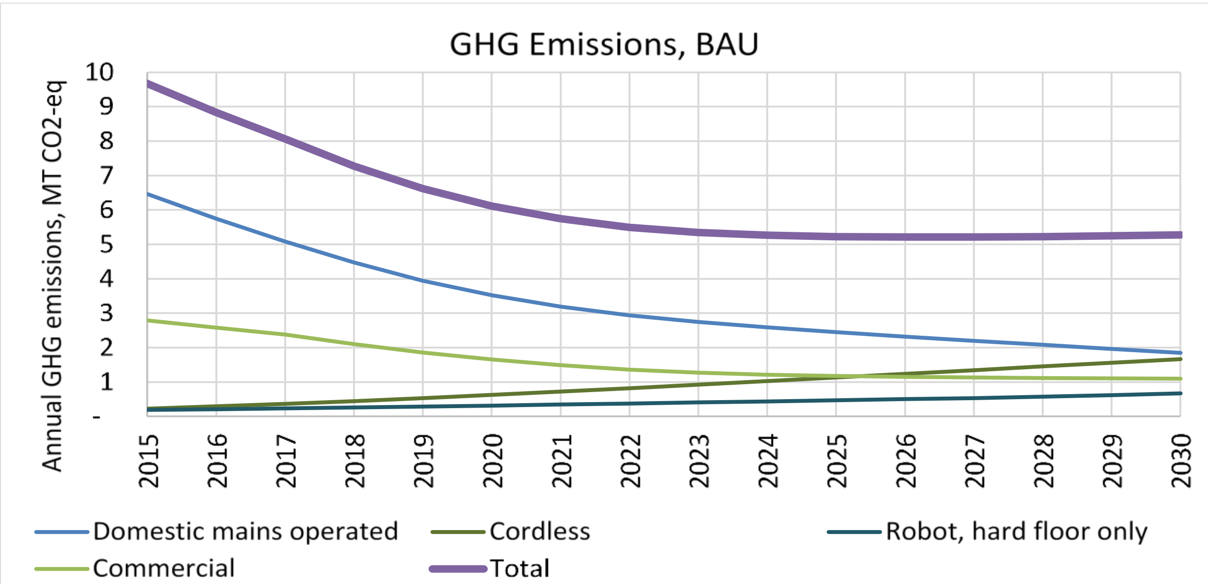
[369] Note again the differences in how the energy consumption is measured for the different vacuum cleaner types, which are not directly comparable, i.e.

Figure 78: Expected energy consumption development in the BAU scenario, 2015-2030



The corresponding emission of greenhouse gasses (GHGs) for the four base cases in the BAU scenario can be seen in Figure 79. The GHG emissions does not increase at the same rate as the energy consumption, because it is expected that more and more renewable energy will be used in the electricity production in the EU.

Figure 79: Expected annual greenhouse gas emissions in the BAU scenario 2015-2030



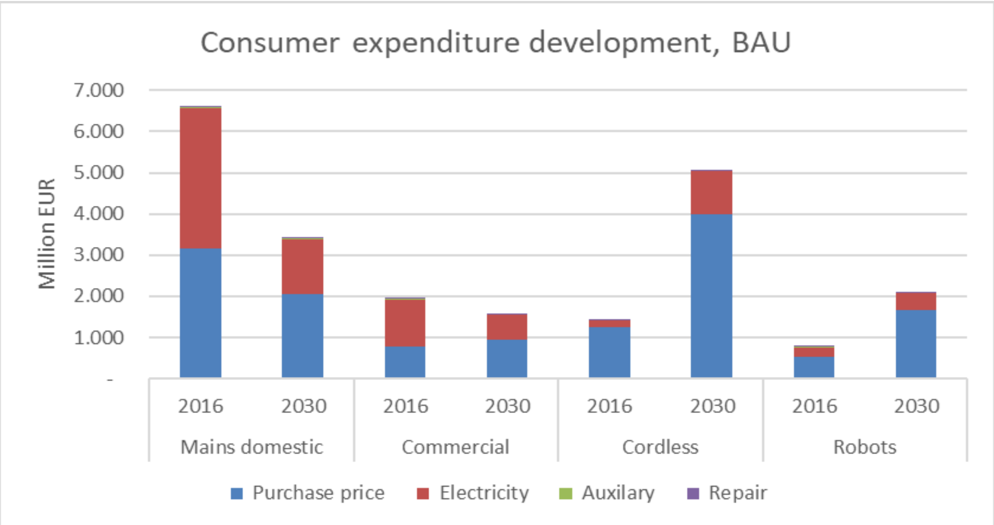
Another effect of the changes in energy consumption is the change in costs for the end-users. Decreasing energy consumption results in savings for the end-users in terms of electricity costs, however, depending on the technology steps and development needed to achieve the energy savings, the product price will increase.

For mains-operated household and commercial vacuum cleaners, which have been in scope of the Regulations for some years now, data exist to make a correlation between development in AE values and consumer purchase price. Based on the GfK data, this correlation was calculated to be 2,1 € increase in purchase price per kWh decrease in the AE value for household mains-operated vacuum cleaners[370]. For commercial vacuum cleaners, the correlation is 2,7 € price increase per kWh AE decrease.

According to the MEErP method the consumer expenditure cost is calculated as all costs paid for by all end-users in the EU28 each year. Hence, the purchase price is paid the year the product is sold (thus based on sales and purchase price every year), while the energy consumption is paid over the course of the lifetime of the vacuum cleaners (thus based on stock energy consumption and electricity prices every year). Repair and maintenance costs as well as auxiliary costs (bags and filters) is split evenly over the lifetime of the vacuum cleaners.

Since the sales and stock of mains-operated vacuum cleaners decreases from 2016 to 2030, the end-user expenditures in EU decreases as well as seen in Figure 80. The stock of commercial vacuum cleaners decreases only slightly, so the decrease in electricity cost from 2016 to 2030 is a mix of decreasing stock and replacement of the stock with more energy efficient products. For cordless and robots the increase in consumer expenditures is mostly due to the increasing sales and for cordless to a small extend the increasing energy consumption per product because the battery and motor size is expected to increase. This is also seen by especially the purchase costs increasing significantly.

Figure 80: Expected development in consumer life cycle costs in the BAU scenario from 2016 to 2030



370 Calculated

13.4 Policy scenarios for energy efficiency and performance

In this section three policy options, PO1, PO2 and PO3, are analysed and compared to the Business as Usual (BAU) scenario. These three options regard only the energy and performance-related requirements. All resource related aspects are treated in policy option PO4. The results of the scenario calculations are the impacts in EU28 of the policy options.

PO1 and PO2 include both ecodesign and energy labelling requirements, while PO3 is a scenario without Energy Labelling, but with stricter Ecodesign limits. The key differences between PO1 and PO2 are the AE and rated power thresholds. In PO1 the thresholds for AE are set at 36 kWh/year and 750 W for rated power, as suggested by some stakeholders. In PO2 the current thresholds for AE of 43 kWh/year and the power limit of 900 W are maintained. All other thresholds are the same in the two policy options, as seen in Table 99. PO3 follows the thresholds of PO1.

All three scenarios also include a more specific division of commercial vacuum cleaners in terms of test methods, thresholds and calculation methods (see Section 9.7.4).

Table 99 shows the ecodesign limits in each of the policy options, represented by numbers, as well as the parameters that should be included in the energy label in each policy option, represented by blue colour. In Table 99 below each of the requirements are presented one by one.

Table 99: Policy Option 1, 2 and 3: Energy and performance related requirements.

Ecodesign Parameter	Commercial	Mains-operated household	Cordless	Robot
	Common parameters for Policy Options 1, 2 and 3			
dpu_{hf}	≥0.98	≥0.98		
dpu_{c}	≥0.75	≥0.75		
*Debris hard floor**	≥0.40	≥0.80	≥0.80	
*Debris carpet**	-	≥0.75	≥0.75	
Dust re-emission	≤0.8%	≤0.8%	Tier 1: ≤3%	
Noise	≤78 dB(A) or ≤80 dB(A) if the product is equipped with a beat and brush nozzle	≤78 dB(A) or ≤80 dB(A) if the product is equipped with a beat and brush nozzle	≤85 dB(A)	≤65 dB(A) Measured from 1.6 m distance
Decrease in air flow with loading	≤15%	≤15%	≤15%	

Ecodesign Parameter	Commercial	Mains-operated household	Cordless	Robot
Motion resistance	40N	40N	40N	
Maintenance power			≤0.5 / 1.0 / 2.0 W	≤0.5 / 1.0 / 2.0 W
Coverage factor				≥80.00%
Policy Option 1				
Annual Energy, AE		≤36 kWh/year		
Energy Index, EI	0,8 m^2/min			
Rated power		≤750 W		
Energy labelling				
Policy Option 2				
Annual Energy, AE		≤43 kWh/year		
Energy Index, EI	0,76 m^2/min			
Rated power		≤900 W		
Energy label				
Policy Option 3				
Annual Energy		≤36 kWh/year		
Energy Index, EI	0,8 m^2/min			
Rated power	≤750 W	≤750 W		
No Energy Labelling				

**Based on very limited data, and require additional testing before final requirements are set.*

13.4.1 Requirements

Annual energy and rated power for household vacuum cleaners

The limits on annual energy consumption and rated power input for mains operated vacuum cleaners were introduced because of the ever increasing wattages used for marketing purposes. However, for cordless and robot vacuum cleaners there is a natural limitation to the possible motor power, because they run on batteries, and large motors will reduce the run time per charge. The rated power is therefore also difficult to measure for these products, because it cannot be measured as power drawn from the grid while the cleaner is operating. Hence, setting rated power limits for robots and cordless is difficult, and will most likely not result in the same energy savings as for mains operated vacuum cleaners.

Requirements with regard to annual energy and rated power are therefore only set for mains operated vacuum cleaners. PO2 includes the same values for AE and rated power as the current ecodesign regulation, whereas PO1 and PO3 includes stricter requirements for both parameters, namely at 36 kWh/year and 750 W.

Even though ecodesign requirements with regard to annual energy are not set for cordless and robot cleaners, it is suggested for the policy options including energy labelling (i.e. PO1 and PO2) to base the label classification on the AE value, calculated according to the formulas presented in task 3.

Energy Index for commercial vacuum cleaners

For commercial vacuum cleaners it is suggested to replace the AE calculation with the equations described in section 9.2.1, resulting in an Energy Index, EI, instead of an annual energy consumption, in order to make the calculation and possible energy label more relevant to the end-users. Based on measurement data from commercial vacuum cleaner manufacturers such a measure has much higher relevance to the commercial customers and the EI results in clear distinguishability between good and not so good machines. The EI should be used both for Ecodesign thresholds instead of AE as well as for the energy label scale in policy options where this is relevant.

Dust pick-up hard floor

The dust pick-up on hard floor is suggested to be maintained at ≥0,98 for mains operated vacuum cleaners in all policy options. It is not suggested to increase this level, since there are still very few vacuum cleaners that have very good dust pick-up performance and annual energy values simultaneously.

For cordless and robot vacuum cleaners, very limited data exist on dust pick-up, however data for cordless vacuum cleaners show that by the far majority of the models perform well below the average mains operated vacuum cleaner. Setting too strict ecodesign performance requirements for cordless and robot vacuum cleaners would remove many products from the market, reducing consumer choice significantly.

For robots the test method is different (flat floor, no crevice), and the results are therefore not directly comparable. The available results show relatively low performance, even on flat floor (around 60% on average), measured when the robot has moved over the floor once (first pass). It is therefore not suggested for the policy options with energy labelling, to show the dust pick-up results on the label, rather than setting an ecodesign requirement.

Dust pick-up carpet

The dust pick-up on carpet is likewise suggested to be maintained at the current ≥0.75 for mains operated vacuum cleaners. Since the average performance of cordless and robot vacuum cleaners are very poor on carpet compared to mains-operated vacuum cleaners, and there is no standard to measure it, it is suggested not to implement ecodesign requirements, when there is an option for the label, i.e. instead include dust pick-up on carpet on the label in PO1 and PO2. However, in PO3, where there is no energy labelling, an ecodesign requirement is suggested instead.

Debris pick-up

In order to make the performance tests more consumer relevant, it is suggested to add a debris pick-up ecodesign requirement for commercial, mains operated and cordless vacuum cleaners. This is expected to put even more emphasis on a good nozzle design that gives good performance in real life as well.

It is suggested to set the requirements at the same value for mains operated household and cordless vacuum cleaners. This is not possible for dust pick-up, since cordless cleaners are not intended for deep cleaning, as simulated by the crevice test on hard floor and the embedded dust test on carpet. Cordless cleaners are, on the other hand, designed to be good at visible cleaning, which is represented by the debris pick-up. Therefore, both the mains operated and the cordless cleaners should be capable to quite easily reach the suggested requirements for debris pick-up.

The debris pick-up is kept as a separate parameter and not included in the AE calculation or averaged with the dust pick-up. According to manufacturers it is easier for most vacuum cleaners to reach a good debris pick-up than a good dust pick-up (deep cleaning). Therefore, including debris in the formula might result in some good AE values, covering over quite low dust pick-up performances due to a good debris pick-up. Hence in order to avoid manufacturers focusing too much on debris instead of deep cleaning, it is suggested to keep debris pick-up separate, but included as a minimum threshold, to avoid the very specialised nozzles developed to perform well in the dust pick-up tests.

For robots, it is a bit different, primarily because the test method is different. Furthermore, the consumer is not performing the vacuuming, and robot vacuum cleaners tend to balance large debris and fine debris pickup. As for the cordless they are thus designed to be good at debris pick-up, and for maintenance of a relatively clean area rather than for intense weekly/monthly cleaning. However, while there is limited data for mains operated and cordless cleaners, there is not data at all for robots regarding debris pick-up. It is therefore not recommended to set a minimum threshold for robots. Once a test is developed, it could be required to make the information available in a data sheet, in the user manual or similar.

For commercial vacuum cleaners it is suggested to set the debris pick-up requirement based on the specific commercial test standard described in section 9.7.4.

Dust re-emission

The dust re-emission is suggested to be improved for mains operated vacuum cleaners, based on average label data received by GfK. Dust re-emission is an important parameter for human health, especially for sensitive demographic groups such as children or people with allergies.

This requirement, however, cannot be applied to cordless or robot vacuum cleaners. For robots there is no test method available, and for cordless cleaners it is very difficult to reach such low dust re-emission values as the mains. The main reason is the limited physical size of the cordless cleaners along with the limited power. High efficiency filters restrict the airflow and create suction performance losses. Therefore a higher limit value is recommended for cordless vacuum cleaners.

Noise

The noise levels of most cylinder type vacuum cleaners are well below the current 80 dB(A) limit, and it is thus suggested to lower the requirements to 78 dB(A) with the exception of vacuum cleaners with active beat and brush type nozzles. These are primarily used for upright vacuum cleaners, which is the reason they have had many difficulties complying with the current 80 dB(A) limit.

For cordless vacuum cleaners, the limited data available shows higher noise levels than for mains operated. This is again due to the limited size of the products, leaving little space for adding sound insulating material to reduce the noise. Furthermore, adding such noise insulation would also restrict the airflow, leading to lower suction performance. Therefore it is suggested also for noise, to impose less strict requirements on cordless vacuum cleaners.

For robots, on the other hand, the noise is lower on average, according to the available data. Measured from 1.6 meter distance, the average is well below the 80 dB(A) and a limit of 65 dB(A) is therefore recommended for robot vacuum cleaners.

Loaded air power

The biggest concern regarding consumer relevance and part loading is the big variation in how each individual product reacts to the dust loading, and the risk that some vacuum cleaners might vary significantly from the test values with empty receptacle when used in real life. Since there are large difficulties in developing a part load test method that is repeatable and reproducible, different approximations was discussed (see task 3). One of them is the air power, or suction power, measured in watts. One way to accommodate the problem with vacuum cleaners that decrease rapidly in performance with dust loading, is to set an ecodesign requirement for the maximum decrease in air power when the vacuum cleaner is full, compared to when it is empty. Initial measurement data from the Round Robin Tests on part and full load air performance measurements show a large variation in how much suction power is lost when filling the receptacle of different vacuum cleaner models. Based on this, a limit of 15% reduction is suggested, but more data should be collected before setting the final requirement.

Motion resistance

It is suggested to add a cap on motion resistance on carpet in order to avoid specialised nozzles that are not practically useful for end-users. The motion resistance cap is set at 40 N. This value is based on measurements on the Wilton carpet, and measured at a constant speed of 0.5 m/sec in accordance with the current test standards. The motion resistance should be measured simultaneously with the dust pick-up on carpet, to avoid different settings or detection of test conditions optimising to each of the measurements.

Maintenance power

The maintenance power requirements are applicable to both cordless and robot vacuum cleaners. The maintenance power is the power consumption in the so-called 'charged and docked' mode, i.e. when the vacuum cleaner is standing in the docking station fully charged. This mode includes any trickle charging, standby consumption etc. that the vacuum cleaner might need. This mode is the one the cordless and robot vacuum cleaners are in most of the time, and as seen by the BAU scenario calculations this is also the most energy consuming mode today. The maintenance power can range between less than 0,5 W to 8 W. Hence the average value presented in the BAU covers a large variance, and large amount of energy is spent in this mode by some models. It is suggested to measure this energy consumption as an average consumption over 24 hours[371], in order to allow for the docking station to consume more energy for short time spans to perform relevant tasks.

The maintenance mode requirements are suggested to follow that of the 2019 requirements in the standby regulation[372]. While vacuum cleaners are in principle covered by the standby regulation, the maintenance of battery power with so-called 'trickle charging' or other functions, it can be used as a loophole to state that this is not a standby mode.

The proposed standby requirements are 0.5 W, with info display 1.0 W, and with networked connection 2.0 W. This includes consumption of the power supply, docking station and the

[371] To avoid circumvention, it should not be allowed to program the appliance in a way that the standby consumption in the first 24-hour period is different, e.g. by not activating function such as software updates until after the first 24-hour period.
[372] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013R0801

robot itself. Since it has been argued that at least robot vacuum cleaners are covered by the current networked standby requirements in the standby regulation, it should already be possible to test and comply with these requirements.

Run time

The run time is a measure of how long the vacuum cleaner can be used when it is fully charged, before it needs charging again. In order to ensure that consumers are not mislead by different statements regarding run times, which is an important marketing parameter for battery driven vacuum cleaners, it is suggested to develop a standardised way of measuring (operational) run time, and include it in the energy labelling in PO1 and PO2. The run time should be measured in the same mode as the dust- and debris pick-up.

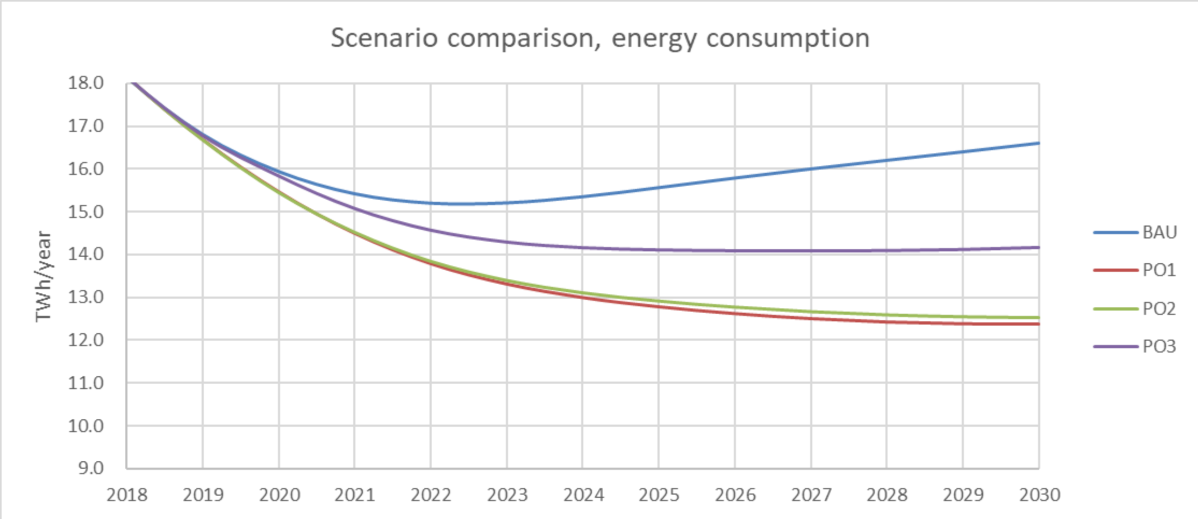
Coverage factor

The coverage factor applies only to robot vacuum cleaners and is a measure of how much of the floor area in a given room the robot covers in its cleaning cycle. At low coverage rates, the cleaning performance measured in tests is not representative of the actual cleaning, because parts of the floor are not covered by the robot at all. No minimum requirement is recommended for the coverage factor, but it is recommended to include the coverage factor in the energy labelling in PO1 and PO2. Furthermore, the coverage factor is included in the AE calculation for robots.

13.4.2 Energy saving potentials

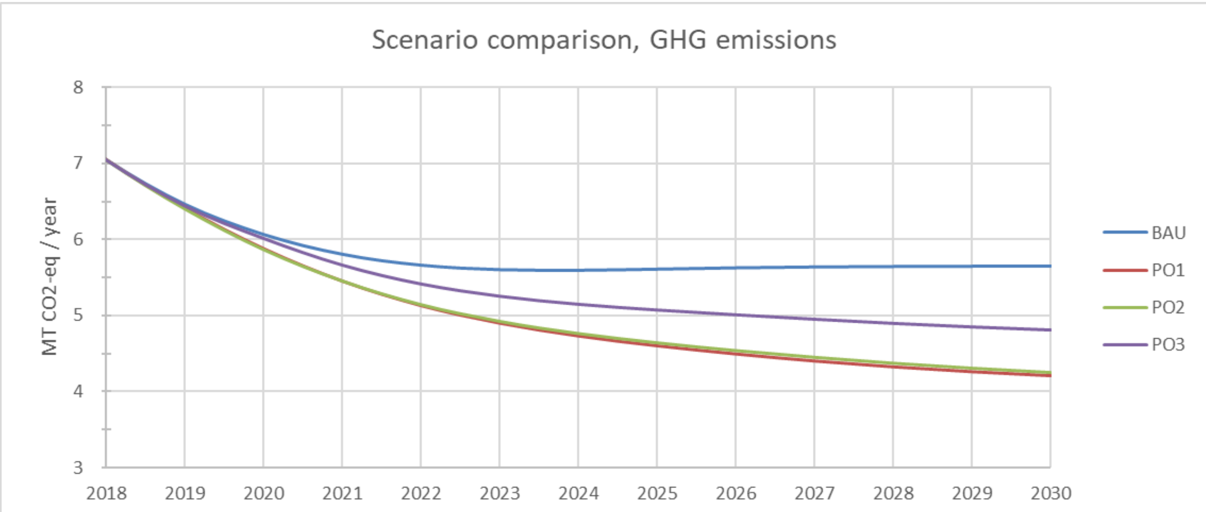
Based on the above requirements and the data presented throughout the study, the impact of PO1, PO2 and PO3 on energy consumption in EU28 has been derived and compared to the BAU scenario. As seen from Figure 81, the energy consumption in all three scenarios is lower than in the BAU scenario, however the savings in PO3 (1.44 TWh/year in 2030) is less than half of the savings in PO1 (3.99 TWh/year in 2030) and PO2 (3.84 TWh/year in 2030).

Figure 81: Energy consumption in PO1, PO2 and PO3 compared to BAU from 2018 to 2030



As shown in the BAU scenario, the greenhouse gas emissions follow the energy consumption, but with the assumption of more renewable energy in the electricity mix in the future. The comparison of GHG emissions in the scenarios can be seen in Figure 82. The PO1 scenario, which has the largest savings, results in savings of around 1.3 Mt CO_2/year by 2030, corresponding to 28% of the annual vacuum cleaner stock greenhouse gas emissions in the BAU scenario.

Figure 82: GHG emissions in PO1, PO2 and PO3 compared to BAU from 2018 to 2030



The energy savings in both PO1 and PO2 are primarily caused by the increased energy efficiency of cordless and robot vacuum cleaners, while only minor energy savings are attributed to setting stricter ecodesign requirements for mains-operated vacuum cleaners as seen from Table 100. Hence the lower motor power threshold of 750 W and the limit for the Annual Energy of 36 kWh/year in PO1 does not contribute to significant energy savings compared to maintaining the current thresholds, illustrated by the small difference between

PO1 and PO2. This small saving potential for setting the stricter limits, is because many products are already way beyond the ecodesign limit. The reason for this can be largely attributed to the Energy Labelling Regulation, and the fact that more than 50% of the products sold today are labelled in energy class A[373].

This is also the reason why setting only the Ecodesign limits and removing the energy label results in only half the savings as having both regulations, as modelled in PO3. It is assumed that without an energy label, the argument for selling more expensive products based on performance and the incentive to develop products with performance/energy consumption beyond the limit values, are removed. While the potential savings for cordless and robots is only a few percentage points lower than in the PO1 and PO2 scenarios, the increasing AE values (up to near the limit value) for household mains-operated and commercial vacuum cleaners causes the energy consumption for these vacuum cleaner types to increase.

The majority of the energy savings in all three policy options are achieved by including cordless and robot vacuum cleaners in scope of the Regulations and secondarily by re-instating an energy labelling regulation for mains operated vacuum cleaners. Since the cordless and robot vacuum cleaners are expected to increase in market share and annual energy consumption, it is important to include them in the regulation(s), not only for their energy saving potential, but also to provide consumer protection and a level playing field among products when cordless and robots starts to compete with and replace the mains-operated vacuum cleaners.

Table 100: Energy savings for each base case in 2030 for PO1, PO2 and PO3 in EU28

	2030 energy consumption, TWh				Annual savings in 2030, TWh			Annual savings, %		
Household mains	6.71	5.30	5.41	6.28	1.41	1.31	0.44	21%	19%	6%
Commercial	3.88	3.18	3.23	3.78	0.70	0.65	0.10	18%	17%	3%
Cordless	2.15	0.83	0.83	0.83	1.32	1.32	1.32	61%	61%	62%
Robots	1.18	0.62	0.62	0.49	0.56	0.56	0.69	48%	48%	59%
Total	**13.93**	**9.94**	**10.09**	**11.38**	**3.99**	**3.84**	**2.55**	**29%**	**28%**	**18%**

Table 101 shows the energy consumption of cordless and robot cleaners in BAU and PO1 (the strictest scenario), divided into maintenance power consumption and power consumption for cleaning (including charging). In 2018 around half of the annual energy consumption is associated with the maintenance power for cordless and ¾ for robots. In

[373] Based on the 2017 label. Se task 2.

the BAU scenario maintenance mode is considered unchanged (but taking into account 2019 requirements in the standby regulation). In the PO1 (and other) scenario maintenance consumption is reduced drastically towards 2030 to less than half of the 2018 values. This is due to the proposed maintenance mode requirement. Also the power for cleaning and charging is decreasing due to better dpu and because the power supplies are expected to become more efficient in order to bring the maintenance power down.

Table 101: Energy consumption of cordless and robot vacuum cleaners in BAU and PO2, kWH/year

Base case	Mode	2018	2020	2025	2030
Cordless, BAU	Maintenance mode, kWh/year	21	21	21	21
	Cleaning, kWh/year	25	28	35	39
	AE, kWh/year	46	49	56	60
Cordless, PO1	Maintenance mode, kWh/year	21	15	8	8
	Cleaning, kWh/year	25	27	30	31
	AE, kWh/year	46	42	38	39
Robots, BAU	Maintenance mode, kWh/year	31	31	31	31
	Cleaning, kWh/year	11	11	11	11
	AE, kWh/year	42	42	42	42
Robots , PO1	Maintenance mode, kWh/year	31	22	13	13
	Cleaning, kWh/year	11	11	10	9
	AE, kWh/year	42	33	23	22

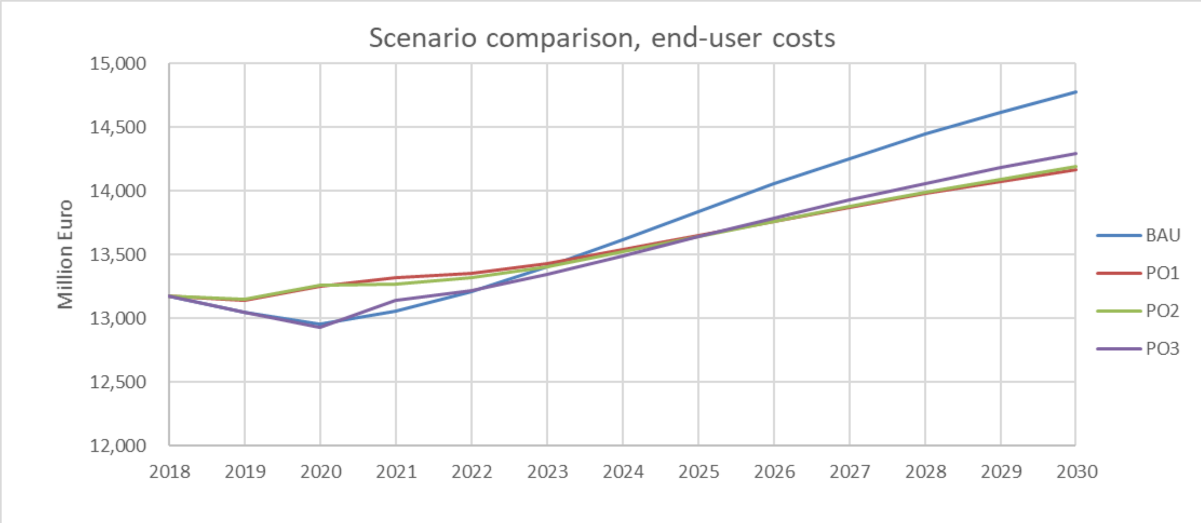
13.4.3 Total consumer expenditure

While the energy saving potential is higher in PO1 and PO2 than in PO3, all three scenarios result in roughly the same monetary savings for the end-users compared to the BAU scenario. Figure 83 shows the total end-user expenditure for all vacuum cleaners in the EU. The cost is composed of total purchase price each year and the electricity cost and maintenance cost of the stock per year (i.e. vacuum cleaners sold the previous years). This is also why in the PO3 scenario the total costs drop under the PO1 and PO2 scenarios in 2019-2026+, because without the energy label the AE values increase slightly, causing lower purchase cost, but the energy consumption of the stock is still low. However, when the stock is replaced with the PO3 products (i.e. no Energy Labelling, only Ecodesign), the costs exceeds those in PO1 and PO2 (around 2027), due to the higher energy consumption. This trend would continue to be more pronounced in the years following 2030, if the model was forecasted further.

The graph in Figure 83 shows, that in the long term (after 2030) the end-user costs will be lowest in the PO1 scenario, but still quite similar to the PO2 and PO3 scenarios. The reason for the small difference is primarily due to how the energy costs are calculated:

with a small annual increase in electricity prices, but a discount rate of 4%, which is larger than the increase in the electricity price, hence giving low value to energy savings.

Figure 83: Total end-user expenditure for all vacuum cleaners in EU28 each year from 2018-2030.



For all the scenarios, the consumer expenditure is lower than in the BAU, however the effect varies between the base cases, as seen in Table 102. For all scenarios the effect on mains-operated household vacuum cleaners is less than 1%. Even though the energy consumption decreases for these products, the increase in purchase cost more or less level out the cost savings related to use of the product for end-users. For the commercial cleaners the effect is larger in PO1 and PO2 than in PO3, since only limited additional ecodesign requirements are set, while the energy label has a larger effect.

For cordless and robot vacuum cleaners, the effect on user expenditures is more or less the same in all three policy scenarios, because both ecodesign and energy labelling requirements are new to these product categories. However, the energy savings are larger in the label scenarios (PO1 and PO2), than in the PO3. The difference between PO1 and PO2 is very small though, showing again that when there is an energy label, the effect of the stricter ecodesign requirements is limited.

Table 102: EU User expenditure for each base case

Consumer expenditure, Million €		Year			2030 Savings
Base case	Scenario	2018	2020	2030	
Mains-operated household	BAU	7,699	6,130	5,060	
	PO1	7,699	6,259	5,054	0%
	PO2	7,699	6,248	5,067	0%
	PO3	7,699	6,179	5,048	0%
Commercial	BAU	2,519	2,272	2,299	
	PO1	2,519	2,197	2,206	4%
	PO2	2,519	2,201	2,213	4%
	PO3	2,519	2,252	2,281	1%
Cordless	BAU	2,013	3,558	4,715	
	PO1	2,011	3,401	4,435	6%
	PO2	2,011	3,401	4,435	6%
	PO3	2,011	3,392	4,434	6%
Robot	BAU	823	1,449	1,968	
	PO1	823	1,389	1,849	6%
	PO2	823	1,389	1,849	6%
	PO3	823	1,388	1,846	6%

13.4.4 Consumer health potentials

As well as the energy savings, which can be directly correlated to the consumer expenditures, the parameters related to consumer health are also affected by the requirements suggested in the policy options.

Table 103 shows the effect of each policy option on the average noise of each vacuum cleaner type. Since there is a significant difference between the different mains operated vacuum cleaner types, these are shown separately in the table. As explained above, it is recommended to set lower limits for vacuum cleaners that do not have beat and brush nozzle, but maintain 80 dB for those that have. There have already been great difficulties for these vacuum cleaners to have a noise level below the maximum of 80 dB, while those with other nozzle types are typically lower.

For most cordless vacuum cleaners, the noise levels are higher than 80 dB at the moment, due to the light construction that does not allow for much sound-insulating material, and the requirement of 85dB s therefore suggested. It is not expected that the average values will change with only the ecodesign requirement, based on the data available. However, with energy labelling, it is expected to decrease a further on average. Robots generally has lower noise values, and therefore 65dB is suggested as a limit. Again, ecodesign alone is not expected to change the average values, but energy labelling is expected to change it slightly. By implementing the label, more information about the noise levels of products on the market will also be available, helping to set more realistic requirements in the future.

Table 103: Average noise levels of each vacuum cleaner type in 2018, 2025 and 2030 in the policy scenarios

Average noise, dB(A)		Sales year		
		2018	2025	2030
Cylinder Mains operated household	BAU	78.8	78.8	78.8
	PO1	78.8	76.9	76.6
	PO2	78.8	76.9	76.6
	PO3	78.8	77.4	77.4
Upright Mains operated household	BAU	80.0	80.0	80.0
	PO1	80.0	80.0	80.0
	PO2	80.0	80.0	80.0
	PO3	80.0	80.0	80.0
Handstick Mains operated household	BAU	79.9	79.9	79.9
	PO1	79.9	79.4	79.0
	PO2	79.9	79.4	79.0
	PO3	79.9	79.7	79.7
Commercial	BAU	79.1	79.1	79.1
	PO1	79.1	77.2	76.9
	PO2	79.1	77.2	76.9
	PO3	79.1	77.6	77.6
Cordless	BAU	83.6	83.6	83.6
	PO1	83.6	83.0	82.6
	PO2	83.6	83.0	82.6
	PO3	83.6	83.0	83.0
Robot	BAU	60.8	60.8	60.8
	PO1	60.8	59.8	58.6
	PO2	60.8	59.8	58.6
	PO3	60.8	60.0	60.0

The average dust re-emissions for the different vacuum cleaner types are shown in Table 104. The dust re-remissions are expected to decrease slightly for the mains-operated household and commercial cleaners due to the new limit of 0.8. For the cordless products, the decrease is much greater, because the values today are very high (for some machines up to around 8% dust re-emission has been measured[374]). Hence, the requirement of maximum 3% dust re-emission is expected to bring the average values down at least 1%-point (PO3), while the energy label is expected to decrease levels even further (PO1 and PO2).

Since dust re-emission cannot yet be measured for robot vacuum cleaners, no data is available, and consequently no requirements have been suggested.

Table 104: Average dust re-emission levels of each vacuum cleaner type in 2018, 2025 and 2030 in the policy scenarios

Average dust re-emission, %		Sales year		
		2018	2025	2030
Cylinder Mains operated household	BAU	0.35%	0.35%	0.35%
	PO1	0.35%	0.30%	0.30%
	PO2	0.35%	0.30%	0.30%
	PO3	0.35%	0.30%	0.30%
Upright Mains operated household	BAU	0.42%	0.42%	0.42%
	PO1	0.42%	0.36%	0.36%
	PO2	0.42%	0.36%	0.36%
	PO3	0.42%	0.36%	0.36%
Handstick Mains operated household	BAU	0.72%	0.72%	0.72%
	PO1	0.72%	0.61%	0.61%
	PO2	0.72%	0.61%	0.61%
	PO3	0.72%	0.61%	0.61%
Commercial	BAU	0.35%	0.35%	0.35%
	PO1	0.35%	0.30%	0.30%
	PO2	0.35%	0.30%	0.30%
	PO3	0.35%	0.30%	0.30%
Cordless	BAU	4.19%	4.19%	4.19%
	PO1	4.19%	2.60%	2.60%
	PO2	4.19%	2.60%	2.60%
	PO3	4.19%	2.99%	2.99%

13.4.5 Conclusions

Based on the scenario analyses above, the energy savings in PO1 and PO2 are quite similar and approximately double that of the PO3 scenario. At the same time consumer

[374] Data supplied by GTT laboratories in accordance with IEC draft standard

expenditure is roughly the same in all three scenarios (might be highest in PO3 in the long term). The user health effects of noise and dust re-emissions are similar in PO1, PO2 and PO3 for mains operated and commercial vacuum cleaners, but for cordless PO1 and PO2 result in the lowest user health impact.

Hence, on all performance parameters energy labelling is expected to lead to larger benefits for the end-users. Based on this a policy option with energy labelling is recommended. However, this is dependent on the development of a methodology to either measure or simulate properly the effect of part loaded dust receptacle.

The difference between the two scenarios including energy labelling (PO1 and PO2) is only the stricter AE limit values, but the effect of this is limited when there is a label pulling the market towards better performance. At the same time, as shown in task 6, these stricter Ecodesign limits do not lead to lower life cycle costs for the end-users. Hence, if a label scenario is chosen, it is recommended to follow PO2. If it is not possible, however, to implement an energy label, the stricter AE requirements (as in PO3) are still required, to at least obtain some of the potential energy savings.

According to the standardisation group working on robot vacuum cleaner standardisation, the test standards are still not mature to be used for Ecodesign and Energy Labelling purposes, partly because the technology is still very new and rapidly evolving, and partly because experience with testing is still too limited and repeatability data is not yet available (Round Robin Tests (RTT) ongoing). However, seeing that other fast developing technologies such as computers are also covered by Ecodesign Regulations, the speed of development of the technology should not be an issue in itself. On the other hand, the lack of robust testing methods could be a barrier for including robot vacuum cleaners in scope of the regulation, but this could be solved by considering a longer implementation time frame.

Taking the test development into account only some of the performance parameters are suggested for robot and cordless vacuum cleaners. At the very least it is highly recommended that both cordless and robot vacuum cleaners are included in scope of the Ecodesign Regulation with requirements on the maintenance mode power consumption and preferably with the range of performance parameters covered in PO2.

13.4.6 Label classes

For a new energy label it is suggested to use the same classes as in the now annulled Energy Label Regulation, but use the letters A-G for the scale, as shown in Table 105.

In addition to the energy classes, the assumed market distribution of the four base cases among the energy classes by the time of application is shown in Table 105. For the mains-operated household cleaners the distribution is based on forecasting the label distribution from GfK for 2016 to 2021. For the other base cases, where there was no data regarding distribution, it was based on the average AE value. Cordless vacuum cleaners are assumed to be the only vacuum cleaner type that can achieve the A+++ (or A) rating, because of the small motors (low ASE) and the expected drastic decrease in maintenance power. However, due to the very low performance (in terms of dpu), these machines will not be A/A/A/A (annual energy/dpu_{hf}/dpu_c/dust re-emission). Hence, no such products are expected to exist upon entry into force of the revised regulation[375].

Table 105: Rescaling of the energy label and assumed distributions

Current label classes	Interval	New label classes	Assumed 2021 market distribution			
			Mains-operated household	Cordless	Robots tier 1	Robots tier 2
A+++	≤ 10	A	0.0%	2%	0%	0%
A++	10 < AE ≤ 16	B	1.0%	9%	0%	1%
A+	16 < AE ≤ 22	C	2.0%	21%	1%	3%
A	22 < AE ≤ 28	D	61.0%	54%	3%	7%
B	28 < AE ≤ 34	E	22.0%	11%	7%	10%
C	34 < AE ≤ 40	F	7.0%	3%	14%	18%
D	40 < AE	G	7.0%	0%	75%	61%

For the other performance parameters it is suggested to change the scales shown on the label. This is primarily based on the findings of the standardisation work, which shows that the expanded uncertainties of the measurements exceed the label class width. It is therefore suggested to reduce the number of classes on each scale from seven to four to make room for broader classes. The suggested performance class intervals are shown in Table 106. As noted previously, the standardisation groups are working on a suggestion for changing the dust re-emission scale to a logarithmic scale rather than a linear one.

Table 106: Suggested label classes for the performance parameters on the energy label

Performance class	Dust pick up on carpet (dpu_c)	Dust pick up on hard floor (dpu_{hf})	Dust re-emission (*dre*)
A	$dpu_c > 0.91$	$dpu_{hf} > 1.11$	$dre \leq 0.02\%$
B	$0.85 \leq dpu_c < 0.91$	$1.07 \leq dpu_{hf} < 1.11$	$0.02\% < dre \leq 0.2\%$
C	$0.80 \leq dpu_c < 0.85$	$1.02 \leq dpu_{hf} < 1.07$	$0.20\% < dre \leq 0.60\%$
D	$dpu_c < 0.80$	$dpu_{hf} < 1.02$	$dre > 0.60\%$

[375] This is also the case even if the performance classes are rescaled as suggested in Table 106, since the criteria for A remains the same as in the previous, annulled Energy Labelling Regulation.

These suggestions are based on RRT measurement data of parameters with an empty receptacle. The standardisation group is currently working on an RRT with partly loaded receptacle, but results of these measurements are not published before the end of this review study. These data can therefore not be shown here, but it is suggested to revisit and re-evaluate the classes suggested in Table 106 when the data is available.

Commercial vacuum cleaners

For commercial vacuum cleaners a new EI is suggested to replace the current AE value, and thus different classes would need to be applied. Since a higher EI value equals a higher productivity (m^2/min) and thus results in a lower energy consumption, the higher the value, the better. This is opposite of the AE scale.

Table 107: Energy label classes for the new commercial EI scale

Label class	Interval	Estimated market distribution by 2021
A	≥4,3	0%
B	4,3 > EI ≥ 3,6	1%
C	3,6 > EI ≥ 2,9	5%
D	2,9 > EI ≥ 2,2	30%
E	2,2 > EI ≥ 1,5	40%
F	1,5 > EI ≥ 0,8	20%
G	0,8 > EI	4%

13.5 Policy scenario for resource efficiency

In this chapter the policy scenario regarding resource efficiency is analysed and compared to the Business as Usual (BAU) scenario. The requirements in PO4 are all aiding in increasing product life through durability and reparability requirements.

Table 108: Policy Option 4: resource efficiency requirements

Ecodesign Parameter	Requirements for mains-operated household and commercial	Requirements for cordless	Requirements for Robots
Motor life	500 hours		
Hose oscillation	40,000 oscillations	40,000 oscillations when a hose is present	
Battery lifetime		600 cycles and maintain 70% capacity	600 cycles and maintain 70% capacity
Spare part availability	8 years (household) 5 years (commercial)	6 years	6 years

Easy changeable repair-prone parts	Hose Power cord roll-up Permanent filters Handle Active nozzles	Battery (4 years) Hose Permanent filters Handle Active nozzles	Battery (4 years) Wheels Brushes Permanent filters
Information requirements on repair	How to repair/change repair-prone parts	How to repair/change repair-prone parts and how to best ensure battery longevity	How to repair/ change repair-prone parts and how to best ensure battery longevity
Information requirements on recycled material	Share of recycled plastic content		

One of the important parameters of increasing product life is the availability of spare parts. In task 6 is it stated that it is feasible to increase the current motor lifetime from 500 hours to 550 hours[376] for mains-operated household and commercial vacuum cleaners since this can be achieved at low costs (i.e. still achievable with universal motors) and this is enough for a product lifetime of >10 years. For robot and cordless vacuum cleaners, a lifetime of at least 600 hours is suggested as a requirement in Task 6, to ensure a lifetime of 6 years with 100 hours of use per year. In task 6 it was not considered to be a problem since the motor types used in cordless and robot vacuum cleaners often have much longer lifetimes than the universal motors with carbon brushed used in main-operated vacuum cleaners. However, based on stakeholder inputs it is argued that a motor lifetime of 500 hours is sufficient for a lifetime of 10 years[377] so manufacturers do not see the benefit of increasing the motor lifetime currently. For cordless and robots, the lifetime of DC-motors are below 600 hours and it would in principle exclude all DC-motors. Also, it is difficult to perform accurate tests reflecting real life use of cordless and robots. In addition, robots and cordless vacuum cleaners are emerging technologies and are currently present in a wide price range. This means that some product is more suited for light duty cleaning/spot cleaning and are only used few hours a year. A motor lifetime requirement would make these products consume more resources and increase the cost. Hence it is suggested to not include a lifetime requirement for cordless and robots and instead give information about the motor lifetime in the product fiche. However in the next revision of the regulation a requirement regarding motor lifetime should be considered as consumer organisation are in favour of such a requirement.

[376] This requirement is suggested disregarding of the motor is tested partly loaded or empty.
[377] With the current assumption on usage

The current requirement of 40,000 hose oscillation is recommended to be maintained and also applied to cordless vacuum cleaners when a hose is present. For robot cleaners, a hose is never expected to be present.

The important aspect of battery lifetime is suggested to be regulated with a minimum requirement for cordless and robot vacuum cleaners. No standard for battery lifetime exists, but the computer Ecodesign Regulation has an information requirement of battery lifetime based on the number of charging cycles it can last. However, the battery capacity falls over time with the number of charging cycles, and the share of power drawn from the battery out of its total rated capacity (also called Depth of Discharge, DoD) is crucial for the lifetime in terms of the capacity left after a number of cycles. It is therefore recommended to set the requirement according to a definition including DoD and threshold for remaining capacity, for example 'after 600 charging cycles with 90% discharge in each cycle, 70% of the battery capacity should remain'[378]. This means that cordless and robots will need 2 batteries on average in their lifetime of 6 years, since they are used 200 times a year. For robots and cordless vacuum cleaners, the battery is essential for a proper lifetime and it is important that the battery is durable and can be exchanged for a fair price. Otherwise consumers may replace their product instead of the battery. However, stakeholders have also expressed concerns about to strict requirements for the battery and capacity. A large battery will consume more resources, have an increased weight and add significant cost to the product (also in the case of replacement). In addition, stakeholders have expressed concerns whether it is possible for the market surveillance to control such measures.

Besides durability requirements there are other possibilities to extend the lifetime of vacuum cleaners. Based on a Deloitte study[379] it seems like the following options have a positive effect on the environment:

- Measures to ensure provision of information to consumers on possibilities to repair the product
- Measures to ensure provision of technical information to facilitate repair to professionals
- Measures to enable an easier dismantling of products
- Measures to ensure availability of spare parts for at least a certain amount of years from the time that production ceases of the specific models
- Different combination of the above-mentioned options

[378] EN 61960:2011 could be used for measuring battery endurance in cycles (part 7.6.2 or 7.6.3 in the standard)
[379] Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV

These measures are also applicable to the different types of vacuum cleaners and information about repair and repair instructions for certain parts are suggested. According to the study performed by Deloitte, the most beneficial measure is to ensure the availability of spare parts. However, the essential/critical spare parts vary. According to preliminary results from an ongoing study on the development of a scoring system for repair and upgrade[380], the most important aspects that define some parts as 'priority parts' are (listed in order of importance):

1. Their frequency of failure
2. Their functional importance
3. The steps needed for their disassembly
4. Their economic value and related repair operations
5. Their environmental impacts

Parts which are likely to fail and are reasonable priced are permanent filters, hoses, handles, accessories in general. These parts are all essential for the function of the machine and are likely to be purchased if they break[381]. Many of the same parts are assumed to be essential for cordless and robots. However, for cordless and robots the battery is also an important spare part, and for robots the rotating brushes.

It is therefore recommended to set requirements on the availability of critical spare parts throughout at least one lifetime of the product. This is 8 years for household mains-operated, 5 years for commercial, and 6 years for cordless and robot vacuum cleaners. However, stakeholders have explained that advancement in battery technology makes it economical unfeasible to produce "older" batteries e.g. if an original cell is out of production new UN and IEC approvals for replacement cells will cost a considerable amount of money. This means there is a risk that the batteries become so expensive that it is unfeasible to buy a battery. Therefore, a 4 years availability of batteries seems appropriate as the consumers then can replace a battery after half a lifetime. The spare parts should be available for the specified number of years after the last unit of a specific model is produced. The repair prone parts should be possible for the user to change, without needing help from a professional repair person, and should therefore be possible to conduct without the need for special tools. Furthermore, an information requirement should be implemented regarding information to the end-user on how to change these parts, as well as how to best maintain the capacity of the battery in cordless and robot vacuum cleaners.

[380] http://susproc.jrc.ec.europa.eu/ScoringSystemOnReparability/index.html
[381] For upright vacuum cleaners, also the belts in the nozzle are expected to be changed if they break

In PO4 an information requirement on the amount of recycled plastic is suggested in order to promote recycling of plastic and support the65% recycling goal from the WEEE Directive. Where the WEEE Directive targets the End-of-Life aspects (collecting and recycling) the Ecodesign Directive targets the design phase and thus the products placed on the market. Since metals are already recycled at high rates, this requirement is based only on the plastic, which has much lower recycling rates. In Figure 63 a conceptual drawing of the recycling sign is presented.

Figure 84: Conceptual drawing of a recycling sign

The main barrier for such a requirement is how to ensure compliance, since it is not possible to easily tell apart recycled and virgin materials, neither for metals nor plastics. One solution is paper proof to have a trail of documentation for the material used and declarations from suppliers about the material's origin.

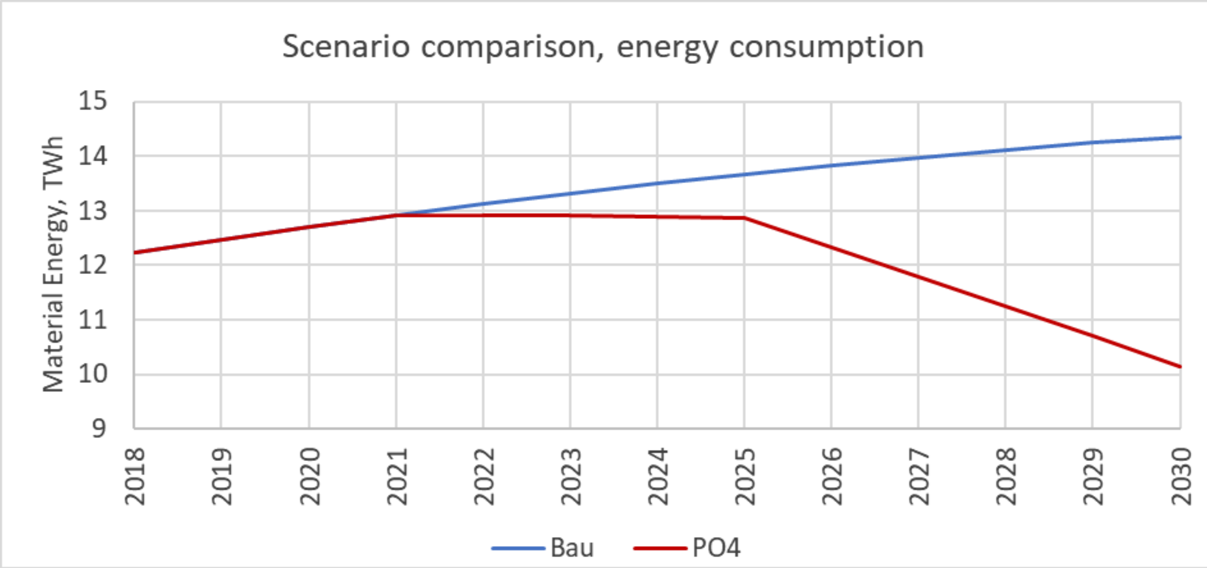
In order to calculate the effect of the two resource policy options, it was assumed that all the requirements in PO4 results in 2 years additional lifetime (increasing lifetime from 8 to 10 years) for mains-operated household vacuum cleaners, corresponding to 25%. Similarly, the lifetime of the other base cases is assumed to increase with 25%. Note that the consumption of spare parts is expected to increase.

13.5.1 Material energy saving potentials

Based on the above requirements and the data presented throughout the study, the impact of PO4 has been derived and compared to the BAU scenario. What is compared in this section is the material energy, i.e. the energy consumed for production and embedded energy of materials, not the energy consumed by the vacuum cleaners in the use phase.

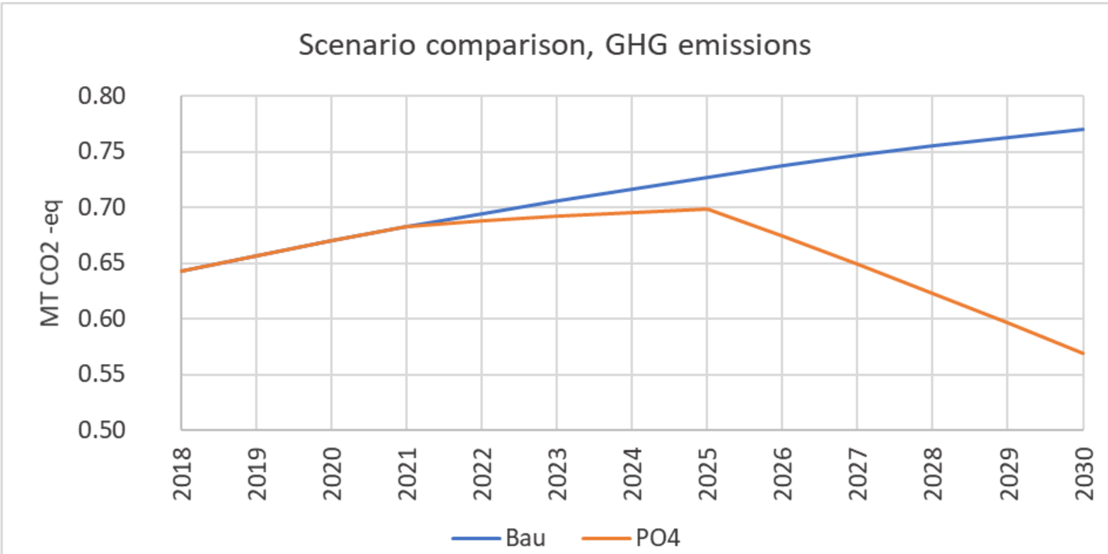
As seen from Figure 85, the material energy in both scenarios is lower than in the BAU scenario from 2022.

Figure 85: Material energy in PO4 compared to BAU from 2018 to 2030 in EU 28



As shown previously, the greenhouse gas emissions follow the energy consumption, which is also the case for material energy and GHG emissions. The PO4 scenario has savings of around 0.2 Mt CO_2-eq/year by 2030 as seen in Figure 86.

Figure 86: GHG emissions in PO4 compared to BAU from 2018 to 2030



The savings in PO4 are caused by an assumed increase in the lifetime of vacuum cleaners of 25% (from 8 to 10 years for mains-operated household vacuum cleaners), and an increased use of recycled plastic. This means that more material (spare parts) are used per vacuum cleaner and that the vacuum cleaners will miss out a potential energy improvement according to the longer lifetime. However, the shift to recycled plastic ensures savings from the first year the information on the label is introduced. The rapid decrease in 2025 is due to the reduction in sales which is a result of the increased lifetime.

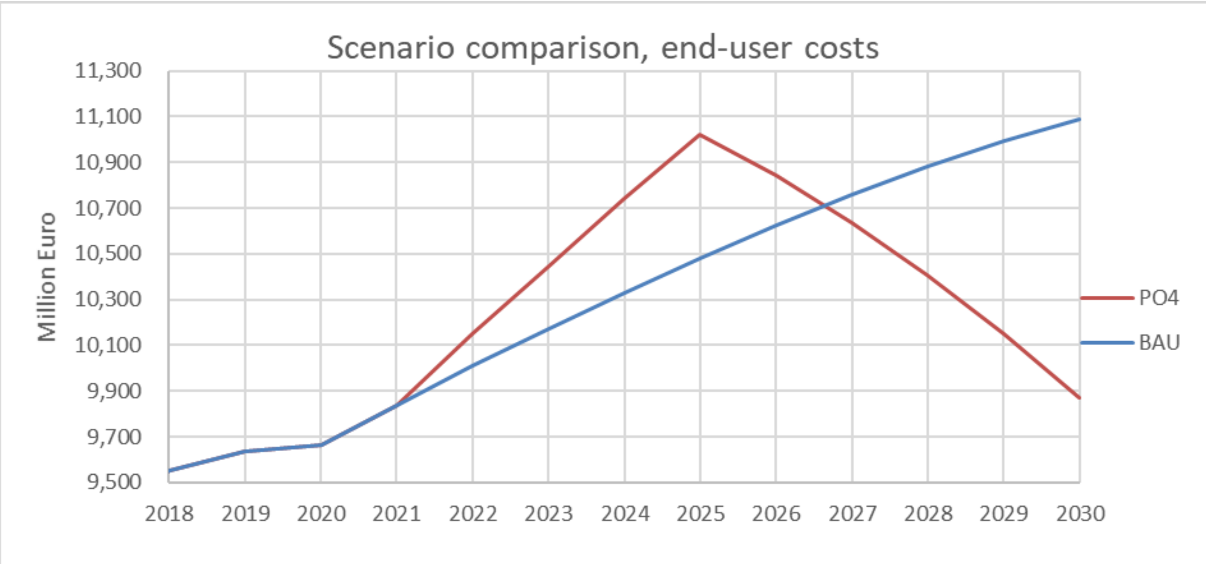
The material energy savings for each type of tumble driers in 2030 is presented in Table 109.

Table 109: Material energy savings for each base case in 2030 for PO4 and PO5 in EU28

	2030 Material energy, TWh		2030 savings, TWh	2030 savings, %
	BAU	PO4	PO4	PO4
Household mains-operated	4.74	3.11	1.64	35%
Commercial	1.17	0.75	0.42	36%
Cordless	5.73	4.26	1.47	26%
Robots	2.70	2.02	0.68	25%
Total	**14.35**	**10.14**	**4.21**	**29%**

The energy saving potential is 29% in PO4, which is also reflected in the end-user expenditures, compared to the BAU scenario. Figure 87 shows the material end-user expenditures for all vacuum cleaners in the EU. The cost is composed of the total sales, the purchase price, increased costs for spare parts and the cost of loss in efficiency (i.e. higher energy costs) when the lifetime is increased. The increased cost of spare parts is responsible for increased costs compared to BAU until the sales are reduced after 2025. Note that as even recycled plastic currently is cheaper it is assumed the content of recycled plastic has no effect on the purchase price.

Figure 87: Material end-user expenditures for all vacuum cleaners in EU each year from 2018-2030.



For PO4, consumer expenditure is lower than in the BAU as seen in Table 110. However, the purchase price of vacuum cleaners might increase if spare parts are made available for a longer period of time as more expenses can occur e.g. higher stocks of spare parts. Also, if the demand for recycled plastic increases it may increase the price of recycled plastic.

Table 110: EU Material end-user expenditures for each base case

Consumer expenditure, Million €		Year			2030 Savings
Base case	**Scenario**	**2018**	**2020**	**2030**	
Mains-operated household	BAU	5,405	4,482	3,635	-
	PO4	5,405	4,859	3,580	2%
Commercial	BAU	1,510	1,468	1,475	-
	PO4	1,510	1,570	1,384	6%
Cordless	BAU	1,893	3,244	4,258	-
	PO4	1,893	3,296	3,511	18%
Robot	BAU	743	1,286	1,718	-
	PO4	743	1,296	1,395	19%

13.6 Parameters on the energy label

In order to include cordless and robot vacuum cleaners as new product types in the scope of a future Energy Labelling Regulation, it might very likely be necessary to also change the label parameters and design. Especially for robots the label might need to look different, since they cannot be compared directly to manually operated vacuum cleaners due to differences in measurement methods and in performance parameters.

The parameters from the annulled energy label, are still relevant:

- Energy efficiency class
- Average annual energy consumption (kWh/year)
- Dust re-emission class
- Carpet cleaning performance class
- Hard floor cleaning performance class
- Sound power level

However, for cordless and robot vacuum cleaners, the battery run time per cycle is an important parameter for end-users and could be added as a number (in minutes) on the label for cordless products. For robots, a similar declaration could be made, however, some stakeholders have suggested instead to show the area the robot can cover within a given time, as a "covered area" per half hour measured in m^2. Furthermore, it has been suggested to add a "navigation class" to the robot label, based on the coverage rate, since this is also an important parameter for end-users. In addition, it is suggested to add information on the content of recycled plastic on the label for all vacuum cleaners.

In summary the following parameters are suggested for each of the vacuum cleaner types in PO1, PO2 and PO4:

Table 111: parameters suggested for the energy label in PO1, PO2 and PO4

Mains operated household	Commercial	Cordless	Robots
Annual energy scale as main scale	Annual energy scale as main scale*	Annual energy scale as main scale	Annual energy scale as main scale
Dust pick-up hard floor	Dust pick-up hard floor	Dust pick-up hard floor	Dust pick-up hard floor
Dust pick-up carpet	Dust pick-up carpet	Dust pick-up carpet	Dust pick-up carpet
Dust re-emission	Dust re-emission	Dust re-emission	
Noise	Noise	Noise	Noise
			Coverage factor/covered area
The content of recycled plastic	The content of recycled plastic	The content of recycled plastic	The content of recycled plastic

**Possibly exchange for a productive number, e.g. area/time, if a test is ready*

13.7 Sensitivity analysis

The sensitivity analysis was performed for two parameters: market penetration (i.e. sales and stock) of robots and cordless vacuum cleaners, and the assumed lifetime extension.

The impact on energy consumption of different sales numbers for robot and cordless is calculated for policy options 1-3, since the sales have an impact on the total energy consumption. The impact of a different lifetime extension as a consequence of the requirements in PO4, is calculated only for the resource parameters, and thus only for PO4.

In order to calculate the sensitivity of the assumptions, the following scenarios were modelled:

- Change in sales in PO1, PO2 and PO3
  - Double/half the sales of robots in 2030. All other sales are stable.
  - 25% increase/decrease in the sales of cordless in 2030. All other sales are stable.
- Expected lifetime extension by spare parts availability in PO4
  - 10%-point increase/decrease of the expected 25% increase in lifetime i.e. 35% increase in lifetime and 15% increase in lifetime.

The impact of these changes is calculated as the difference in TWh (use phase or material energy). In Table 112 and Table 113 the impact of changing the sales of robot and cordless vacuum cleaners is presented. The tables include the original scenarios, a scenario which double sales by 2030 and a scenario with half the sales by 2030.

Table 112: Change in robot vacuum cleaner sales and the effect in BAU, PO1, PO2 and PO3

	2020	2025	2030	2020	2025	2030
	Savings, TWh			Change from original, %		
BAU (original)	16.205	16.074	17.399	-	-	-

With double robot sales	16.357	16.684	18.548	0.9%	3.8%	6.6%
With half robot sales	16.129	15.769	16.824	-0.5%	-1.9%	-3.3%
	Savings, TWh			Change from original, %		
PO1 (original)	0.506	2.926	4.502	-	-	-
With double robot sales	0.527	3.178	5.053	4.0%	8.6%	12.2%
With half robot sales	0.496	2.799	4.227	-2.0%	-4.3%	-6.1%
	Savings, TWh			Change from original, %		
PO2 (original)	0.521	2.790	4.350	-	-	-
With double robot sales	0.541	3.043	4.900	3.9%	9.0%	12.7%
With half robot sales	0.511	2.664	4.075	-2.0%	-4.5%	-6.3%
	Savings, TWh			Change from original, %		
PO3 (original)	-0.370	-1.337	-1.832			
With double robot sales	-0.370	-1.332	-1.818	0.0%	-0.3%	-0.7%
With half robot sales	-0.370	-1.339	-1.838	0.0%	0.2%	0.4%

Table 113: Change in cordless vacuum cleaner sales and the effect in BAU, PO1, PO2 and PO3

	2010	2015	2020	2025	2030	
	Savings, TWh			Change from 100% robots, %		
BAU (original)	16.205	16.074	17.399			
With double cordless sales	16.366	16.793	18.772	1.0%	4.5%	7.9%
With half cordless sales	16.044	15.356	16.026	-1.0%	-4.5%	-7.9%
	Savings, TWh			Change from 100% robots, %		
PO1 (original)	0.506	2.926	4.502			
With double cordless sales	0.520	3.120	4.953	2.7%	6.7%	10.0%
With half cordless sales	0.492	2.731	4.052	-2.7%	-6.7%	-10.0%
	Savings, TWh			Change from 100% robots, %		
PO2 (original)	0.521	2.790	4.350			
With double cordless sales	0.535	2.985	4.800	2.7%	7.0%	10.4%
With half cordless sales	0.507	2.596	3.899	-2.7%	-7.0%	-10.4%
	Savings, TWh			Change from 100% robots, %		
PO3 (original)	-0.370	-1.337	-1.832			
With double cordless sales	-0.370	-1.352	-1.899	-0.2%	1.2%	3.7%
With half cordless sales	-0.371	-1.321	-1.764	0.2%	-1.2%	-3.7%

In Table 112 and Table 113 it is seen that the sales of robots and cordless vacuum cleaners has an impact on the results. In general, if more vacuum cleaners are sold (increase in the penetration rate) the impact of vacuum cleaners on energy consumption increases, as well as the potential savings in PO1 and PO2. This means that the relative change with an increase/decrease in sales are small e.g. if the sales of robots are doubled towards 2030 the overall energy consumption will increase by 6.6% in the BAU scenario, but the savings in PO1 will increase by 12.2%. Meaning that the energy consumption in PO1 (with current assumption) is 12.897 TWH in 2030. With increased sales (double) of robots the resulting energy consumption in PO1 is 13.495 TWH, or a change of 4.6% in energy consumption. This means that even with a relatively high change in the sales of robots and cordless, the overall result is still valid.

In Table 114 the impact of the expected increase in lifetime is calculated. Note that BAU is the current assumption on lifetime, PO4 is the current assumed increase in lifetime in PO4 (25%), PO4 +10% is an expected increase in lifetime of 35% and PO4 -10% is an expected increase in lifetime of 15%.

Table 114: Change in the expected increase in lifetime in policy option 4

	2030 Material energy, TWh				Savings, TWh			Savings, %		
	BAU	PO4	PO4 +10%	PO4 -10%	PO4	PO4 +10%	PO4 - 10%	PO4	PO4 +10%	PO4 - 10%
Household mains-operated	4.74	3.11	2.72	3.49	1.64	2.03	1.25	35%	43%	26%
Commercial	1.17	0.75	0.66	0.85	0.42	0.51	0.32	36%	44%	27%
Cordless	5.73	4.26	3.72	4.79	1.47	2.01	0.94	26%	35%	16%
Robots	2.70	2.02	1.77	2.28	0.68	0.93	0.43	25%	34%	16%
Total	**14.35**	**10.14**	**8.87**	**11.41**	**4.21**	**5.47**	**2.94**	**29%**	**38%**	**20%**

The change in lifetime is difficult to predict, but even an increase of 15% in the lifetime will cause a reduction of 20% in the material energy consumption (including the increase in the content of recycled plastic). If the increase is 35% the savings is almost 40% of the material energy (5.5 TWh in 2030).

13.8 Conclusions and recommendations

Based on the data and analyses presented in this report, it is recommended to include cordless and robot vacuum cleaner in scope, but with different requirements than mains operated vacuum cleaners.

If it is technically possible and feasible to develop a reproductive and repeatable test methods, that either measure or simulate the performance of vacuum cleaners with part load, it is recommended to follow policy option 2. This entails maintaining the same AE and rated power requirements, but implementing a new energy label regulation.

Policy option 1 with stricter ecodesign requirements is not suggested, as this would leave no room for a full label scale (i.e. 7 classes). If the number of classes were reduced, it might be possible, however, as showed in the scenario analysis this will give little savings in addition to PO2.

If a part load test is not technically possible or feasible, on the other hand, it is recommended to set stricter ecodesign requirements for AE and rated power, according to PO3. This will ensure that at least some of the potential savings are obtained, even though it will be around only half the savings than with an energy label.

In addition, it is recommended to include in policy option 4 resource requirements and information requirements on the content of recycled plastic on the label. Policy option 4 can be applied regardless of the choice of other policy options in connection with durability, reparability and availability of spare parts requirements. The information on the content on recycled plastic can only be added to PO1 and PO2. Without a label, the potential savings will be reduced.

If requirements PO4 is applied, it is suggested to adopt the formulation on resource requirements from, e.g. the refrigerating appliances/washing machines to ensure coherence across the different product groups regarding resource efficiency.

Other specific recommendations include:

- Remove the definition of "full size battery operated vacuum cleaner" and instead use the definitions of robot and cordless vacuum cleaners. Have only one category for cordless vacuum cleaners without any sub-division. Leave handheld vacuum cleaners (not for floor cleaning) out of the scope.
- Include cordless and robot cleaners in scope of both the regulations, but:
  - Consider the timing of when they should be included from, which might not be the same for both product types, and might to some extent depend on finalisation of the test standards
  - Analyse in more detail, preferably with additional data, which requirements are appropriate and consider implementing them in two tiers to give the market and manufacturers time to adapt
  - At the very least make sure that maintenance mode requirements are set within a relatively short time frame
- Use the EI calculation instead of the AE calculation for commercial vacuum cleaners, and make a separate label design.
- Rescale the label to an A-G scale and rescale the performance parameters scales to only four classes (A-D).

    - The timing of re-introducing the labelling regulation and including more nuanced performance standards is important. Changing the standards might influence the limit value of Ecodesign requirements and the energy label scales.
    - Make specific label designs for mains operated household, cordless, robot and commercial vacuum cleaners.
- Set the verification tolerances according to the measured expanded uncertainties when final results are available, and in accordance with the new label scales

14. Annexes

I. Annex A – Elaboration of standards

Elaboration of standards under request M/540

The responsible WG dealing with Mandate M/540 is WG 6 "Surface cleaning appliances" that operates under CENELEC TC 59X, the broad CENELEC TC that is responsible for standards regarding "Performance of household and similar electrical appliances". WG 6, Surface cleaning appliances, has subdivided specific parts of the mandate into several sub-working groups as shown in Table 115.

Table 115: CENELEC TC 59X WG 6 sub-working groups

Sub-working group	Specific part
WG 06-01	Water filter vacuum cleaners
WG 06-02	Uncertainties for vacuum cleaners
WG 06-03	Commercial surface cleaning appliances
WG 06-04	Durability of suction hoses

CENELEC TC 59X WG 6 Surface cleaning appliances cooperates very closely with their counterparts on IEC level within IEC SC 59F (see Table 116). IEC WGs agreed to address considerable content of the Standardisation Request (M/540) because it is relevant worldwide. Examples: full-size battery operated vacuum cleaners, robot vacuum cleaners etc. Also other relevant issues are handled in the respective IEC WGs - e.g. Wilton carpet test (in IEC SC 59F WG 9). Experts are mostly the same in both CENELEC and IEC WGs. Meetings are held in combination or jointly as far as possible.

Table 116: IEC TC 59 SC 59F Working groups and advisory groups

Working group	Title
IEC TC 59 SC 59F/ WG2	Acoustical noise of household appliances
IEC TC 59 SC 59F/ WG3	Dry surface cleaning appliances
IEC TC 59 SC 59F JWG4	Wet surface cleaning appliances linked to ASTM-INTERNATIONAL
IEC TC 59 SC 59F/ WG5	Surface cleaning robots
IEC TC 59 SC 59F/ WG6	Commercial surface cleaning machines
IEC TC 59 SC 59F/ WG7	Cordless (battery operated) vacuum cleaners
IEC TC 59 SC 59F/ WG9	Test equipment and test material
IEC TC 59 SC 59F/ AG1	CAG Chairman's Advisor Group
IEC TC 59 SC 59F/ AG2	Hard floor cleaning
IEC TC 59 SC 59F/ AG3	Advisory group on airborne noise from surface cleaner

1. Durability of the hose and operational lifetime of the motor

Durability testing of the hose and operational motor lifetime are part of the new EN 60312-1:2017 standard which was handled through a Unique Acceptance Procedure (UAP)[382] and has recently been harmonised[383].

The efforts of CLC TC59X WG 6 to produce a harmonised standard implementing the durability requirements was closely linked to the special review study on vacuum cleaners of the European commission prepared by VHK[384]. This special review study followed Article 7(2) of Commission Regulation (EU) No 666/2013 on Ecodesign requirements for vacuum cleaners[385], which specified that the durability requirements on hose (at least 40 000 oscillations) and motors (at least 500 hours at half-loaded receptacle) had to be reviewed. The study started in December 2015 and the final study report was published in June 2016.

Durability of the hose

The current test set-up and test-procedure in Clause 6.9, 'Repeated bending of hose' in the harmonised standard EN 60312-1:2017 has been used for many years by industry and consumer associations and is in principle unproblematic. For the durability test of the hoses the problem lay with the definition of the hoses: Which hoses (primary, secondary) of which types of vacuum cleaners (cylinder, upright) will need to be subject to the test.

Both upright and cylinder vacuum cleaners are, for the purpose of the current Regulation, dry vacuum cleaners. Section 6.9 of the harmonised standard EN 60312-1:2017 defines primary and secondary as follows:

"This test is only applicable to hoses that constitute the primary structural link between the floor-supported main body of a cylinder vacuum cleaner and a separate cleaning head or cleaning head/tube assembly that, in normal use, is used to clean a floor from an upright standing position (see Figure Z.1).

This test is not applicable to hoses that, in normal use, remain affixed at both ends to a vacuum cleaner with a cleaning head that, in normal use, forms an integral part of, or is permanently connected to, the vacuum cleaner housing. This configuration can often be found on upright vacuum cleaners (see Figure Z.2)[386]. Such hoses may be released at one end to allow other cleaning tasks to be carried out (see Figure Z.3)[387].

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[382] The Unique Acceptance Procedure (UAP) is a procedure which may be applied to an EN standard, in order to achieve rapid approval. The UAP combines the 2 voting stages (Enquiry and Formal) and does not allow technical comments. The duration of a UAP is approximately 1 year.
[383] OJ publication C 267/4, 11-08-2017
[384] http://ia-vc-art7.eu/
[385] Commission Regulation (EU) No 666/2013 of 8 July 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for vacuum cleaners, OJ L 192, 13.7.2013, p. 24–34
[386] A test regarding durability of such hoses is under development. https://www.techstreet.com/standards/bs-en-60312-1-2017?product_id=1950146
[387] Section 6.9.1 of the harmonised standard EN 60312-1:2017

Figure Z.1 – Typical cylinder vacuum cleaner with primary hose

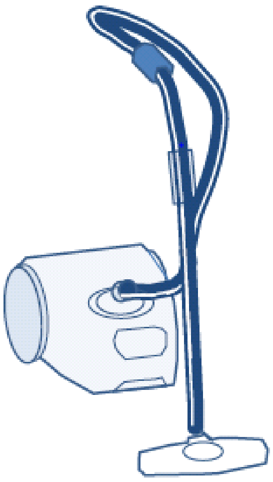


Figure Z.2 – Typical upright vacuum cleaner with secondary hose (contour front and back)

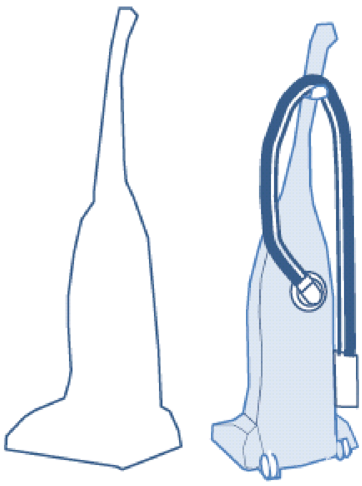
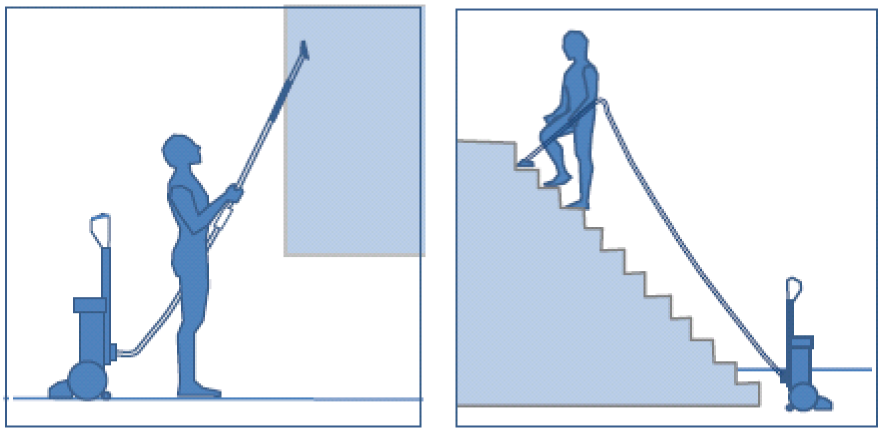


Figure Z.3 – Typical upright vacuum cleaner with secondary hose used for cleaning curtains (left) and stairs (right).



The test is not applicable for:

- Hoses that are permanently housed within other components of a vacuum cleaner, or that cannot be removed from a vacuum cleaner without the use of tools;
- Hoses that join two or more components, where, in all usage modes, the structural link between those components is provided by features other than the hose itself (an example is shown in Figure Z4);
- Hoses that are provided as additional accessories or where another primary hose is provided for general use.

Figure Z4 – Example of a hose joining two or more components

Durability of the motor

Clause 5.9, Performance with loaded dust receptacle, is excluded[388] from the harmonised standard EN 60312-1:2017. This part of the standard explains how to load the receptacle which is needed for the operational motor-life test:

6.Z3.1 Purpose
The purpose of this test is to determine the stationary operational life-time of a dry vacuum cleaner suction and agitation device motor.

6.Z3.2 Test method
The dry vacuum cleaner, equipped as in its normal operation with hose and tube (if applicable) and nozzle, shall be operated as stated in 4.6. It is allowed to run intermittently with periods of 14 min 30s on and 30 s off in maximum power setting.

This test is operated with a half loaded receptacle; hence the dust receptacle shall be loaded with 50 % of the amount of test dust required according to 5.9. Alternatively, an empty dust receptacle can be used during the test. In this case the recommended testing time shall be increased by 10 % of the stated motor life value for testing with a half loaded dust receptacle.

The tube grip of dry vacuum cleaners with suction hose or the handle of other dry vacuum cleaners shall be held as for normal operation at a height of 800 mm ± 50 mm above the test floor. The nozzle shall not be in contact with the floor, but lifted 1 cm off the floor.

If the dry vacuum cleaner is provided with an agitation device, it shall be running. If manufacturer’s instructions require different settings of the agitation device for use on carpets and use on hard floor, the agitation device shall be operated with the respective settings for 50% each of the total testing time.

Test with half loaded dust receptacle: After 50 h ±5h of operation, the vacuum cleaner shall be equipped with a clean dust receptacle and new filters (see 4.5). This procedure, with

[388] Clauses 5.9, 6.15, 6.Z1.2.3, 6.Z1.2.4, 6.Z1.2.5, 6.Z2.3 and 6.Z3 are not part of the present citation. In clause 7.2.2.5 read ‘A2 fine test dust’ instead of ‘test dust’.

the receptacle loaded with the same amount of test dust as for the first cycle, shall be repeated in steps of 50 h ±5h.

Test with empty dust receptacle: After 100 h ± 5 h of operation, the vacuum cleaner shall be equipped with a clean dust receptacle and new filters (see 4.5).

Changing or maintenance of dust receptacles and filters shall be carried out in accordance to the manufacturer's instructions and this shall be recorded, see 4.5. End of life is reached when the suction motor and, if applicable, the agitation device stops operating or the recommended testing time has elapsed.

NOTE The 30 second off period is not included in the calculation of overall motor life."

2. Water filter vacuum cleaners

As water filter vacuum cleaners were not addressed in existing standards, this aspect has been added to the harmonised standard EN 60312-1:2017. All tests were checked and amended where necessary in order to make them applicable for water filter vacuum cleaners. The following definitions have been added to the 2017 version:

Water filter vacuum cleaner: Dry vacuum cleaner that uses water as the main filter medium, whereby the suction air is forced through the water entrapping the removed dry material as it passes through.

Water filter system: removable water filter components which are in contact with the water"

3. Full size battery operated vacuum cleaners

Work on this part of the mandate is mostly done by IEC SC 59F WG 7. The new draft standard "IEC 62885-4 Surface cleaning appliances – Part 4: Cordless dry vacuum cleaners for household or similar use – Methods for measuring the performance" focusses on battery operated vacuum cleaners to be used on the floor by the user from an erect standing position and is based on the EN 60312-1 for dry vacuum cleaners. The new draft standard IEC 62885-4 is currently at CD stage. It is subject to parallel voting on CENELEC level.

All tests were checked and amended where necessary for battery operated vacuum cleaners. This includes specific measurement methods for the energy consumption of the batteries. Another parameter which is considered to be highly relevant for battery operated vacuum cleaners is "run time". This is the duration such an appliance can be used by customers while a reasonable suction power is provided. A new test was elaborated which is included in the draft standard.

Handheld battery operated vacuum cleaners for above-the-floor cleaning are left for a future edition.

4. Robot vacuum cleaners

Robot vacuum cleaner standards are developed on a worldwide level by IEC SC 59F WG 5 and in cooperation with CENELEC TC 59X WG 6 the potential Energy labelling and Ecodesign requirements will be addressed in a new standard "IEC 62885-7 Surface cleaning appliance – Part 7: Dry-cleaning cleaning robots for household use – Methods of measuring performance". The new standard amends the existing test standard IEC (EN) 62929:2014 - Cleaning robots for household use. Dry cleaning: Methods of measuring performance.

IEC 62929:2014 is applicable to dry cleaning robots for household use in or under conditions similar to those in households. The purpose of this standard is to specify the essential performance characteristics of dry cleaning robots and to describe methods for measuring these characteristics. This standard is neither concerned with safety nor with performance requirements.

IEC 62929 contains measurement of:

- Dust removal from hard flat floors and from carpets - box test
- Dust removal from hard flat floors and from carpets - straight line test
- Autonomous navigation/coverage test
- Average robot speed

The following additional tests are planned for the next voting stage[389] of the new draft standard IEC 62885-7:

- Obstacle overcome capability
- Energy consumption
- Debris pick-up – box and or straight line
- Fibre pick-up – box

The overall conclusion by the Standardisation work group (TC 59X WG 6) is that the standards are not mature enough to be used for Energy Labelling / Ecodesign purposes. The main reasons are:

- There is limited experience with tests because standard is new (published in 2014) or under development
- There is no data for repeatability available; RRT has yet to be concluded
- Still considerable change on the market

The forecasted publication date is July 2020[390].

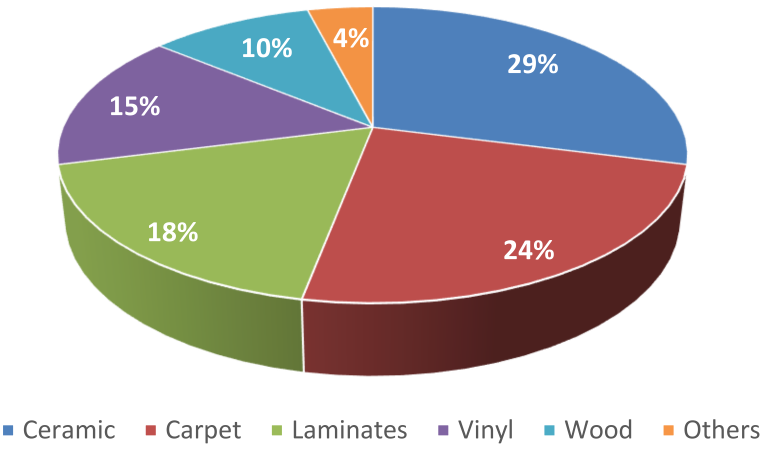
5. Measurement with market-representative carpet(s) and hard floor(s)

This part of the mandate is executed in close collaboration with CEN TC 134, Resilient, textile and laminate floor coverings. TC 134 presented figures of EU market shares for floor coverings. As can be seen in Figure 88, carpets cover about 24% of the total floor area, hard floors about 30% (laminate and parquet), resilient floors about 17% and ceramics about 29%.

[389] CDV is Committee Draft for Vote, similar to the Enquiry vote within CENELEC and is estimated to take place June 2018 http://www.iec.ch/dyn/www/f?p=103:23:0::::FSP_ORG_ID:1395

[390] http://www.iec.ch/dyn/www/f?p=103:23:0::::FSP_ORG_ID:1395

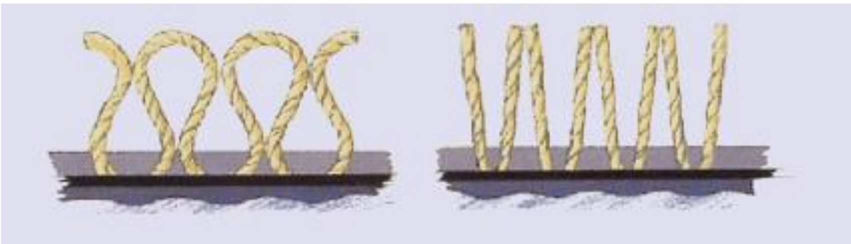
Figure 88: Total EU market for floor coverings in 2015, equalling 1900 million m2 and 15% of global market[391]



Carpets

The analysis also showed that domestic cut pile and domestic loop pile, shown in Figure 89, will cover around 90% of the domestic carpet share in the EU. Therefore, two cut pile and two loop pile carpets are chosen and will be distributed to the test labs[392].

Figure 89: left: domestic loop pole, right: domestic cut pile[393]



Resilient floors

For resilient floors two samples are also proposed; the Cushion Vinyl (embossed) and Luxury Vinyl Tiles (LVT) planks. The pictures shown in Figure 90 are examples of Cushion Vinyl and Luxury Vinyl Tiles planks and might differ from the samples distributed to the test labs and are merely shown as illustration.

[391] EU market share floor coverings (Source: presentation CEN TC 134 at the February 2017 meeting in Hartmannsdorf)
[392] Status as of November 2017
[393] Picture source: presentation CEN TC 134 at the February 2017 meeting in Hartmannsdorf

Figure 90: left: Allura Vinyl Tile[394], right: Viva Cushion vinyl[395]

Laminate

For laminate floors also two kinds are proposed the Quick Step Impressive[396] and Colours Gawler[397].

Parquet

One kind of parquet is proposed the Maxistab[398].

Testing

During the initial tests 7 different floor coverings were distributed to 13 laboratories. The proposed selection of flooring includes: 2x synthetic carpets "The Noble Collection - Saxony 180" (cut pile) and Gala 13 (loop pile) and 5x types of hard floors, thereof: 2x Laminate (impressive; Colour Gawler), 2x Vinyls (Novilon, Allura) and 1x Parquet (Maxistab).

Findings regarding carpets were presented during the standardisation meeting in March 2019 in Brussels, based on 6 laboratories:
- Saxony 180 is not suitable to become a test carpet (preliminary results showed longer conditioning process to get a stable result, low dpu level with high fluctuation, structure changed after few runs),
- Gala 13 could be qualified to become a test carpet (preliminary results showed higher level dpu with sufficient stability, lower motion resistance, no change in ranking (depending on nozzle)).

The hard floors findings showed no differences on all hard floors for dpu with debris and very little to no differences on all hard floors for dpu with fine dust

A report on the results regarding tests on market representative floors will be presented to the Commission as part of M/540.

[394] https://www.forbo.com/flooring/nl-nl/producten/luxe-vinyltegels-en-stroken/allura/ba9wax
[395] https://www.forbo.com/flooring/en-uk/products/for-your-home/novilon-cushion-vinyl/novilon-viva/bqsjty#7400
[396] https://www.quick-step.be/nl-be/campagnes/impressive-laminaatvloeren
[397] http://www.classen.de/en/laminate-flooring
[398] https://www.meisterwerke.com/de/declaration-of-performance/markenauswahl/schulte-raeume/

6. Consumer organization tests

Which?

Which? is an independent consumer organization based in the UK. Every year they test over 3600 products and cover the essential features of a product. Tests performed on cylindrical and upright vacuum cleaners are[399]:

- Cleaning of fine dust and dirt: For the carpet test a machine spreads super-fine dust over a carpet and grinds it in. The vacuum cleaner is then placed onto a test rig, which pulls and pushes it back and forth five times as it sucks up the dust. This test is repeated for smooth and creviced wood floors.
- Cleaning of debris: Vacuum cleaners are also challenged to pick up larger debris. For this Which? used a large amount of dry rice.
- Dust re-emission: To test if vacuum cleaners keep fine dust safely locked away inside, specialist machinery is used to test how much dust and fine particles the vacuum cleaners retain.
- Suction power while the bag or canister fills up: The vacuum cleaner is put on the test rig again, and measuring takes place on the suction power when bags or canisters are empty, and again when they are filled with dust and debris.
- The time it takes to pick up pet hair and longer hair: Real cat and dog fur are combed into an area of carpet and the time is measured how long it takes to pick all of the hair up. This test is repeated for longer hair of real human and it is tested how long it takes to remove the fluff from a cushion with the provided upholstery tool.
- Manoeuvrability: A panel of experts was asked to assess the manoeuvrability of the vacuum cleaner in common scenarios, from vacuuming up and down stairs to moving it across different and uneven surfaces. They also check how easy it is to change and use the attachments and to empty the bag or canister.
- Noise: The sound of each vacuum cleaner is tested in a lab

Certain assessments are more important than others and so Which? carried out different weights to categories the vacuum cleaners: 75% cleaning and filtration 20% ease of use 5% noise and energy use.

Which? tested also robot vacuum cleaners[400] and the focus was on:

- Dust and dirt removal: Super fine Arizona sand is spread over thick Wilton carpet, and chunky lentils are spread over a hard floor to test how effectively each robot can pick up mess from different surfaces. After the robot vacuum cleaner returns to its charging station the amount of dust/dirt pick up is measured.

  Similar to the cord vacuum cleaners test above real cat and dog fur are combed into an area of carpet and the amount of hair picked up is measured (not the time).
- Floor coverage: A specially designed room complete with tables, chairs, lamps, rugs and low hanging curtains is built to see how well each robot gets on navigating around a typical room. Cameras were installed in the room and sensors were

[399] http://www.which.co.uk/reviews/vacuum-cleaners/article/how-we-test-vacuum-cleaners
[400] http://www.which.co.uk/reviews/robot-vacuum-cleaners/article/how-we-test-robot-vacuum-cleaners

attached (in three places) on each robot so that what spots the robot covers and which areas it fails to reach can be monitored.

- Navigation round obstacles: The maximum height of a ridge is tested so that each robot vacuum cleaner can climb over. Furthermore, a wide array of everyday obstacles is put in the path of each robot to see how they handle this. The test room has a tangle of wires, tables and chairs, a domed floor lamp and fold out chairs to try and trip up each robot cleaner.
- User friendliness: The out of the box setting is tested furthermore, it is tested how easy it is to programme and schedule a cleaning cycle and also how easy or difficult it is to do regular maintenance on your robot, such as emptying the dust container and cleaning any filters.

Which?'s overall ratings for robot vacuums ignore price and are based on: Cleaning - 52% Navigation and obstacle avoidance - 28% Ease of use - 18% Noise - 2%

Cordless vacuum cleaners[401] are tested focusing on:

- Dust removal and re-emission: Fine Arizona sand is used to see how much dust each vacuum cleaner picks up, as well as how much is re-emitted. The test continues till the vacuum cleaners' battery is only 20% charged. Also here, the ability to pick up pet fur is tested, both the amount as the time it takes to pick it up is measured.

  The suction of each cordless model is tested on three different surfaces - laminate, floorboards and carpet. 25g of dust is used and a test comprises of two runs on each surface type, the amount dust in the canister is measured at the end.
- Battery lifetime: The time is measured how long it takes to fully charge and run completely empty. This test is performed on the most powerful setting (not standard as most manufacturers use). To further test the battery also the pick-up capabilities is tested when only 20% of its charge remains.
- Noise: The sound of each vacuum cleaner is tested

Overall ratings are based for 75% on suction, filtration and battery for 20% on ease of use and 5% noise.

Stiftung Warentest

Stiftung Warentest is an independent German consumer organization who tests products and services according to scientific methods in independent institutes and publishes the results in their publications. The Stiftung Warentest tested corded vacuum cleaners, battery and robot vacuum cleaners.

Corded vacuum cleaners are tested according to the following features:

- Dust absorption test: The standardized dust intake is measured in accordance with the EN 60312-1. For the test of Duracord carpet, smooth hard floors and crevices the receptacles are filled with 200 grams of test dust or when this is not possible the vacuum cleaners are tested with a negative pressure of 40 percent of the initial value. Also the fibre uptake is measured.

[401] http://www.which.co.uk/reviews/cordless-vacuum-cleaners/article/how-we-test-cordless-vacuums

- Handling: Five persons (testers) make an everyday test and they assess the operating instructions, set up and dismantling of the devices, as well as handles, switches, displays and storage - additionally and the carrying of the devices. Further test points: How well can carpet and hard floors, stairs and upholstery be cleaned, cleaning of the nozzles, changing of the dust bag and filter or empty the receptacle.
- Dust retention capacity: the fine dust content in the inlet and exhaust air is compared as the degree of separation. The more dust remains in the filter, the higher the separation efficiency, the better.
- Noise: sound power level is tested according EN 60704-2-1.
- Power Consumption: during the dust absorption test described above the electricity consumption of the vacuum cleaner is measured (the result refers to $10m^2$).
- Durability test: The lifetime of the motor is tested by letting the vacuum cleaner run up to 600 hours; and up to 95 hours for cordless hand-held vacuum cleaners with assessment of the battery time reduction.

  Impact test are performed so will a vacuum cleaner hit 1.000 times a post and go 10.000 over sleepers. The nozzle must exceed 1.200 falls from a height of 80cm and the cable extraction must succeed 6.000 pulls. Furthermore the hose fittings are pivoted for 40000 and the pipes and hoses are squeezed with a load of 70 kg for 10 seconds.
- Safety: In accordance with EN 60335-1 and -2-2, the electrical safety of the vacuum cleaners is checked.

Battery operated vacuum cleaners are tested the same way as the corded vacuum cleaners the only differences are that with the dust absorption test 25 grams and 50 grams are fed to the vacuum cleaner. The battery recharge times are evaluated, and the vacuum cleaners will undergo 67.500 cycles on the crank test instead of the threshold test. The following features have been tested for robot vacuum cleaners:

- Dust absorption test: The tests were conducted in accordance with EN 62929 on carpet and hard floors.
- Navigation: The navigation test is carried out in a test room in accordance with EN 62929, the inventory was slightly modified (compared to the dust absorption test room) and an additional outdoor area of approx. 2 m^2 was created before the entrance door.
- Handling: Five **experts evaluated the** instruction manual **and** tested benefits of **the cleaner** controls/displays**, the ease of emptying the** dust box**,** cleaning of filters **and** unit **and** remote-control capability**,** defined space **and** carrying the device**.**
- Environmental characteristics: Sound power was tested according to EN 60704-2-1 on carpet and hard floors

  Dust re-emission was tested according to EN 60312-1 and the annual power consumption for daily cleaning of the test room (about 20 square meters) was calculated, including running and charging times, maintenance charging of the battery and maintenance mode power consumption of the charger.

- Durability: The vacuum cleaners ran non-stop in a test room with short pile carpet for 16 weeks[402]. They ran until the battery had to be charged. After recharging, they continued cleaning again.

Consumentenbond

The Dutch independent consumer organization tested cylinder vacuum cleaners[403]. The features that were tested are:

- Cleaning performance: Tests are performed on carpets and hard floors including crevices. To test the cleaning of pet fur/hair synthetic fibres are used to mimic real pet hair. Furthermore, the suction power is measured when the receptacle fills up.
- Durability test: Motor lifetime is tested according to EN 60312-1 chapter 6.10.

  The mechanism to roll up the cable is tested by unwinding it 1.000 times and let it roll up again.
- Dust re-emission
- Energy consumption: The energy consumption is measured while vacuuming 10m^2 of carpet and hard floors.
- Noise

[402] Stifftung Warentest, 2/2017, page 63 it is written in the Haltbarkeit section “16 Wochen”
[403] https://www.consumentenbond.nl/stofzuiger/hoe-wij-testen

II. Annex B – GfK data coverage

Data coverage of the data purchased from GfK.

Country	Coverage	Population	GDP (bill. EUR)
Austria	90%	8 690 076	349.5
Belgium	88%	11 311 117	421.6
Czech Republic	89%	10 538 275	163.9
Germany	74%	82 175 684	3 134.0
Denmark	83%	5 659 715	266.2
Spain	83%	46 445 828	1 114.0
Finland	82%	5 487 308	214.1
France	90%	66 759 950	2 225.0
Great Britain	95%	65 382 556	2 367.0
Greece	95%	10 783 748	175.9
Croatia	75%	4 190 669	45.8
Hungary	94%	9 830 485	112.4
Ireland	90%	4 724 720	265.8
Italy	89%	60 665 551	1 672.0
Luxembourg	70%	576 249	54.2
Netherland	81%	16 979 120	697.2
Poland	93%	37 967 209	424.3
Portugal	94%	10 341 330	184.9
Romania	90%	19 760 314	169.6
Sweden	85%	9 851 017	462.4
Slovenia	85%	2 064 188	39.8
Slovakia	89%	5 426 252	81.0
Bulgaria	0%	7 153 784	47.4
Cyprus	0%	848 319	17.9
Latvia	0%	1 968 957	25.0
Lithuania	0%	2 888 558	38.6
Estonia	0%	1 315 944	20.9
Malta	0%	434 403	9.9
Total		510 221 326	14 800
Total coverage		430 709 693	12 580
		84%	85%

III. Annex C - Sales and stock data

Vacuum cleaner sales in each category, 1995 to 2030, million units.

Year	Cylinder household	Cylinder commercial	Upright Household	Upright Commercial	Handstick Mains	Handstick cordless	Robot	Total
1995	14.81	1.78	2.61	0.31	0.30	0.51	-	**20.32**
1996	14.81	1.78	2.61	0.31	0.30	0.51	-	**20.32**
1997	14.81	1.78	2.61	0.31	0.30	0.51	-	**20.32**
1998	14.81	1.78	2.61	0.31	0.30	0.51	-	**20.32**
1999	14.81	1.78	2.61	0.31	0.30	0.51	-	**20.32**
2000	14.81	1.78	2.61	0.31	0.30	0.51	-	**20.32**
2001	15.82	1.90	2.79	0.34	0.32	0.55	-	**21.71**
2002	13.71	1.64	2.42	0.29	0.28	0.48	-	**18.81**
2003	15.88	1.91	2.80	0.34	0.32	0.55	-	**21.80**
2004	15.95	1.91	2.82	0.34	0.32	0.55	-	**21.89**
2005	16.92	2.03	2.99	0.36	0.34	0.59	-	**23.22**
2006	19.02	2.28	3.36	0.40	0.38	0.66	-	**26.10**
2007	23.52	2.82	4.15	0.50	0.47	0.82	-	**32.28**
2008	25.16	3.02	4.44	0.53	0.51	0.87	-	**34.53**
2009	25.09	3.01	4.43	0.53	0.50	0.87	-	**34.43**
2010	25.01	3.00	4.41	0.53	0.50	0.87	-	**34.33**
2011	24.80	2.98	4.18	0.50	0.57	0.99	0.15	**34.18**
2012	25.96	3.12	4.17	0.50	0.68	1.18	0.32	**35.92**
2013	25.82	3.10	3.94	0.47	0.76	1.31	0.48	**35.88**
2014	25.17	3.02	3.64	0.44	0.82	1.42	0.63	**35.13**
2015	25.28	3.03	3.44	0.41	0.91	1.56	0.79	**35.43**
2016	25.73	3.09	3.29	0.39	1.00	1.74	0.97	**36.22**
2017	25.47	3.06	3.04	0.37	1.08	1.86	1.13	**36.01**
2018	25.90	3.11	2.87	0.34	1.18	2.04	1.32	**36.78**
2019	26.30	3.16	3.02	0.36	1.17	2.57	1.34	**37.92**
2020	25.07	3.01	2.91	0.35	1.25	4.24	1.45	**38.28**
2021	24.58	2.95	2.62	0.31	1.46	5.72	1.57	**39.22**
2022	24.03	2.95	2.61	0.31	1.56	6.55	1.78	**39.80**
2023	23.43	2.95	2.60	0.31	1.66	7.39	2.00	**40.35**
2024	22.77	2.95	2.58	0.31	1.77	8.25	2.22	**40.85**
2025	22.06	2.95	2.56	0.31	1.87	9.11	2.45	**41.32**
2026	21.31	2.95	2.53	0.31	1.98	9.99	2.67	**41.74**
2027	20.51	2.95	2.50	0.31	2.08	10.87	2.90	**42.12**
2028	19.67	2.95	2.46	0.31	2.18	11.75	3.12	**42.46**
2029	18.79	2.95	2.43	0.31	2.28	12.63	3.35	**42.75**
2030	17.88	2.95	2.38	0.31	2.38	13.51	3.58	**43.00**

Calculated stock of each vacuum cleaner category, 1995 to 2030, million units.

Year	Cylinder household	Cylinder commercial	Upright Household	Upright Commercial	Handstick Mains	cordless	Robot	Total
1995	14.8	1.8	2.6	0.3	0.3	0.5	-	**20.3**
1996	29.6	3.5	5.2	0.6	0.6	1.0	-	**40.6**
1997	44.4	5.2	7.8	0.9	0.9	1.5	-	**60.7**
1998	59.1	6.7	10.4	1.2	1.2	1.9	-	**80.5**
1999	73.6	7.9	13.0	1.4	1.5	2.3	-	**99.6**
2000	87.4	8.8	15.4	1.6	1.8	2.6	-	**117.5**
2001	100.9	9.5	17.8	1.7	2.0	2.9	-	**134.7**
2002	110.0	9.6	19.4	1.7	2.2	3.0	-	**146.0**
2003	118.5	9.8	20.9	1.7	2.4	3.2	-	**156.6**
2004	124.2	10.0	21.9	1.8	2.5	3.3	-	**163.7**
2005	128.7	10.3	22.7	1.8	2.6	3.5	-	**169.5**
2006	133.8	10.7	23.6	1.9	2.7	3.6	-	**176.4**
2007	142.8	11.7	25.2	2.1	2.9	3.9	-	**188.6**
2008	153.1	12.9	27.0	2.3	3.1	4.2	-	**202.6**
2009	163.2	13.9	28.8	2.5	3.3	4.5	-	**216.1**
2010	172.9	14.8	30.5	2.6	3.5	4.8	-	**229.1**
2011	182.0	15.5	31.9	2.7	3.7	5.2	0.2	**241.1**
2012	191.5	16.1	33.2	2.8	4.1	5.7	0.5	**253.7**
2013	199.6	16.5	34.0	2.8	4.5	6.2	0.9	**264.5**
2014	205.6	16.6	34.3	2.7	4.9	6.9	1.5	**272.5**
2015	210.0	16.7	34.0	2.6	5.4	7.5	2.2	**278.5**
2016	213.2	16.8	33.4	2.5	5.9	8.3	3.0	**283.2**
2017	214.9	16.8	32.3	2.4	6.5	9.2	3.9	**286.0**
2018	216.2	16.9	30.9	2.2	7.2	10.0	4.9	**288.5**
2019	217.5	17.0	29.7	2.2	7.8	11.4	5.8	**291.4**
2020	217.3	16.9	28.5	2.1	8.4	14.2	6.7	**294.2**
2021	216.5	16.8	27.2	2.0	9.1	18.3	7.6	**297.5**
2022	215.1	16.7	26.1	1.9	9.9	22.9	8.5	**301.0**
2023	213.0	16.6	25.1	1.9	10.7	28.0	9.5	**304.7**
2024	210.2	16.5	24.3	1.8	11.5	33.5	10.5	**308.3**
2025	206.7	16.4	23.6	1.8	12.3	39.2	11.7	**311.7**
2026	202.4	16.3	23.0	1.8	13.2	45.0	12.9	**314.7**
2027	197.5	16.3	22.6	1.7	14.1	51.0	14.2	**317.3**
2028	192.0	16.3	22.1	1.7	15.0	56.9	15.6	**319.5**
2029	186.0	16.3	21.8	1.7	15.9	62.8	16.9	**321.3**
2030	179.6	16.2	21.5	1.7	16.8	68.6	18.4	**322.8**

IV. Annex D - Calculated collection rate

Based on data collected from Eurostat the collection rate is calculated in Table 117.

Table 117: Calculated collection rate in EU 2014[404]

	Average EEE placed on the market 2011-2013	Weee collected 2014	Collection rate[405]
Austria	17,270	8,415	49%
Belgium	40,998	13,028	32%
Bulgaria	2,986	3,790	127%
Cyprus	1,095	124	11%
Czech Republic	15,448	6,235	40%
Germany	172,507	126,943	74%
Denmark	13,955	5,405	39%
Estonia	1,281	331	26%
Greece	12,510	3,246	26%
Spain	48,850	14,263	29%
Finland	8,926	2,680	30%
France	158,873	34,478	22%
Croatia	3,699	317	9%
Hungary	10,853	5,633	52%
Ireland	10,403	1,920	18%
Iceland	504	354	70%
Italy	68,298	20,983	31%
Liechtenstein	53	117	219%
Lithuania	2,250	1,422	63%
Luxembourg	1,604	412	26%
Latvia	1,256	400	32%
Malta	752	8	1%
Netherlands	20,233	10,219	51%
Norway	16,831	5,570	33%
Poland	45,977	19,495	42%
Portugal	10,653	8,594	81%
Romania	14,240	1,021	7%
Sweden	24,301	5,790	24%
Slovenia	2,458	940	38%
Slovakia	5,259	1,969	37%
United Kingdom	149,963	34,770	23%
Total	884,286	338,872	38%

[404] Due to how the numbers are calculated it is possible to collect more than 100 % (This is also related to how the values are compiled in each country)

V. Annex E– Test results from consumer organisations

NETHERLANDS

Consumentengids June 2017, Steeds wisselen van mondstuk?. p/52-56

	Model & Brand	Price	Test score	hardfloor	crevices	carpet dust	carpet fibres	full bag	ergonomics	dust re-emiss	noise	dust	energy	bag (zak)or nobag (bak)	power
				55%						**20%**	**10%**	**9%**	**6%**		
		Eur													**W**
1		180	7.5	7.7	7.8	7.1	7.6	10.0	8.0	7.5	8.3	5.9	6.6	zak	800
2		180	7.4	7.9	7.9	7.7	8.2	9.1	7.8	7.0	8.4	5.0	6.7	zak	800
3		180	7.4	7.8	7.8	7.5	8.2	8.9	7.9	6.7	8.3	5.7	6.5	zak	800
4		160	7.4	7.8	7.9	7.6	8.0	9.1	7.7	6.9	8.3	5.2	7.4	zak	700
5		170	7.4	7.9	6.6	8.7	8.3	10.0	7.7	5.0	9.9	8.0	6.0	zak	650
6		180	7.3	7.5	8.7	6.4	7.0	7.5	8.1	5.8	9.9	7.5	6.3	zak	650
7		170	7.3	7.2	6.9	6.3	7.0	10.0	7.5	6.2	9.8	8.2	6.5	zak	700
8		105	7.1	7.9	8.3	8.8	8.2	7.5	7.9	4.6	9.7	4.3	7.2	zak	600
9		240	7.1	7.1	7.1	5.5	6.5	9.5	8.0	5.6	9.9	7.6	6.8	bak	650
10		195	7.0	7.1	7.0	5.1	7.7	9.1	7.8	5.6	9.9	6.8	6.3	zak	750
11		230	7.0	7.2	6.7	7.5	6.2	10.0	7.2	6.7	8.4	5.8	6.6	zak	800
12		140	6.8	6.4	6.7	5.2	8.0	5.3	7.8	6.8	9.5	5.2	7.9	zak	600
13		160	6.8	7.4	6.8	8.8	8.2	6.4	7.8	4.8	9.9	4.3	6.2	bak	750
14		160	6.7	7.0	7.1	8.3	7.9	5.2	7.8	5.7	8.5	4.9	6.7	zak	600
15		170	6.7	5.8	7.0	2.2	7.8	3.7	8.1	6.1	9.9	10.0	7.7	zak	650
16		80	6.6	6.9	4.9	8.1	7.7	6.2	7.9	5.5	9.1	3.9	7.4	bak	700
17		80	6.6	6.9	7.5	8.4	5.7	7.5	6.9	4.7	7.7	7.2	7.7	zak	700
18		330	6.6	7.6	6.9	8.5	7.2	7.1	7.9	4.3	9.0	2.8	6.5	bak	750
19		100	6.4	6.7	4.4	7.6	8.1	6.4	7.1	5.9	8.7	3.0	7.2	zak	700
20		330	6.4	5.7	6.6	3.8	8.0	1.3	7.7	5.0	9.9	9.7	6.6	bak	700
21		155	6.2	6.0	6.1	4.0	7.8	3.4	8.1	6.4	8.3	4.0	6.5	zak	650
22		175	6.2	6.5	6.8	4.7	6.4	7.7	8.0	3.9	7.1	6.8	7.5	zak	620
23		290	6.2	5.6	7.9	4.8	5.7	2.0	7.1	6.7	9.6	4.0	7.4	zak	650
24		330	6.2	6.3	4.6	6.5	7.6	5.9	7.8	5.0	9.9	4.9	5.3	bak	900
25		205	6.1	5.8	8.9	3.9	7.7	1.3	5.6	4.7	9.7	6.1	6.8	bak	700
26		170	5.9	5.8	5.4	3.0	8.0	4.6	7.3	5.5	8.2	4.8	6.8	bak	750
27		250	5.8	5.1	2.7	4.6	8.0	1.3	8.1	6.1	9.8	7.7	1.5	zak	750
28		350	5.4	5.5	5.2	8.6	8.3	1.8	1.0	3.5	9.2	4.0	6.4	bak	800
29		70	5.3	6.4	7.1	4.7	6.1	7.9	7.8	6.0	4.3	3.8	8.0	zak	800
30		100	4.6	4.3	3.4	2.6	5.8	2.1	7.9	5.5	6.5	1.7	6.2	bak	750
	average	**187.8**	**6.6**	**6.7**	**6.6**	**6.2**	**7.4**	**6.3**	**7.4**	**5.7**	**8.9**	**5.6**	**6.6**		**714.0**

NETHERLANDS

Consumentengids July/August 2018, Strengere regels voor stofzuigers. p/26-29

Model & Brand	Price	Test score	Cleaning total	hardfloor	crevices	carpet dust	carpet fibres	full bag	ergonomics	Hardfloor	Carpets	dust re-emiss	noise	Energy	Bag	power	Energy efficiency
	Eur		**55%**						**20%**			**10%**	**9%**	**6%**		**W**	
1	180	7.5	7.8	6.9	8.6	8.4	10	7.0	5.4	4.7	4.0	9.4	8.5	7.8	Yes	550	A+
2	190	7.5	7.5	6.9	6.9	8.4	9.4	7.8	6.9	6.9	6.2	9.4	5.8	8.2	Yes	550	A+
3	140	7.3	7.9	7.3	8.5	8.3	10	7.3	5.4	6.2	3.2	9.3	6.5	6.3	Yes	700	A
4	150	7.3	7.2	6.9	6.3	7.0	10	7.5	6.2	8.5	4.7	9.8	8.2	6.5	Yes	700	A
5	155	7.3	7.5	8.7	6.4	7.0	7.5	8.1	5.8	7.7	4.7	9.9	7.5	6.3	Yes	650	A
6	240	7.2	6.7	7.4	8.3	8.4	1.1	8.0	5.9	6.9	5.5	9.9	10	6.7	Yes	650	A
7	300	7.2	6.8	6.5	8.2	8.2	2.1	7.7	6.1	6.2	3.2	10	8.3	8.5	Yes	650	A+
8	220	7.1	7.1	7.1	5.5	6.5	9.5	8.0	5.6	8.5	5.5	9.9	7.6	6.8	No	650	A
9	120	6.9	6.7	6.6	8.6	8.3	2.5	7.9	5.4	3.2	1.7	9.7	7.8	7.5	Yes	750	A
10	275	6.9	6.8	6.2	5.9	8.6	6.4	7.6	5.7	7.7	2.4	9.9	7.4	5.4	Yes	650	A
11	495	6.8	7.7	5.6	8.5	8.3	10	7.9	4.2	6.9	4.7	9.1	4.9	6.3	No	700	A
12	70	6.6	6.9	4.9	8.1	7.7	6.2	7.9	5.5	6.2	4.7	9.1	3.9	7.4	No	700	A
13	80	6.6	6.9	7.5	8.4	5.7	7.5	6.9	4.7	5.5	4.0	7.7	7.2	7.7	Yes	700	A
14	120	6.6	6.6	6.5	8.5	8.2	2.4	7.9	5.2	4.7	4.0	8.6	7.7	6.9	Yes	750	A
15	65	6.5	6.4	5.6	6.2	7.5	5.1	7.5	5.8	7.7	4.7	9.8	5.1	6.7	Yes	750	A
16	260	6.5	5.6	4.6	4.7	7.2	3.2	8.0	6.0	8.5	4.7	9.9	9.8	6.4	Yes	650	A
17	80	6.4	6.3	7.0	6.5	7.4	3.7	7.4	6.3	9.2	4.7	9.9	3.1	6.9	Yes	600	A
18	140	6.4	6.9	5.8	7.7	8.2	5.3	7.9	4.5	3.2	3.2	8.2	4.6	7.4	No	700	A
19	150	6.4	7.1	5.0	8.3	7.2	10	7.3	4.2	6.9	2.4	9.0	3.5	6.4	No	650	A
20	280	6.4	6.4	6.6	8.6	8.2	1.3	7.1	5.0	6.9	6.9	9.9	4.5	7.3	No	600	A
21	325	6.4	7.0	4.2	6.7	8.3	10	7.2	4.9	7.7	4.0	9.9	4.8	2.7	No	890	C
22	150	6.3	6.6	8.2	1.9	8.7	5.7	8.0	6.8	9.2	6.2	8.2	3.8	2.1	Yes	890	C
23	295	6.3	6.4	7.4	5.2	8.7	2.1	7.8	4.6	7.7	3.2	9.9	8.1	3.0	No	850	A
24	95	6.2	6.4	5.3	8.9	8.4	1.5	8.0	5.4	5.5	3.2	9.3	3.1	6.5	Yes	650	A
25	160	6.2	6.4	7.2	2.2	8.5	6.8	8.0	6.6	10	4.7	8.1	4.4	2.2	Yes	890	C
26	175	6.1	6.6	5.9	7.6	8.1	5.7	7.7	4.1	7.7	4.7	7.7	5.1	6.8	Yes	620	A
27	65	5.5	6.2	4.1	8.3	7.9	3.0	8.1	5.2	6.2	4.0	1.7	4.6	7.0	Yes	700	A
28	75	5.5	6.1	5.6	8.4	8.2	1.1	7.9	5.3	7.7	5.5	3.9	2.9	7.4	Yes	700	A
29	395	5.5	4.5	4.6	2.7	4.5	2.0	8.1	6.3	10	9.2	9.0	4.6	7.5	No	650	A+
30	65	5.3	5.9	5.2	8.3	5.8	3.9	7.3	4.7	5.5	3.2	9.3	8.1	7.6	Yes	700	A
31	90	5.3	5.1	2.8	4.0	7.5	4.8	7.5	5.2	8.5	4.0	8.5	4.5	6.9	No	650	A
32	49	4.8	4.4	5.8	6.2	6.8	1.0	1.0	4.6	8.5	6.2	8.4	2.4	7.2	No	700	A
average	**176.5**	**6.5**	**6.6**	**6.1**	**6.8**	**7.7**	**5.3**	**7.5**	**5.4**	**7.1**	**4.5**	**8.8**	**5.9**	**6.4**		**693.4**	

BELGIUM, Test Achats, June 2017

Cylinder types

Model (all with bag)	Euro	W	kg
1	200	800	7
2	265	700	7.2
3	194	800	7.4
4	120	600	5.6
5	133	600	5.6
6	134	750	5.8
7	325	750	7.8
8	181	750	8.1
9	181	750	6.7
10	162	800	5.8
11	213	650	7.5
12	97	700	5.4
13	161	600	5.3
14	319	650	7.8
15	163	650	6.2
16	108	750	5.9
17	157	800	6.2
18	150	800	6.3
19	69	700	5.8
20	80	700	6.3
21	116	700	6.1
22	75	700	4.8
Average	**163**	**714**	**6.4**

GERMANY Stiftung Warentest, 2017, Cylinder type vacuum cleaners

								Previous, classes annulled Energy Label			
Model	**Price Euro**	**Declared W**	**Measured W**	**Volume Receptacle**	**Cable m**	**Weight kg**	**Length hose cm**	**Energy**	**Re-emission**	**Carpet**	**Hardfloor**
Bag											
1	208	650	800	2.2	12.3	7.5	107	A	A	B	A
2	240	800	743	3.4	10.6	7.4	104	A	A	B	A
3	157	750	753	2.1	9.1	6.5	90	A	A	C	A
4	197	750	852	2.6	12	7.4	91	A	A	A	A
5	228	750	796	3	11.1	6.7	92	A	A	A	A
6	283	650	721	2.6	10.9	8.1	81	A	A	B	A
No bag											
7	278	700	786	1.7	10.7	8.7	108	A	A	C	A
8	286	800	899	1.5	9.5	8.6	103	A	A	B	A
9	310	650	743	1.9	10.7	8.1	88	A	A	C	A
10	192	750	803	1.3	8.9	7.1	92	A	A	A	A
11	187	700	782	1.5	11.9	7	91	A	A	C	A
12	130	800	766	2.1	9.3	6.7	90	A	A	C	A
	225	**729**	**787**	**2.2**	**10.6**	**7.5**	**94.8**				

GERMANY Stiftung Warentest, Feb. 2018, Cordless vacuum cleaners

				Battery run-time min			
Model	Price Euro	Volume Receptacle L	Weight kg	**Maximum power (W)**	**Minimum power (W)**	Measured battery charge time (min.)	Battery price Euro
1	400	0.9	3.7	15	82	310	100
2	500	0.6	2.6	8	27	209	65
3	250	0.5	3.1	19	62	306	105
4	175	0.4	2.5	14	42	140	38
5	205	0.6	3.4	18	67	116	68
6	169	0.6	2.8	37	76	202	72
7	120	0.4	2.5	30	74	255	60

8	100	0.4	2.9	17	-	283	50
9	151	0.7	2.3	30	-	181	50
10	100	1.0	2.2	15	-	276	30
Avg.	217	0.6	2.8	20		228	64

GERMANY Stiftung Warentest, June 2018, Cylinder type vacuum cleaners

Model	Price Euro	Declared W	Measured W	Volume Receptacle L	Cable m	Weight kg	Previous, annulled Energy Label classes			
							Energy	**Re-emission**	**Carpet**	**Hardfloor**
Bag										
1	279	550	633	3.4	11.7	7.4	A+	A	C	A
2	227	650	827	2.2	12.1	7.5	A	A	B	A
3	165	600	684	2.4	9.8	6.2	A	A	B	A
4	229	700	845	2.3	11.8	7.4	A	A	A	A
5	130	750	764	1.6	9.0	6.4	A	A	B	A
6	125	800	757	2.0	9.1	6.8	A	A	C	A
7	159	500	474	2.3	8.9	5.6	A+	A	A	A
8	79	750	742	2.2	8.8	5.2	A	A	D	A
9	219	500	577	3.2	13.1	7.0	A+	A	B	A
10	90	700	687	1.8	8.8	6.2	A	B	D	B
11	76	750	770	1.8	8.6	4.9	A	A	C	A
No bag										
12	355	700	786	3.7	10.8	8.7	A	A	B	A
13	340	550	598	2.6	9.5	8.6	A+	A	C	A
14	150	750	776	1.9	9.2	6.8	A	A	C	A
15	177	700	776	1.9	7.3	5.8	A	B	C	A
16	199	650	621	2.4	10.3	7.2	A+	A	C	A
17	250	750	755	2.5	11.1	8.3	A	A	A	A
18	73	700	717	2.0	9.1	5.9	A	A	D	A
19	149	800	758	2.4	8.0	6.7	A	A	A	A
20	250	600	633	2.0	9.6	7.3	A	A	C	B
Avg.	**186**	**673**	**709**	**2.3**	**9.8**	**6.8**				

Other tests

https://robomow.jimdo.com/vorwerk-vr200/

Basisfunktion aller Modelle:

Intelligente Eckenreinigung (D-Shape mit CornerClever-Technologie) / Saugt systematisch in Bahnen (LaserSmart-Kartierung&Navigation) / Präzise Navigation durch 360° Laser-Ortung (5x / Sekunde) / Spot Cleaning / Hindernis und Abgrundsensor / Room Positioning System erstellt eine genaue virtuelle Karte, weiß daher immer wo er ist und wie er zur Basis zurückfindet / Wochenreinigungsprogramm (pro Tag 1 Vorgang) / Multi Room Cleaning und automatisches Aufladen / High Performance Saugleistung - extra starkes und effizientes Saugsystem
Magnetband (Begrenzungsstreifen) zur Absperrung / Bodenerkennung (Teppich, Fliesen, Holzböden)

	Neato Botvac Serie				Neato Botvac D-Serie Neu: SpinFlow, Reinigungswerkzeug, leiser			Vorwerk	
								VR100	VR200
Standard Filter	1	0	0	0	1	0	0	1	0
Mikro HEPA Filter (Performance)	0	1	1	3	0	3	0	0	0
Ultra-Leistungsfilter (Ultra-Performance)	0	0	0	0	0	0	3	-	-
Standard-Lamellenbürste Teppich	1	1	1	1	1	1	1	0	0
Anti-Allergie & Tierhaarbürste	0	0	1	1	1	1	1	1	1
Bürstenbreite (cm / Zoll)	27,6 / 10,9	27,6 / 10,9	27,6 / 10,9	27,6 / 10,9	27,6 / 10,9	27,6 / 10,9	27,6 / 10,9	24 / 9,4	24 / 9,4
Abstand Rundbürste-Seitenwand (cm)	2	2	2	2	2	2	2	4	3
Seitenbürste	1	1	1	1	1	1	1	1	1 (vorne)
Abstand Seitenbürste-Ecke (cm)	4	4	4	4	4	4	4	4	0
Akku (Typ/Volt/mAh)	NiMH/12V/3.600	NiMH/12V/3.600	NiMH/12V/3.600	NiMH/12V/3.600	NiMH/12V/3.600	NiMH/12V/3.600	LiIon/14,4V/4.200	LiIon/14,4V/4.400	LiIon/14,4V/4.400
Wh	43,2	43,2	43,2	43,2	43,2	43,2	60,5	64	84
Ultraschall-Sensoren	nein	nein	nein	nein	nein	nein	nein	nein	3 vorne
Sensoren am LDS (Bumper)	nein	nein	nein	nein	nein	nein	nein	nein	2
Boden / Wand / Stoßfänger-Sensoren	2 / 1 / 4	2 / 1 / 4	2 / 1 / 4	2 / 1 / 4	2 / 1 / 4	2 / 1 / 4	2 / 1 / 4	2 / 1 / 4	3 / 1 / 4
Staubbehälter (Liter)	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,7	0,5
Lautstärke in dB *(ECO-Modus)*	75 (-)	75 (-)	75 (-)	75 (-)	70 (-)	70 (-)	70 *(67)*	70 (-)	70 *(67)*
Luftfluss in CFM (Cubic Feet per Minute)	32,7	32,7	32,7	32,7	32,7	32,7	38,75	-	-
Saugsystem	High Performance III	High Performance III	High Performance III	High Performance III	High Power IV	High Power IV	High Power IV	-	-
Display (Anz.d.Farben / Größe / Zeilen)	4 / 3,5 x 2,8 / 7	4 / 3,5 x 2,8 / 7	4 / 3,5 x 2,8 / 7	4 / 3,5 x 2,8 / 7	4 / 3,5 x 2,8 / 7	4 / 3,5 x 2,8 / 7	> 4 / 3,5 x 2,8 / 6	sw-ws / 4,6 x 4,4 / 7	3 / 3,5 x 2,8 / 6
Fernbedienung IR / App (WLAN)	nein / nein	nein / nein	nein / nein	nein / nein	nein / nein	nein / nein	nein / ja	nein / nein	ja / geplant
Kletterhilfe	nein	nein	nein	nein	nein	nein	nein	nein	ja
Spot-Reinigung (m) / Modus 1x-2x	1,2 x 1,8 / nein	1,2 x 1,8 / nein	1,2 x 1,8 / nein	1,2 x 1,8 / nein	1,2 x 1,8 / nein	1,2 x 1,8 / nein	2x2 + 4x4 / ja	1,2 x 1,5 / nein	1,2 x 1,5 / nein
Trage/Transport-Funktion	Griffmulde	Griffmulde	Griffmulde	Griffmulde	Griffmulde	Griffmulde	Griffmulde	Griffmulde	Griff ausklappbar
Hygien. Entleerung Staubbehälter	nein	nein	nein	nein	nein	nein	nein	nein	ja
Größe (B x L x Höhe) (cm)	33,5 x 32,1 x 10,1	33,5 x 32,1 x 10,1	33,5 x 32,1 x 10,1	33,5 x 32,1 x 10,1	33,5 x 32,1 x 10,1	33,5 x 32,1 x 10,1	33,5 x 32,1 x 10,1	33 x 32 x 10	34 x 34 x 9
Erscheinungsjahr	2014	2014	2014	2014	2015	2015	2015	2011	2014

VI. Annex F - Impacts over a lifetime of vacuum cleaners calculated in the EcoReport Tool

Table 118: All impact categories for mains-operated household vacuum cleaners. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste							
Total Energy (MJ)	675	192	206	2,436	14	-100	3,423
of which, electricity (MJ)	135	115	0	2,420	0	-24	2,647
Water – process (litre)	69	2	0	1	0	-8	63
Water – cooling (litre)	746	54	0	115	0	-39	876
Waste, non-haz./landfill (g)	1,035	633	154	1,281	45	-247	2,901
Waste, hazardous/ incinerated (g)	54	0	3	39	0	-4	91
Emissions (Air)							
GWP100 (kg CO_2-eq)	32	11	15	104	0	-6	155
Acidification (g SO_2-eq.)	203	46	44	461	1	-42	712
VOC (g)	0	0	2	54	0	0	56
Persistent Organic Pollutants (ng i-Teq)	12	2	1	6	0	-5	16
Heavy Metals (mg Ni eq.)	37	5	8	25	0	-11	65
PAHs (mg Ni eq.)	64	0	6	6	0	-22	54
Particulate Matter (g)	81	7	274	10	2	-19	356
Emissions (Water)							
Heavy Metals (mg Hg/20)	76	0	0	11	0	-22	66
Eutrophication (g PO_4)	4	0	0	1	0	0	4

Table 119: All impact categories for commercial vacuum cleaners. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total

Other Resources & Waste							
Total Energy (MJ)	883	284	230	8,320	12	-119	9,611
of which, electricity (MJ)	46	170	0	8,296	0	-2	8,511
Water – process (litre)	59	3	0	1	0	-2	61
Water – cooling (litre)	993	79	0	379	0	-12	1,438
Waste, non-haz./landfill (g)	1,507	964	166	4,328	48	-347	6,667
Waste, hazardous/ incinerated (g)	61	0	3	132	0	-1	195
Emissions (Air)							
GWP100 (kg CO2-eq)	38	16	16	355	0	-7	419
Acidification (g SO2-eq.)	253	68	48	1,573	0	-53	1,890
VOC (g)	0	0	2	185	0	0	188
Persistent Organic Pollutants (ng i-Teq)	23	6	1	20	0	-8	41
Heavy Metals (mg Ni eq.)	34	13	8	84	0	-12	128
PAHs (mg Ni eq.)	144	0	7	21	0	-47	125
Particulate Matter (g)	63	11	342	34	1	-16	434
Emissions (Water)							
Heavy Metals (mg Hg/20)	95	0	0	37	0	-29	104
Eutrophication (g PO_4)	4	0	0	2	0	0	6

Table 120: All impact categories for cordless vacuum cleaners. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste							
Total Energy (MJ)	964	94	170	2,500	14	-103	3,639
of which, electricity (MJ)	551	56	0	2,495	0	-61	3,042
Water – process (litre)	145	1	0	1	0	-15	132
Water – cooling (litre)	342	26	0	114	0	-10	472
Waste, non-haz./landfill (g)	1,119	324	136	1,294	23	-139	2,758
Waste, hazardous/ incinerated (g)	50	0	3	40	0	-4	89
Emissions (Air)							
GWP100 (kg CO2-eq)	51.2	5	12	106.8	0	-6	170
Acidification (g SO2-eq.)	389	23	37	474	1	-46	877
VOC (g)	1	0	1	56	0	0	58
Persistent Organic Pollutants (ng i-Teq)	12	2	1	6	0	-2	19
Heavy Metals (mg Ni eq.)	140	5	7	27	1	-17	163
PAHs (mg Ni eq.)	66	0	5	6	0	-12	66
Particulate Matter (g)	263	3	171	13	6	-30	426
Emissions (Water)							
Heavy Metals (mg Hg/20)	79	0	0	12	0	-12	79
Eutrophication (g PO_4)	2	0	0	0	0	0	3

Table 121: All impact categories for robot vacuum cleaners. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste							
Total Energy (MJ)	1,738	134	170	2,309	5	-33	4,324
of which, electricity (MJ)	1,125	81	0	2,302	0	-23	3,485
Water – process (litre)	287	1	0	3	0	-5	286
Water – cooling (litre)	536	38	0	107	0	-2	678
Waste, non-haz./landfill (g)	1,955	441	136	1,200	8	-43	3,698
Waste, hazardous/ incinerated (g)	92	0	3	37	0	-1	131
Emissions (Air)							
GWP100 (kg CO2-eq)	93	7	12	99	0	-2	210
Acidification (g SO2-eq.)	704	32	37	440	0	-14	1,198
VOC (g)	3	0	1	51	0	0	55
Persistent Organic Pollutants (ng i-Teq)	16	2	1	6	0	0	23
Heavy Metals (mg Ni eq.)	270	4	7	26	0	-6	301
PAHs (mg Ni eq.)	70	0	5	6	0	-2	80
Particulate Matter (g)	526	5	171	14	2	-11	708
Emissions (Water)							
Heavy Metals (mg Hg/20)	107	0	0	11	0	-3	116
Eutrophication (g PO_4)	4	0	0	0	0	0	4

VII. Annex G – Commercial vacuum cleaner Energy Index formulas and parameters

The data and results presented in this section are based on the work of commercial vacuum cleaner manufacturers. Multiple solutions and different equations were investigated to arrive at a useful and representative EI measure. The following analyses are based on the EI equations form section 9.2.1 and results from the existing measurement methods with addition of the commercial debris pick-up test (section 9.7.4).

The results in Table 122 illustrate the sensitivity of the EI rating to each of the performance parameters included in the equations. Each of the parameters listed in the first column was varied from minimum to maximum (column 2 and 3) in the calculations for AE and EI, respectively, to evaluate how large an influence it would have on the scales and how many classes on the energy label.

Table 122: Results from commercial vacuum cleaner manufacturers on EI variation

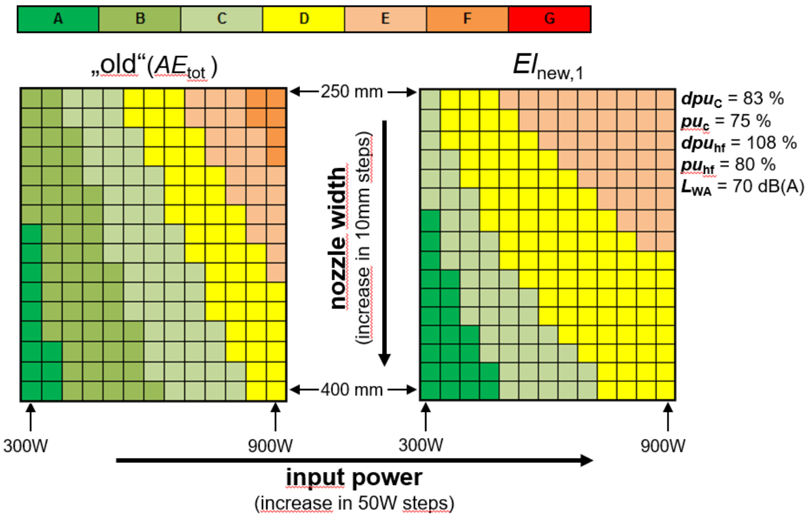
Varied key parameter	From.. MIN	..To MAX	Range ΔMAX-MIN	Existing AE calculation (kWh/year)		New EI calculation (m^2/min)	
	Parameter variation			ΔMAX-MIN	#class	ΔMAX-MIN	#class
Nozzle width	250 mm	400 mm	150 mm	7,9	1,3	1,34	1,9
Carpet dpu	75,0%	92,0%	17,0%	3,0	0,5	0,13	0,2
Hard floor dpu	98,0%	115,0%	17,0%	4,5	0,7	0,13	0,2
Debris pick-up	20,0%	100,0%	80,0%			1,25	0,9
Input power	300 W	900 W	600 W	18,4	3,1	1,32	1,9
Sound power	58 dB(A)	80 dB(A)	22 dB(A)			0,42	0,6

Table 123: Examples of EI values for commercial vacuum cleaners in the low/mid/best range

	w_{nozzle}	P_C [W]	dpu_C	$pu_{debris,C}$	P_{hf}	dpu_{hf}	$pu_{debris,hf}$	L_{WA}	$EI_{new,1}$
ECO-LIMIT	200mm	900W	75,0%	20,0%	900W	98,0%	20,0%	80dB(A)	**0,76**
LOW	250mm	700W	77,0%	30,0%	800W	100,0%	50,0%	75dB(A)	**1,28**
MID	300mm	500W	80,0%	50,0%	550W	106,0%	80,0%	74dB(A)	**2,12**
BEST	350mm	350W	92,0%	100,0%	400W	113,0%	100,0%	68dB(A)	**3,41**

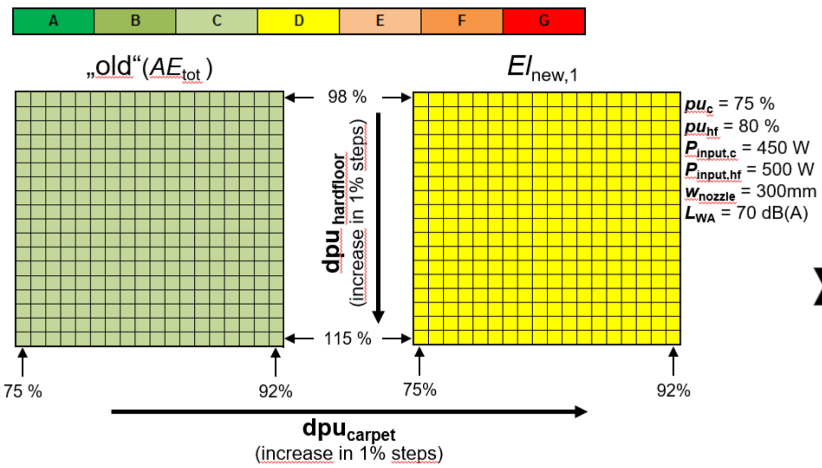
There are currently no vacuum cleaners in the "BEST" segment. Most are in the "MID" segment, corresponding to around class D/E (section 13.4.6 on label classes). A and B are thus empty.

The Comparison to the old AE-value shows the different weighting of nozzle width and input power



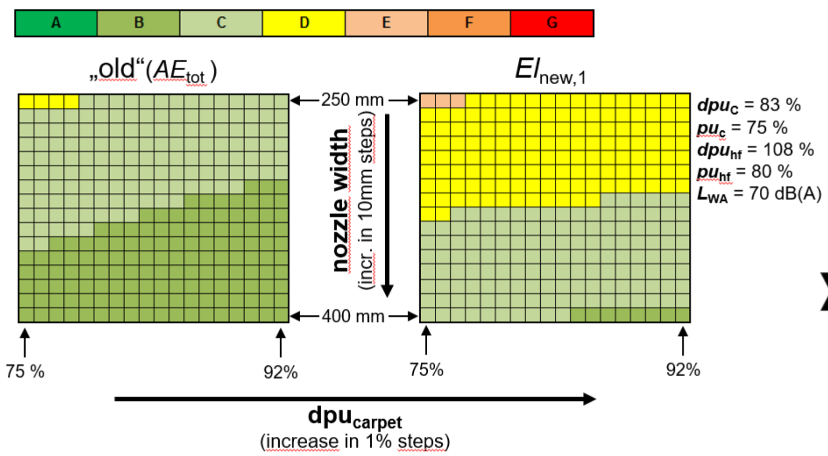
- Horizontal run through shows the influence of the input power:
  AE_{tot} : 5 classes
  $EI_{new,1}$: 3 classes
- Vertical run through shows the influence of the nozzle width:
  AE_{tot} : 2 classes
  $EI_{new,1}$: 3 classes
- Diagonal run through shows the combined influence

same behavior and therefore same weighting of the fine dust cleaning performance at both approaches



- “Fine dust” cleaning performance shows almost no class change in both cases
- Horizontal run through: dpu_C
  AE_{tot} : max. 1 class
  $EI_{new,1}$: max. 1 class
- Vertical run through: dpu_{hf}
  AE_{tot} : max. 1 class
  $EI_{new,1}$: max. 1 class

The Comparison shows again the larger influence of the nozzle widt



- “Fine dust” cleaning performance shows almost no class change in both cases
- Horizontal run through: dpu_C
  AE_{tot} : max. 1 class
  $EI_{new,1}$: max. 1 class
- Vertical run through: w_{nozzle}
  AE_{tot} : 2 classes
  $EI_{new,1}$: 3 classes

VIII. Annex H – Data for cordless vacuum cleaners

The data and test results presented in this annex are based on measurements performed by the laboratory GTT (Suzhou GTT Service Co[406]). The tests are performed according to the existing Ecodesign standards / draft standards and provided at no cost to the Commission and Industry, in order to provide the study team with comprehensive data. In total 13 cordless vacuum cleaners were tested by GTT and the full ecodesign test reports were provided[407]. Below the summarised results of the tests can be seen.

- 4 out of the 13 stick vacuums (31%) achieved the minimum carpet cleaning performance requirements of ≥ 75% per the current Ecodesign regulation. The average cleaning of these 4 vacuums was 85% at an average run time of 12.5 minutes. Comparatively, 9 out of the 13 stick vacuums (69%) fell below the Ecodesign performance requirements with an average cleaning performance of 57% at an average run time of 19 minutes.

- Out of the 13 stick vacuums, 7 (54%) achieved the minimum hard floor crevice cleaning performance requirements of ≥98% per the current Ecodesign regulation. The average cleaning of these 7 vacuums was 103.3% with an average run time of 20.5 minutes. Comparatively, 6 out of the 13 stick vacuums (46%) fell below the Ecodesign performance requirements with an average cleaning performance of 5.5% and an average run time of 19 minutes.

- 3 out of the 13 stick vacuums (23%) met the minimum dust re-emission requirements of ≤1.0%. The average dust re-emissions of the 13 stick vacuums was 4.0%, essentially 4 times the current limit.

- 5 out of the 13 stick vacuums (38.5%) met the noise level requirements of ≤80 dBA sound power when tested on carpet. 3 out of the 13 stick vacuums (23%) met the noise level requirements on hard floor.

- Run time of all stick vacuums tested ranged from approximately 8 to 30 minutes with an average run time of 18.5 minutes. There was very little difference in average run time between carpet and hard floor.

[406] http://gttlab.com/a/English/
[407] Uploaded on the study website: https://www.review-vacuumcleaners.eu/documents

- Annual energy consumption ranged from 7.7 to 25.5 kWH/year on carpet for all 13 stick vacuums. The energy consumption calculations were based on the proposed method for calculating effective power consumption of each vacuum per the CDV of IEC 62885-4 cordless vacuum standard (It should be noted that no calculations of annual energy consumption could be determined for testing on hard floor crevice for 6 of the 13 stick vacuums because the hard floor crevice dust pickup results were ≤20% cleaning, resulting in infinite energy consumption calculations per the equation in the Ecodesign regulation.) The average annual energy consumption for those stick vacuum products that met the current Ecodesign performance requirements for both carpet and hard floor cleaning was approximately 13.9 kWH/year.

- None of the current cordless products tested meet all of the current Ecodesign performance requirements.

The table below lists the models tested and the price segments to which they belong in a random order. Price segments were divided as: high: >300€, middle: 150-300 €, low: <150 €.

Model No.	Price segment
Bosch VCA S010V32	High
Philip FC6823	High
Rowenta RS-RH5730	Mid
Bissell 2280N	Low
AEG AR180L21BCP	Mid
DEIK VC-R1093	Low
Hoover 94LD1711	Low
Vax Blade 24V DD767-2	Low
Gtech AirRam AR29	Mid
Dyson A7Y-UK-KHJ3008A	High
Hoover FD22G011	Low
Grundig VCH9630	Low
Black+Decker SVA420 H1	Low

	Annual Energy (kWh)		Power mode setting	Nozzle setting	
	Carpet	Hardfloor		Carpet	Hardfloor
Cordless no. 1	7.70	3.47	1 mode only	with brush bar	without brush bar
Cordless no. 2	25.46	18.53	Max (3 modes)	carpet nozzle	hardfloor nozzle
Cordless no. 3	16.96	-	1 mode only	brush bar open	brush bar open
Cordless no. 4	19.34	-	Max (2 modes)	brush bar open	brush bar open
Cordless no. 5	14.84	-	1 mode only	brush bar open	brush bar close
Cordless no. 6	20.92	16.79	Max (3 modes)	brush bar open	brush bar open
Cordless no. 7	18.15	7.52	Max (2 modes)	brush bar open	brush bar open
Cordless no. 8	15.27	10.08	Max (2 modes)	brush bar open	brush bar open
Cordless no. 9	13.06	-	Max (2 modes)	brush bar open	brush bar open
Cordless no. 10	21.61	-	Max (2 modes)	brush bar open	brush bar open
Cordless no. 11	13.47	-	1 mode only	brush bar open	brush bar open
Cordless no. 12	8.30	4.49	Max (2 modes)	brush bar open	brush bar open
Cordless no. 13	11.94	9.21	Max (2 modes)	brush bar open	brush bar open

	Motor Rated Power (W)	Battery Type	Battery Volts DC	Battery mAh	Number of Battery Cells
Cordless no. 1	100	Lithium	22	2000	12
Cordless no. 2	525	Lithium	25.2	2600	7
Cordless no. 3	130	Lithium	22.2	2000	-
Cordless no. 4	95	Lithium	14.4	2000	4
Cordless no. 5	-	Lithium	14.4	N.A.	4
Cordless no. 6	-	Lithium	32.4	-	9
Cordless no. 7	-	Lithium	25	-	7
Cordless no. 8	-	Lithium	21.9	2100	6
Cordless no. 9	75 W	Lithium	18	2000	5
Cordless no. 10	-	Lithium	18	-	5
Cordless no. 11	-	Lithium	22.2	-	6
Cordless no. 12	100 W	Lithium	21.6	2150	6
Cordless no. 13	180 W	Lithium	21.6	2000	6

	Dust pick up (%)		Dust re-emissions (%)	Noise Carpet dB(A)	Noise Hardfloor dB(A)
	Carpet	Hardfloor		Brush ON	Brush ON
Cordless no. 1	74.1	105.6	7.866	83.1	84.7
Cordless no. 2	91.5	106.5	0.001	86.3	86.3
Cordless no. 3	61	5.7	7.025	85.2	85.2
Cordless no. 4	43.5	7.9	1.803	82.7	83.4
Cordless no. 5	44.2	3.4	4.251	79.1	78.5
Cordless no. 6	87.6	104.5	0.586	82.9	83.7
Cordless no. 7	58.4	99.7	8.648	83	83.4
Cordless no. 8	77.2	101.9	6.574	79.4	81.8
Cordless no. 9	57	8.5	6.29	79.2	81.7
Cordless no. 10	48	3.5	0.294	78.8	79.6
Cordless no. 11	62.1	3.7	2.852	77.2	79.1
Cordless no. 12	64	99.6	2.568	80.9	84.3
Cordless no. 13	85.7	105.2	2.98	84	84.8

	Peff (W)		Runtime (min:s) on carpet		Runtime (min:s) on hardfloor	
	Carpet	Hardfloor	t90%rt	t40%rt	t90%rt	t40%rt
Cordless no. 1	160.62	114.47	07.09	29:05	19.44	42:45
Cordless no. 2	590.88	520.24	07.58	07.58	08.43	08.43
Cordless no. 3	232.09	219.50	12.42	20.20	13.37	20.45
Cordless no. 4	153.64	159.40	04.47	19.42	05.08	19.44
Cordless no. 5	126.36	119.58	14.28	15.03	16.24	16.54
Cordless no. 6	458.94	460.55	11.31	12.08	10.34	11.17
Cordless no. 7	236.99	203.71	20.42	20.42	23.51	23.51
Cordless no. 8	282.41	266.89	06.08	12.42	05.46	12.55
Cordless no. 9	165.53	153.25	06.19	20.41	06.39	18.31
Cordless no. 10	206.64	167.66	13.48	13.48	14.50	14.50
Cordless no. 11	183.47	139.06	22.53	23.24	21.30	23.35
Cordless no. 12	134.62	131.63	13.08	29:36	11.27	28:40
Cordless no. 13	243.47	243.68	07.39	15.55	07.18	14.25

Pictures of the cordless cleaners included in the data, in a random order:

Product photo:

Overview of the sample

Overview of the sample

Filter

Tube

Cleaning head

Cleaning head

Product photo:

Overview of the sample

Container

Container+HEPA

Sample with accessories

Cleaning head

Cleaning head

Product photo:

Overview of the sample

Overview of the sample

Container

Container+Micro filter+Foam

Cleaning head with brush bar

Cleaning head without brush bar

Product photo:

Overview of the sample

Container

Container

Cleaning head

Cleaning head with brush bar

Cleaning head without brush bar

Product photo:

Overview of the sample

Container

Filter

Sample with accessories

Cleaning head

Cleaning head

Product photo:

Overview of the sample

Container

Container+Micro filter+Foam

Tube

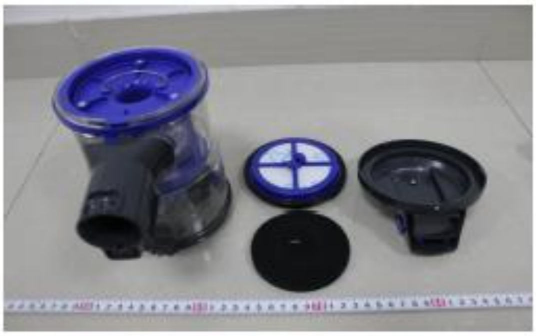
Cleaning head

Cleaning head

Product photo:

Overview of the sample

Container



Container+Micro filter+Foam

Tube

Cleaning head

Cleaning head

Product photo:

Overview of the sample

Container

Container+Micro filter

Tube

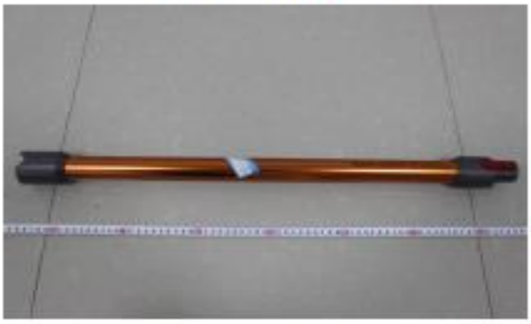
Cleaning head

Cleaning head

Product photo:

Overview of the sample

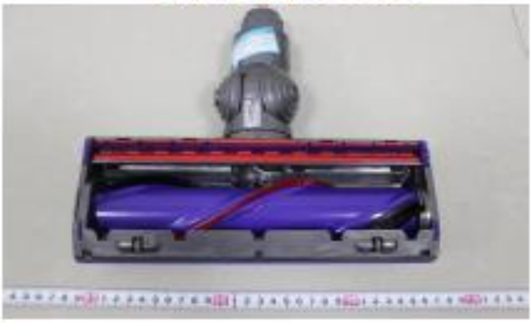
Container+Filter



Tube

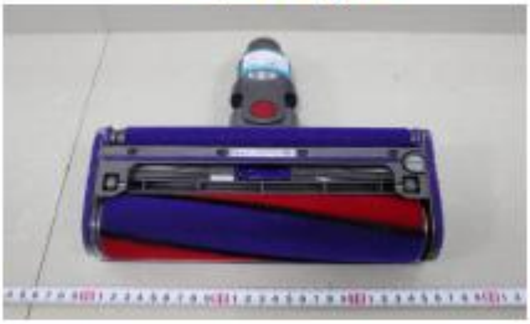
Sample with accessories

Carpet cleaning head



Carpet leaning head

Hard floor cleaning head



Hard floor cleaning head

Product photo:

Overview of the sample

Container

Container+HEPA

Sample with accessories

Cleaning head

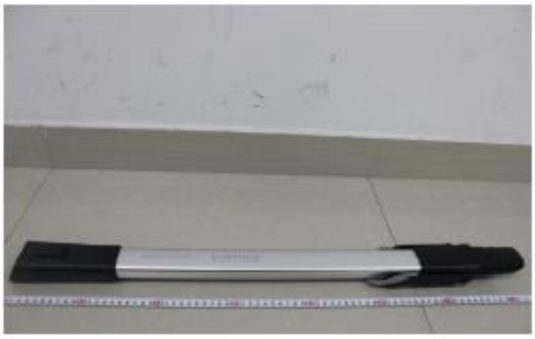
Cleaning head

Product photo:

Overview of the sample

Container

Container+Micro filter+Foam



Tube

Cleaning head

Cleaning head

Product photo:

Overview of the sample

Container

Filter

Sample with accessories

Cleaning head

Cleaning head

Product photo:

Overview of the sample

Container

Container+Micro filter+Foam

Sample with accessories

Cleaning head

Cleaning head