Review study on household tumble driers

Final report

June 2019

The information and views set out in this study are those of the author(s) and do not necessarily reflect the official opinion of the European Commission

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Project website: https://www.review-tumbledriers.eu/

Implements Framework Contract: № ENER/C3/2015-619 LOT 2

Specific contract no.: ENER/C3/SER/FV 2017-438/02/FWC 2015-619 LOT2/04/SI2.757437

This study was ordered and paid for by the European Commission, Directorate-General for Energy.

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I. Preface

This is the draft final report for the review of Ecodesign Regulation (EU) No 932/2012[1] and Energy Labelling Regulation (EU) No 392/2012[2] for household tumble driers. The final report includes all tasks of the MEErP methodology, including recommendations for revision of the regulations.

Task 1 outlines the scope of the regulations and of the review study, including product categorisation, as well as the relevant standards and legislation, including those under development, related to tumble drier energy consumption and resource efficiency.

Task 2 gives an overview of the tumble drier market including sales, stock and base data on consumer costs, including stock back casting and forecasting covered by available data. Furthermore task 2 presents an overview of market trends concerning product design and features and how they are affecting tumble driers performance considering the parameters shown in the energy label, energy class distribution and the energy efficiency of all products in scope of this review study.

Task 3 presents latest trends in consumer behaviour, lifetime and an overview of the current end-of-life practices for tumble driers. Consumer behaviour aspects presented are those affecting energy consumption and efficiency, such as loading habits. Furthermore, here it is discussed whether these aspects are properly reflected in test standards and measurements conditions. Tumble driers lifetime is also investigated, and whether there are differences in lifetime between different heating technologies, in particular for heat pump tumble driers. A preliminary conclusion has been drawn on the appropriateness of the current verification tolerances, as defined in Annex III and Annex V of the Ecodesign and Energy Labelling Regulations respectively. This is based on expert judgment and in line with conclusions from the household washing machines' preparatory study.

Task 4 reviews the technical aspects of tumble driers and outlines the current technology levels in terms of average and best available technologies (BAT), as well as which technologies are expected to enter the market (best not yet available technology, BNAT). Besides the effect on energy consumption, the technologies are also reviewed in terms of resource efficiency. This analysis is the basis to define the base case technology, which will be presented and used in subsequent tasks to define the base cases.

Task 5 presents the proposed base cases and the environmental and economic impacts of each of them. The environmental impacts include those from the whole life cycle of the

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[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0932&from=EN
[2] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0392&from=EN

base cases, including the production, distribution, use (incl. repair and maintenance) and end-of-life. They are reported by the impact categories given in the EcoReport tool. The economic impacts are reported as the life cycle costs of the base cases for the end-users, according to the methodology used in the EcoReport tool.

Task 6 outlines the design options for improving the environmental performance of the base cases, based on input from technology assessment reported in task 4. It also reports the effect of these design options on the consumer's life cycle costs and selects those that don't entail excessive costs. Design options are outlined for both energy and resource efficiency improvements.

Task 7 presents first the evaluation of the existing regulations in the context of the Better Regulation framework, focusing specifically on the regulations' effectiveness, efficiency and relevance. Afterwards it outlines the proposed policy options for each base case, using the selected design options in task 6 as starting point, and presents the opportunities and barriers from each of them. It also presents the impacts of these policy options in the scenario analyses and concludes with potential recommendations for the revision of the regulations

II. Table of Contents

III. List of tables

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V. List of acronyms and abbreviations

AEc	Annual Energy Consumption
bln	Billion
Cdry	Average condensation efficiency of the standard cotton drying programme at full load
$Cdry_{1/2}$	Average condensation efficiency of the standard cotton drying programme at partial load
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
Ct	Weighted condensation efficiency
dB	Decibels
dBa	Average noise level
dP	Difference in pressure
dT	Difference in temperature
Edry	Energy consumption of the standard cotton drying programme at full load
$Edry_{1/2}$	Energy consumption of the standard cotton drying programme at partial load
EEE	Electrical and Electronic Equipment
EEI	Energy Efficiency Index
Egdry	Gas consumption of the standard cotton drying programme at full load
$Egdry_{1/2}$	Gas consumption of the standard cotton drying programme at partial load
EoL	End-of-Life
ESO	European Standards Organizations
ETSI	European Telecommunications Standards Institute
EuP	Energy using Products
FtF	Face-to-Face
GHG	Greenhouse Gases
IMC	Initial Moisture Content
kt	Kilotonnes
LWA	Weighted average value of sound power level
MEErP	Methodology for Ecodesign for Energy related Products
MEPS	Minimum Energy Performance Standards
mln	Million
mt	Megatonnes
NACE	Nomenclature generale des Activites economiques dans les Communautes europeennes
OEM	Original Equipment Manufacturer
PA	Polyamide
PCB	Printed Circuit Board
P_o	Power consumption in off mode
P_l	Power consumption in left-on mode
PO1	Policy Option 1
PO2	Policy Option 2
PO3	Policy Option 3
PO4	Policy Option 4
PP	Polypropylene
PRODCOM	PRODuction COMmunautaire
SAEc	Standard Annual Energy Consumption
SEc	Standard Energy Consumption per cycle
Tdry	Programme time for the standard cotton drying programme at full load
$Tdry_{1/2}$	Programme time for the standard cotton drying programme at partial load
TDs	Tumble driers
TWh	Terawatt hour
WEEE	Waste of Electrical and Electronic Equipment
Wh	Watt-hours

VI. General background

The Commission Regulation (EU) No 932/2012 with regard to ecodesign requirements for household tumble driers entered into force in November 2012 (with requirements applicable from November 2013) with the following timeline:

- From November 2013, specific ecodesign requirements on the Energy Efficiency Index (EEI) for all household tumble driers and on the condensation efficiency for condenser household tumble driers applied.
- From November 2014, generic ecodesign requirements on calculation of energy consumption and information provided in booklet applied for all household tumble driers.
- From November 2015, more stringent EEI and condensation efficiency requirements applied.

The Commission's Regulation No 392/2012 with regard to Energy Labelling of household tumble driers entered into force in May 2012 and applied from May 2013.

The objective of the Regulations is to ensure the placing on the market of technologies that reduce the life-cycle environmental impact of tumble driers, leading to estimated electricity savings of up to 9.5 TWh per year in 2030, corresponding to 4.2 Mt CO_2-eq per year, according to the Commission Staff Working Document derived from the Impact Assessment (2012)[3].

The Regulations cover electric mains-operated and gas-fired household tumble driers and built-in household tumble driers, including those sold for non-household use. Household combined washer-driers and household spin-extractors are exempted.

The Ecodesign Regulation was amended by the horizontal Regulation (EU) 2016/2282 with regard to the use of tolerances in verification procedures, while the 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 with regard to the use of tolerances in verification procedures.

Both the ecodesign and the energy labelling Regulations are scheduled for review, and this review study therefore aims to do so by updating the existing preparatory study on

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[3] https://ec.europa.eu/energy/sites/ener/files/documents/td_impact_assessment.pdf

household tumble driers published in March 2009[4]. This is done following the principles of the MEErP method. Additionally, this study should:

- Assess the verification tolerances set out in the Regulations
- Assess the efficiency of air-vented appliances
- Assess resource efficiency aspects (most likely disassembly, recyclability, reparability and durability) following the adoption of the Circular Economy Package in December 2015[5] and the last Ecodesign Working Plan 2016-2019[6]
- Evaluate the impact of the existing Regulations, including an analysis of the relevant questions, answers, evidences based related to the basic criteria (efficiency, effectiveness and relevancy) which are specific to evaluations in the context of the 'Better Regulation' framework.

[4] https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/laundry-driers/finalreport-lot16-laundry-driers.pdf
[5] https://ec.europa.eu/commission/publications/european-commission-proposals-circular-economy_en
[6] https://ec.europa.eu/energy/sites/ener/files/documents/com_2016_773.en_.pdf

VII. Executive summary

Scope and review of relevant legislation and standards

The overall scope of this review study is proposed to remain the same as the scope of the ecodesign and energy labelling Regulations[7] for household tumble driers.

Gas-fired technologies represent a niche part of the market. There is no indication this will change in the future, according to the limited input from stakeholders on this drier type. Excluding gas-fired technologies from the scope would prevent them from being regulated which may affect negatively their energy efficiency and the way they are perceived by consumers.

The review of relevant legislation provided insight of all the links between different product legislations and of relevant standards for measuring energy and resource efficiency of these type of appliances. This review showed that there continues to be legal basis for reviewing the current regulations and identified synergies with other product measures.

Market analysis

Sales and stock analyses show an overall increase in sales after 2010 (see Table i), which has been dominated by heat pump tumble driers, while the other technologies have decreased in sales numbers. The total sales increased on average 1.6% per year from 2007 to 2016 according to purchased data[8], but it is predicted that the market will stabilise with a slower decrease towards 0% per year in 2030[9].

Table i: Derived tumble drier sales from 1990 to 2030

Sales, million units		1990	1995	2000	2005	2010	2015	2020	2025	2030
Condenser	Heat pump	-	-	-	-	0.34	2.22	3.05	3.60	4.46
	Heat element	3.55	3.55	3.44	2.38	2.54	1.78	1.68	1.55	1.11
Air-vent	Heat element	0.14	0.14	1.06	1.66	1.11	0.75	0.59	0.39	-

[7] Commission Regulation (EU) No 932/2012, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0932&from=EN and Commission Delegated Regulation (EU) No 392/2012, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0392&from=EN

[8] Provided by GfK in 2018

[9] Assumption presented to APPLiA in Brussels, 21st of December 2017. No comments were provided to this assumption.

Sales, million units		1990	1995	2000	2005	2010	2015	2020	2025	2030
	Gas-fired	0.001	0.001	0.001	0.001	0.001	0.000	0.001	-	-
Total		**3.70**	**3.70**	**4.50**	**4.04**	**3.99**	**4.74**	**5.32**	**5.53**	**5.57**

The assessment has shown that there is no difference in lifetime between the different drier types, which has been slightly adjusted to 12 years (from 13 years in the preparatory study), according to more recent sources[10]. Considering sales trends and lifetime, the stock of tumble driers from 2000 to 2030 is shown in Table ii. This shows that the condenser driers will remain dominant in the market, and that heat pump driers will nearly triple the heating element driers by 2030 concerning condenser driers.

Table ii: Stock of tumble driers from 2000 to 2030

Stock, million units		2000	2005	2010	2015	2020	2025	2030
Condenser	Heat pump	0.00	0.00	0.44	7.27	21.18	34.89	44.61
	Heat element	24.82	29.38	31.26	29.09	25.17	21.45	18.73
Air-vented	Heat element	17.31	20.71	19.61	15.16	10.67	7.63	4.70
	Gas-fired	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Total		**42.15**	**50.10**	**51.32**	**51.53**	**57.03**	**63.98**	**68.18**
Penetration rate		**NA**	**NA**	**25.0%**	**24.2%**	**25.8%**	**27.7%**	**28.3%**

The 2018 penetration rate of household tumble driers in the EU is 24.7%, counting on a total number of households in the EU of about 217 million. Considering market trends and expected number of households in the EU, the expected penetration rate in 2030 is 28.3%. The energy class distribution of tumble driers on the market has evolved since 2013 (see Figure 1, Figure 2, Figure 3), where the Energy Labelling Regulation was applicable. Heat pump condenser driers present the largest shift and the most efficient driers. The energy class distribution for has remained more constant, although air-vented are more stagnant than condenser driers.

Data were not available for gas-fired tumble driers, but based on information from GfK, it was possible to track from a desktop research three of the models on the EU market which have a market share of 63%. Two of these three models (covering 61% of the market) feature an A+ energy class and the other features a C energy class. Gas-fired air-vented driers on the market are thus able to reach a higher energy class than the heating element air-vented drier. Similar trends are observed with annual energy consumption where heat

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[10] CECED and Umwelt Bundesamt

pump condenser driers have evolved rapidly towards a lower level while heating element driers (both condensers and air-vented) have increased their absolute energy consumption increase following an increase in rated capacity. The condensation efficiency for both heat pump and heating element condensing driers have increased somewhat, with the largest increase being in heat pump driers.

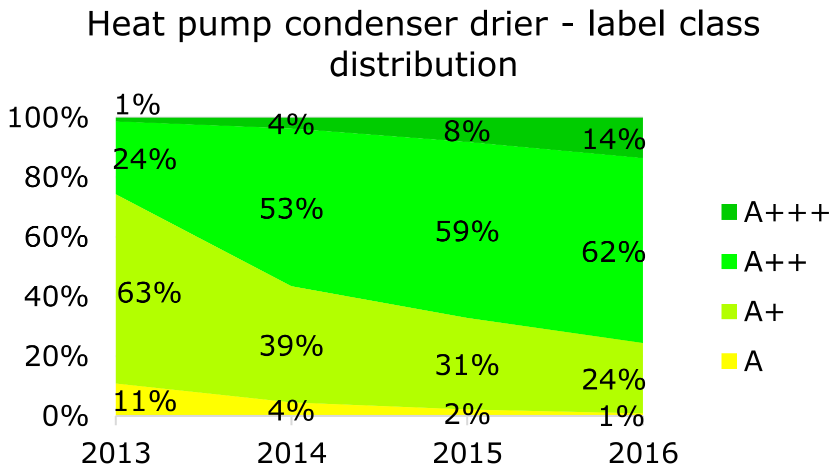

Figure 1: Energy class distribution and development for heat pump tumble driers

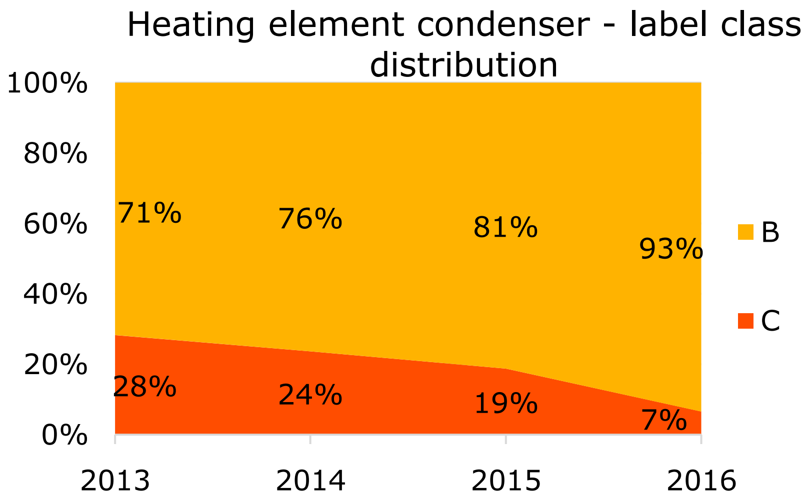

Figure 2: Energy class distribution and development for heating element condenser tumble driers

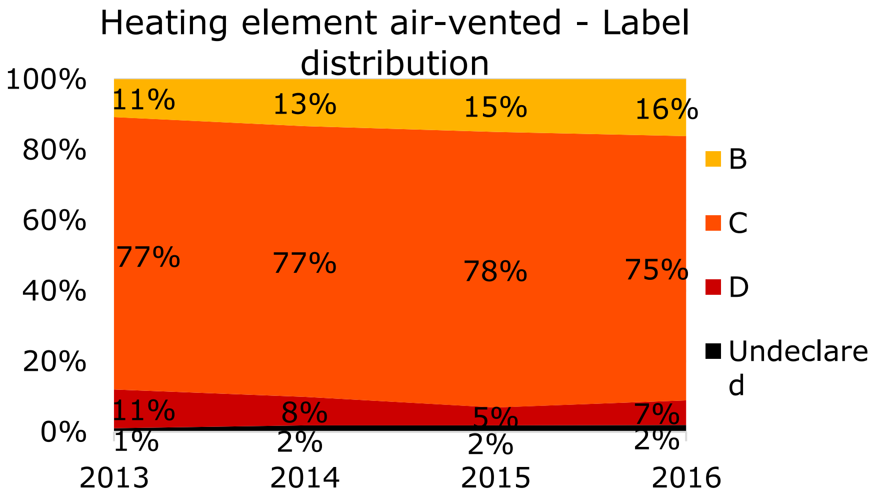

Figure 3: Energy class distribution and development for heat element air-vented tumble driers

The current and projected sales-weighted average rated capacity is increasing as it can be seen in Figure 4. Gas-fired air-vented driers average rated capacity remains largely the same thus it is not shown in the figure. The rest are steadily increasing.

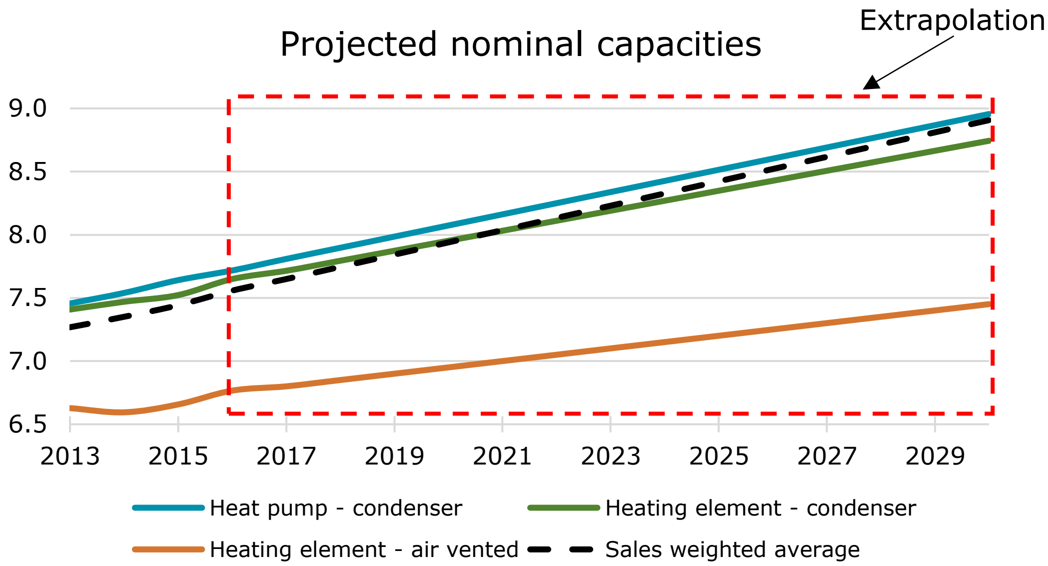

Figure 4: Sales-averaged rated capacity for all non-gas drier types (values in the red box are linearly projected).

The consumer price including VAT was calculated from the data on unit sales and total market value collected by GfK, and it is observed that heat pump condenser driers have become slightly cheaper while the price of heating element condenser driers have gone in the opposite direction (see Table iii). Heat pump driers' price has decreased despite the increase of driers in energy classes A++ and A+++ (24% and 1% in 2013 compared to 62% and 14% in 2016).

Table iii: Unit retail prices in EUR for household tumble driers

Unit prices, EUR		2013	2014	2015	2016
Condenser	Heat pump	734	681	648	615
	Heating element	234	232	357	340
Air-vented	Heating element	225	310	244	228
	Gas-fired	225	310	326	343

User behaviour

The two most important parameters affected by user behaviour that have an influence on the energy and/or condensation efficiencies of a tumble drier are:

- The average number of drying cycles per week
- The loading of the drier per cycle, i.e. how much is the machine filled in average with respect to its rated capacity

The number of **cycles per week** has decreased from the preparatory study (2008) to the APPLiA survey (2018). This is consistent with the increase in rated capacity but might also be due to the very different scopes of the surveys. An APPLiA survey is used as a reference and concludes that each tumble drier is running an average 2.05 cycles/week equivalent to 107 cycles per year. This indicates that the yearly cycles have decreased from 160 in current Regulation, to 107, but differences were found between different studies indicating a certain degree of uncertainty. However, generally the trend observed from newer studies/surveys indicate a lower number of cycles.

The **loading of the drier** is important as it affects the specific energy consumption of the drier in terms of the energy used per kg of dried laundry as well as the total assumed energy consumption per year per drier. Comparing the average nominal (rated) capacity and the average load, the real energy consumption is dependent on part load efficiencies of the driers (see Figure 5). According to the test standard tumble driers are tested for energy consumption at full and at half capacity which gives an average loading testing factor of 71%[11].

[11] (3*1+4*0.5)/7*100%

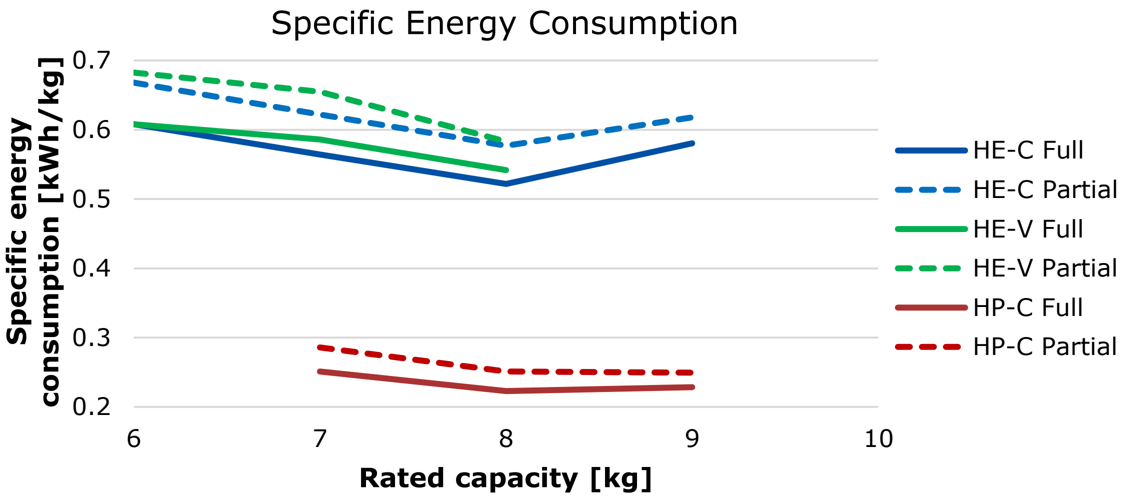

Figure 5: Specific energy consumption of three types of driers, at full and half (partial) load: Condensing with heating element (HE-C), Air-vented with heating element (HE-V) and condensing with heat pump (HP-C)[12]

Multiple studies have investigated average washing machine loads, but few new studies are directly targeting drying behaviour. The newest study targeting drying behaviour is an APPLiA consumer survey which concluded an average load of 4.4kg used as a reference throughout this study.

Conclusions from the washing machine studies[13] indicated that the loading of the washing machine was independent of the rated capacity. This conclusion is assumed to be applicable to tumble drying user behaviour as well meaning that the load per cycle is 4.4kg and independent on the rated capacity of the machine.

If the average load of 4.4 kg of laundry is used, then driers with a capacity of 7kg or more (which is >98% of all sold condensing driers and >70% of air-vented driers in 2016) is on average running below even the average loading testing factor of 71%. The driers are hence labelled at running conditions which they seldom, if ever, operate in.

The current testing procedures at full and half load conditions can hence be used as a comparative tool between products but is unlikely to represent the real annual energy consumption for the average user, and less so in the future with foreseen increasingly large capacity driers on the market. Changing the calculation method in the regulations that define the average loading to reflect the real use could potentially reverse the trend of manufacturers producing unnecessary large units, and emphasize the importance of having driers which can efficiently operate both while being fully loaded and being almost empty.

[12] Source: APPLIA Model database 2016, n=177.
[13] See section 3.1.2 for references

Data in task 3 to 5 indicates that a tumble drier loaded at 50% of the rated capacity will use more energy per kg of laundry than the same drier loaded at 100%. This is to some extend due to the loss associated with heating up the tumble drier itself which does not depend on the amount of laundry loaded in the machine. This loss is directly dependent on the thermal capacity of the drier, which (according to stakeholders) does not vary much between the same type of drier (e.g. heat pump condenser) at different rated capacities. This means that two machines at e.g. 7kg and 9kg can behave almost identical at 4.4kg of load as they have very small physical differences. The energy consumption per cycle is hence dependable on the load (in kg) but not so much on the rated capacity. As the load is assumed fixed, the rated capacity has little significance when assessing the total yearly energy consumption of the drier.

Concerning resource efficiency and product durability, the **average lifetime of household tumble driers** is falling. Overall the lifetime for large household appliances has declined from 14.1 years to 13.0 years between 2004 and 2012.. This highest reduction in lifetime was observed for freezers and tumble driers where the lifetime decreased from 18.2 to 15.5 years and 13.6 to 11.9 years, respectively. So, the average lifetime of tumble driers is in the current study reduced to 12 years from 13 years used in the preparatory study. Regarding heat pump condenser driers, the lifetime seemed to have been reduced for the first models available on the market but today the manufacturers have no indication to suggest the that heat pump condenser driers should have a shorter lifetime than other types of tumble driers. Based on a consumer study performed by APPLiA the durability of heat pump condenser driers is not expected to present particular issues and the consumers rarely experience any technical failures.

A way to improve the lifetime of household appliances is to design products that are easier and less costly to repair so it is more affordable for the consumers to repair than replace appliances. Currently repair and maintenance are expected to be done by professionals and in some cases by the end-user. Whether measures that can facilitate repair have a positive effect on the environment can be difficult to quantify, but based on a Deloitte[14] study it seems like the following options have a positive effect:

- 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

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[14] Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV.

- 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

Critical spare parts are the parts that are important for the function of the tumble driers and that are more subject to failure within the lifetime of a product. Based on a survey and inputs from manufacturers[15], the critical spare parts have been identified based on:

- Their functional importance for the functioning of the drier
- Their ease of replacement and any potential improvement in this regard
- Their frequency of replacement within the lifetime of the drier

From this assessment, it was concluded that critical spare parts to be considered for further reparability and durability requirements are:

- Pumps
- Motors
- Fans
- Heating elements

Technology overview

No major technical improvements at product level have emerged on the market for tumble driers since the preparatory study. The four main types of tumble driers still exist. However, very few models of gas-fired tumble driers have been available for sale on the EU market without any major technological developments in the past 10 years[16]. The focus in this task was thus to look at any technological developments at component level.

The tumble drier unit consists of multiple components which can be of different types and qualities. Some are found in all tumble driers types and from these, the following components and their configurations have a major influence on the energy consumption:

- The motor type and setup
- The presence of variable speed drives for fans and drum motors
- The controller, including humidity sensor components
- The drum design and sealing method
- The cleaning of lint filters and heat exchangers

Additionally, for condensing driers:

[15] Stakeholder consultation
[16] According to input from industry

- Air to air heat exchanger type, material, and size

And furthermore, for heat pump condensing driers

- Compressor size, type and motor

Based on input from industry[17], Table iv shows a list of the major components and technologies having an impact on the energy efficiency of the drier. Each component/technology and relevant improvement options are described in more details in section 4.1.

[17] Questionnaire sent to APPLiA members on technologies during months February-March 2018

Table iv: List of components for the average tumble drier.
HP-C = Condensing heat pump drier, HE-C = Condensing heating element drier, HE-V = air-vented heating element drier, GA-V = air-vented gas fired drier.

Tumble drier technology/Component	Average drier on the market	*Relevant for*			
		HP-C	**HE-C**	**HE-V**	**GA-V**
MOTORs					
Motor type setup (one or multiple)	One	x	x	x	x
Motor type (drum)	AC-Induction	x	x	x	x
Motor type (compressor)	AC-Induction	x			
↳ If permanent magnet, has REM	No	x	x	x	x
VSD on motor drum drive	No	x	x	x	x
VSD on motor fans	No	x	x	x	x
VSD on compressor motor	No	x			
CONTROLLER					
Type of automatic controller	Automatic moisture sensor controller (direct way)	x	x	x	x
HEAT EXCHANGER (Air to air)					
Heat exchanger material	Aluminium		x		
Heat exchanger type	Plate-fin		x		
Self-cleaning heat exchangers	No		x		
HEAT EXCHANGER (Refrigerant - air)					
Heat exchanger material	Aluminium fins + copper tubes	x			
Heat exchanger type	Fin-and-tube	x			
Self-cleaning heat exchangers	No	x			
COMPRESSOR					
Compressor size	400-600 W	x			
DRUM					
Drum material	Steel	x	x	x	x
Direct Drive	No	x	x	x	x
Drum leakage	High/Medium	x	x		
FILTERS[18]					
Anti-clogging design	No	x	x	x	x

Table v shows the BAT for each component. Note that heat pump driers *always* outperform the other types and should hence still be classified as the BAT tumble drier.

[18] Both the primary lint filter, and for the condenser lint filter for HP-C driers without self-cleaning heat exchangers.

Table v: List of components for the BAT-tumble drier.
HP-C = Condensing heat pump drier, HE-C = Condensing heating element drier, HE-V = air-vented heating element drier, GA-V = air-vented gas fired drier.

Tumble drier technology/Component	BAT-Tumble drier	*Relevant for*			
		HP-C	**HE-C**	**HE-V**	**GA-V**
MOTOR					
Motor type setup (One or multiple)	One / Multiple	x	x	x	x
Motor type (Drum)	BLDC[19]	x	x	x	x
Motor type (Compressor)	BLDC[179]	x			
↳ If permanent magnet, has REM	No	x	x	x	x
VSD on motor drum drive	Yes	x	x	x	x
VSD on compressor motor	Yes	x			
CONTROLLER					
Type of automatic controller	Automatic moisture sensor controller (direct way)	x	x	x	x
HEAT EXCHANGER (Air to air)					
Heat exchanger material	Aluminium		x		
Heat exchanger type	Plate-fin		x		
Self-cleaning heat exchangers	No		x		
HEAT EXCHANGER (Refrigerant - air)					
Heat exchanger material	Aluminium fins + cobber tubes	x			
Heat exchanger type	Fin-and-tube	x			
Self-cleaning heat exchangers	No / Yes	x			
COMPRESSOR					
Compressor size	400-600 W	x			
DRUM					
Drum material	Stainless Steel	x	x	x	x
Direct Drive	No	x	x	x	x
Drum leakage	Low (<10%)	x	x		
FILTERS[169]					
Anti-clogging design	Yes	x	x	x	x

Regarding improved resource efficiency at End-of-Life different options are available for design improvements and covers both more holistic guidelines and product specific suggestion.

Regarding critical raw materials, household tumble driers may contain several categorised as critical. Raw materials like vanadium and phosphorous are designations of steel used as alloying elements. These alloying elements are not included in this assessment as they are

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[19] A synchronous permanent magnet motor, i.e. brushless permanent magnet motor (BLDC). Can also be referred to as ECM/PMSM

very difficult to quantify, and more obvious choices (due to larger quantities) are present such as:

- Printed circuit boards which may contain several critical materials such as gold, silver, palladium, antimony, bismuth, tantalum etc[20]. For tumble driers, it is assumed they are low grade, but higher grades could be available in the future due to the implementation of more functions (network functions).
- Compressor and heat exchangers which may contain copper (but according to manufacturers it is possible also to produce heat exchangers with aluminium fins and tubes)
- Wires which may contain copper
- Motors which may contain copper and rare earth elements (magnets)

Material efficiency requirements can be very difficult to model, as the material efficiency is dependent on the waste handling system which again are dependent on the commodity prices. The current preferred waste processing is shredding but within the next 20 years it may change significantly, and it is therefore difficult in later tasks to quantify any measure towards improved material efficiency. Also, when products are shredded with other types of products the impact of any requirements toward a specific product may be reduced. Material requirements may therefore have greater effect if they are aligned across all product groups.

Dishwashers and washing machines may in the future have the most ambitious requirements regarding resource efficiency[21] according to proposed amendments to the current Ecodesign Regulations for these products[22]. Previously there have been different requirements regarding information relevant for the disassembly but one of the greatest barriers towards increased repair and refurbishment is the lack of available spare parts[23].

The low collection rate of tumble driers[24] can challenge the improvement potential of any suggestions regarding resource efficiency since many products do not reach the desired recycling facility. The collection rate is expected to increase and reach the targets set out

[20] http://www.wrap.org.uk/sites/files/wrap/Techniques%20for%20recovering%20printed%20circuit%20boards%2C%20final.pdf
[21] Note that vacuum cleaners also have ambitious requirements with regard to durability and lifetime.
[22] Proposals have been voted positively and will be publicly available later this year (2019)
[23] Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV.
[24] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waselee&lang=en

in the WEEE Directive[25] in 2019. The current low collection rates cannot be directly addressed in the Ecodesign Regulation since this is not related to the design of the product.

Based on the list of critical raw materials and the WEEE Directive the following components and materials are of special interest:

- Printed circuit boards which may contain several critical materials such as gold, silver, palladium, antimony, bismuth, tantalum etc.[26]
- Compressor and heat exchangers which may contain copper (but according to manufacturers it is possible also to produce heat exchangers with aluminium fins and tubes)
- Wires which may contain copper
- Motors which may contain copper and rare earth elements (magnets)

Definition of base cases, Environment and Economics

Even though heat pump driers account for almost half of the EU tumble drier market, heating element driers still persist and may continue to be sold. Sales figures however indicate a steady reduction of heating element air-vented sales, and these types are assumed to be discontinued around 2029. This is not the case for gas-fired air-vented driers, as they continue to be sold and the current available data does not present evidence for a discontinuance of these models before 2030[27].

Considering this, the base cases have been split into the four main tumble driers heat source technologies in the market, in order to differentiate life cycle costs and environmental impacts and investigate improved design options at this segregated level:

1. Base case 1: Condenser tumble driers (heating element)
2. Base case 2: Condenser tumble driers (heat pump)
3. Base case 3: Heating element air-vented
4. Base case 4: Gas-fired air-vented

Table vi shows the key performance parameters concerning use of the four selected base cases, which have been averaged according to sales based on available data from previous tasks.

Table vi: Key performance parameters for the four selected base cases

[25] http://ec.europa.eu/environment/waste/weee/index_en.htm
[26] http://www.wrap.org.uk/sites/files/wrap/Techniques%20for%20recovering%20printed%20circuit%20boards%2C%20final.pdf
[27] Gas-fired manufacturers did not provide input on the future sales trends of this product type

	Parameter	Base case 1: Condenser, Heating element	Base case 2: Condenser, Heat pump	Base case 3: Air vented, Heating element	Base case 4: Air-vented, Gas fired	Sources and notes
Performance	Average nominal rated capacity [kg]	7.7	7.8	6.8	6.8	Figure 33 (GfK)
	Average load per cycle [kg]	4.4	4.4	4.4	4.4	Standard value corresponds to 71% of the rated capacity at the current regulation[28] and rated capacity. Real value from section 3.1.2 (APPLiA).
	Average energy consumption per cycle (E_{dry}), 100% loaded [kWh]	4.4	1.9	4.0	1.9	Specific energy consumption from Figure 44 (APPLiA) at full load, multiplied with the nominal capacity. Gas data based on WhiteKnight ECO43.
	Average energy consumption per cycle ($E_{dry½}$), 50% loaded [kWh]	2.4	1.0	2.2	1	Specific energy consumption from Figure 44 (APPLiA) at partial load, multiplied with 50% of the nominal capacity. Gas data based on WhiteKnight ECO43.
	Average annual energy consumption [kWh]	258	109	269	121	Cycles/year multiplied with the average energy consumption per cycle
	Average energy class	B	A^{++}	C	A^{+}	Figure 19, Figure 21 (GfK). Based on data from 2016.
	Average condensation efficiency class	B	B	-	-	Figure 25 (GfK). Based on data from 2016.
	Average lifetime [years]	12	12	12	12	Section 2.2.1 in report
	Average cycle time, full load (T_{Dry}) [minutes]	129	163	123	94	Figure 34, Figure 35 (GfK). Based on data from 2016. Gas data based on WhiteKnight ECO43.
	Average noise level [dBa]	>66	65	>66	62	Figure 38, Figure 39 (GfK). Based on data from 2016. Gas data based on WhiteKnight ECO43.

[28] The loading factor is here defined as the average weight (in kg of dry laundry) of the laundry used to test the energy consumption of the drier divided by the rated capacity. The average loading is the average weight of 3 cycles at 100% the rated capacity and 4 cycles at 50% the rated capacity. This yield $\frac{3*100\%+4*50\%}{7} = 71\%$

For all types of driers, the rated capacity has increased from 5.4kg up to 7.8kg. The load has increased as well, from 3.4kg to 4.4kg. Cycle time has increased for all drier types. This can partly be explained by the increase in capacity, but also due to the fact that the general drying temperature seems to be lower for heat pump driers, as the cycle time has increased more (in percentages) than the rated capacity.

Concerning the environmental assessment, the use phase continues to have the highest environmental impacts of household tumble driers, in particular regarding total energy and global warming potential. The total energy and emission of greenhouse gases during the life cycle for the different base cases (i.e. BC) are:

- BC 1: Total energy – 31,348 MJ, Global Warming Potential – 1,369 kg CO2-eq
- BC 2: Total energy – 16,230 MJ, Global Warming Potential – 781 kg CO2-eq
- BC 3: Total energy – 32,068 MJ, Global Warming Potential – 1,399 kg CO2-eq
- BC 4: Total energy – 10,108 MJ, Global Warming Potential - 532 kg CO2-eq

The lifecycle impacts of the base cases have served as reference values for the improvement options and policy scenarios assessment in Tasks 6 and 7.

The consumption of materials of high importance has also been determined for the base cases, in particular gold and copper, as it follows:

- BC 1: 0.121 grams of gold and 2170 grams of copper corresponding to a market value of 4.2 EUR and 12.8 EUR respectively
- BC 2: 0.157 grams of gold and 5100 grams of copper corresponding to a market value of 5.5 EUR and 30.1 EUR respectively
- BC 3: 0.12 grams of gold and 0.755 grams of copper corresponding to a market value of 4.3 EUR and 4.5 EUR respectively
- BC 4: 0.12 grams of gold and 0.755 grams of copper corresponding to a market value of 4.3 EUR and 4.5 EUR respectively

Both copper and gold have limited impacts compared with the impacts from energy consumption in the use phase. Copper is responsible for less than 0.5 % of the emission of CO2-eq over the lifetime and gold has an even lower impact.

The lifecycle costs of household tumble driers indicate that the highest consumer expenses are different for the four base cases:

- BC 1: the highest cost is for the use of the drier (407 EUR) and the lowest is the installation (25 EUR). The total LCC is 911 EUR.
- BC 2: the highest cost is for the purchase of the drier (615 EUR) and the lowest is the installation (25 EUR). The total LCC is 900 EUR.

- BC 3: the highest cost is for the use of the drier (518 EUR) and the lowest is the repair and maintenance cost (50 EUR). The total LCC is 871 EUR.
- BC 4: the highest cost is for the purchase of the drier (374 EUR) and the lowest is the repair and maintenance cost (50 EUR). The total LCC is 615 EUR.

Design options

After the assessment of the potential technological improvements to reduce the environmental impacts of household tumble driers considering input from task 4, five different individual and clustered design options were identified, which do not entail excessive life cycle costs. These are shown in Table vii.

Table vii: Selected design options and their application for base cases

Design options	Description	Applicability to BC			
		1	2	3	4
1 + 2 + 10	Increased motor efficiencies (drums, fan's and compressor's) by replacing asynchronous and induction motor with permanent magnet sync. motors (BLDC) and information on refrigerants (for BC2 only) use to inform the customer on alternatives with lower GWP.	Only drum and fan	√	-	-
1 + 3	Increased motor efficiencies (drum's & fan's) + multi motor setup to have a better on/off control of the different subsystems	-	-	√	√
8	Switching heating technology to heat pump for condenser driers	√	-	-	-
12	Modular design for easy access of critical parts for professionals and ensuring availability of spare parts after 2 years	√	√	√	√
13	Modular design for improving dismantling of driers and enhance recovery of materials at end-of-life	√	√	√	√

The potential environmental benefits (Total Energy as TE and Global Warming Potential as GWP) and life cycle costs (LCC) of design options compared to the baseline (i.e. those quantified in task 5) are shown in Figure 6, Figure 7, Figure 8, and Figure 9. Design option 12 is not shown, since potential environmental savings have not been estimated using the Eco-Report tool. However, this design option is further assessed in Task 7.

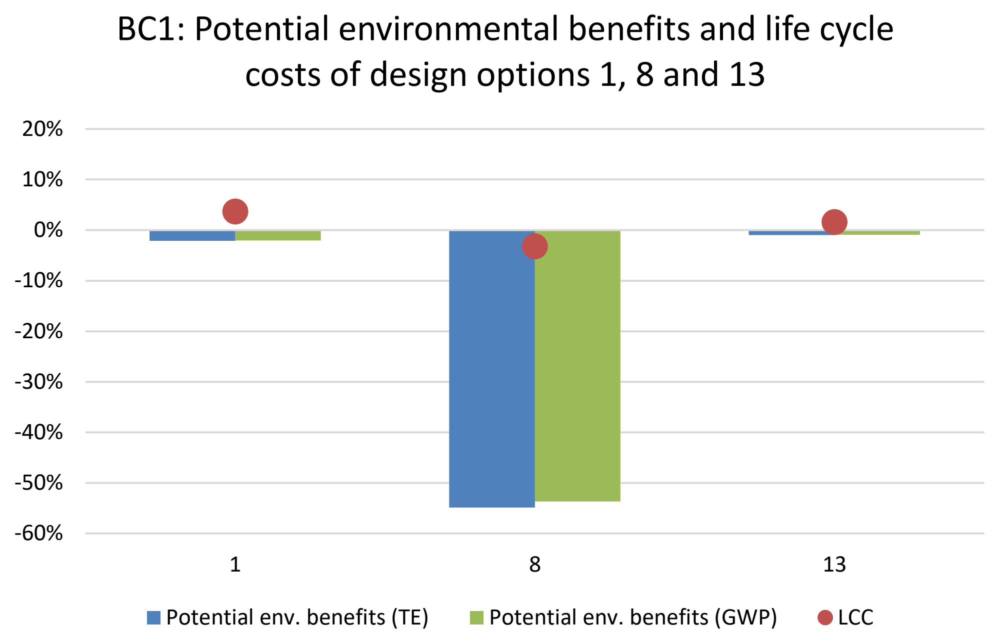

Figure 6: Aggregated potential environmental benefits and life cycle costs of design options for BC1 (negative numbers are net savings compared to baseline) - TE=Total Energy, GWP=Global Warming Potential

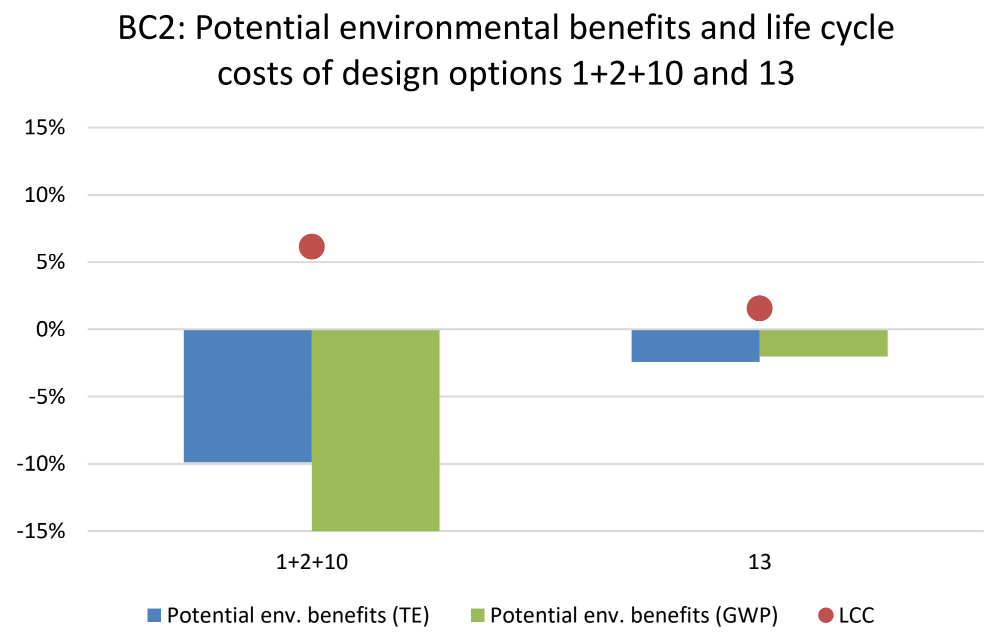

Figure 7: Aggregated potential environmental benefits and life cycle costs of design options for BC2 (negative numbers are net savings) - TE=Total Energy, GWP=Global Warming Potential

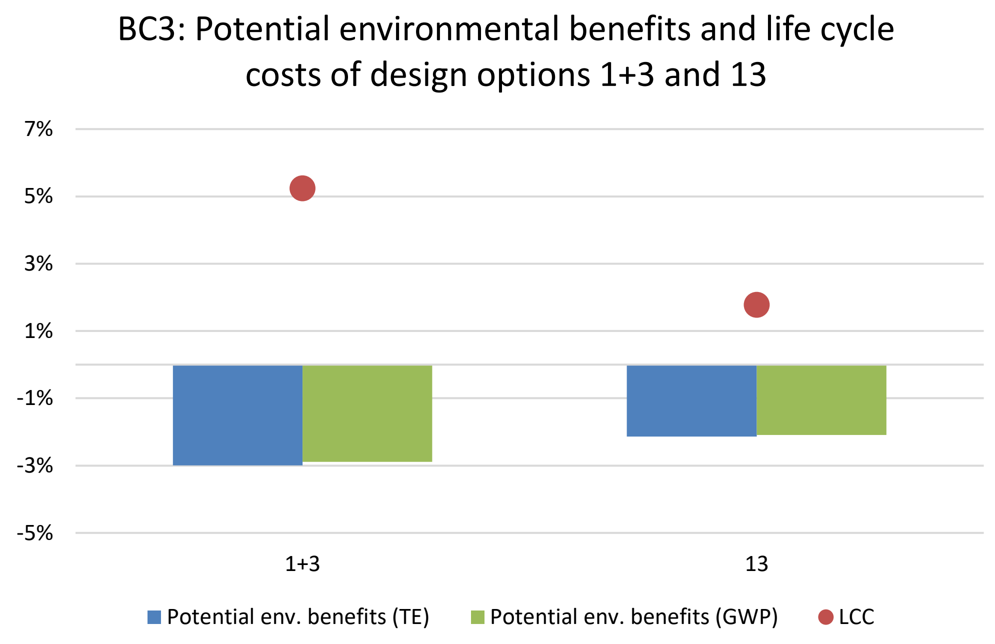

Figure 8: Aggregated potential environmental benefits and life cycle costs of design options for BC3 (negative numbers are net savings) - TE=Total Energy, GWP=Global Warming Potential

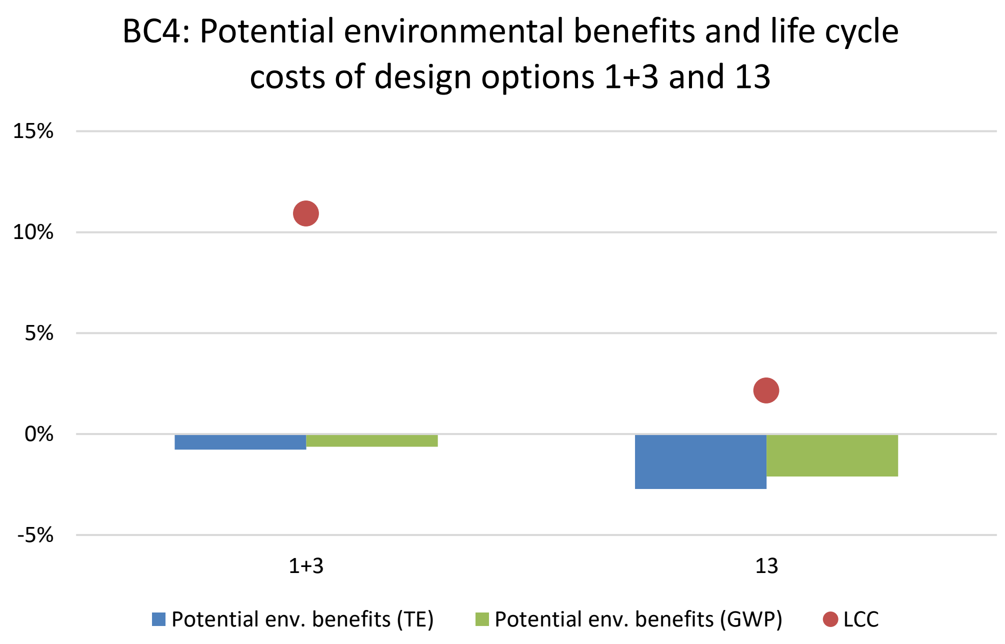

Figure 9: Aggregated potential environmental benefits and life cycle costs of design options for BC4 (negative numbers are net savings) - TE=Total Energy, GWP=Global Warming Potential

Overall, the potential environmental benefits at product level are much larger for condenser driers than for air-vented driers, however, some environmental improvement potential can be seen concerning resource efficiency. Design option 8 is by far the design option presenting the largest potential environmental benefits in terms of total energy and GWP, and it is the only design option presenting net life cycle costs savings for the consumer (i.e. presents the LLCC). These selected design options are further investigated when using them as starting point to define the policy options in task 7.

Scenarios

The policy options have been developed using the design options selected in task 6 as starting point. However, other aspects were also reviewed in the current regulations, based on collected input from previous tasks. These have been integrated in all of the policy options, and are listed below:

- **Real life use of household tumble driers**: Information gathered in previous tasks indicates that some of the parameter values in the regulations related to use of the appliances are no longer valid. In order to reflect real use, the scenario analyses show consumption and emissions values using real use values, in particular regarding loading and cycles per year. In addition to this, values on annual energy consumption can be difficult to interpret by consumers since they are not aware of the number of cycles they use the appliance every year. It is thus proposed to show the energy consumption information on the label per cycle rather than per annum. This is also to be aligned with proposed requirements for washing machines which would create a better understanding of the information by the consumers. Showing the energy consumption per cycle requires that the Energy Efficiency Index (EEI) is also calculated per cycle to ensure full alignment of what is communicated to consumers. A new EEI formula calculation has thus been developed using consumption and performance data (for more details see section 7.2)
- **Low power modes**: Power consumption requirements for low power modes are not included in the current regulations. Instead, the consumption of low power modes are integrated in the formula to calculate the annual energy consumption. However, it is proposed to remove these modes from the calculation of the energy consumption and instead include requirements for low power modes in the ecodesign regulation. Subsequently, this means exempting tumble driers from the horizontal standby regulation.
- **Rescaling energy classes distribution (EEI)**: The current energy class intervals have been modified based on the new EEI calculation method, which uses energy

consumption per cycle rather than per year. The new rescaling has also considered the current distribution of energy classes on the EU market, and proposes to eliminate all classes over A, and reallocating the below classes according to the conditions in the Energy Labelling Framework Regulation from 2017. This was also done considering intervals spread so the verification tolerances are not compromised (for more details see section 7.3.3).

- **Rescaling condensation efficiency**: In line with the re-scaling of the energy classes also the condensation efficiency classes were re-scaled. Currently, 96% of the available models are in the top 2 classes (A or B), and the full range of classes is thus not utilised. The current ecodesign requirement corresponds to a condensation efficiency of 70 %. Considering most of the driers have efficiencies of 80-100% (i.e. 95%), it is proposed to review requirement to 80%. Due to the smaller interval, it wouldn't be appropriate to use all 7 performance classes, as the intervals would be too narrow. Instead, splitting into four classes above the current ecodesign requirements (A to D) would make class intervals more evenly distributed.

Five Policy Options (PO) are proposed which are presented in Table viii. They reflect the progress in technical innovation since the adoption of the current regulation, but also existing and future technical innovations that can provide energy savings as presented in task 6. In addition, the proposed policy options are to give consumers access to better information in order to increase potential energy savings.

Table viii: Proposed POs for review of Ecodesign and Energy Labelling Regulations of household tumble driers

Policy Option	Proposed requirements	Implementation date
PO1**a** – Energy average of market	ECODESIGN • Condenser driers (BC1 & BC2): Revised EEI levels & condensation efficiency requirements reflecting current market + Information requirement on refrigerant used in product manual (only BC2) • Air-vented driers (BC3 & BC4): Revised EEI levels requirements reflecting current market ENERGY LABELLNG • Condenser driers (BC1 & BC2): Revision and rescaling of EEI & condensation efficiency levels from A to G reflecting current market+ Information requirement on refrigerant used in product manual (only BC2) • Air-vented driers (BC3 & BC4): Revision and rescaling of EEI from A to G reflecting current market	2021 (Energy Labelling) 2023 (Ecodesign)
PO1**b** – Energy BAT (Ecodesign only)	ECODESIGN • Condenser driers (BC1 & BC2): Revised EEI levels and condensation efficiency requirements reflecting BAT +	2023 (Ecodesign)

Policy Option	Proposed requirements	Implementation date
	Information requirement on refrigerant used in product manual (only BC2) • Air-vented driers (BC3 & BC4): Revised EEI levels requirements reflecting BAT	
PO2 – Energy BAT	ECODESIGN • Condenser driers (BC1 & BC2): Revised EEI levels and condensation efficiency requirements reflecting BAT + Information requirement on refrigerant used in product manual (only BC2) • Air-vented driers (BC3 & BC4): Revised EEI levels requirements reflecting BAT ENERGY LABELLNG • Condenser driers (BC1 & BC2): Revision and rescaling of EEI and condensation efficiency levels from A to G reflecting BAT+ Information requirement on refrigerant used in product manual (only BC2) • Air-vented driers (BC3 & BC4): Revision and rescaling of EEI from A to G reflecting BAT	2021 (Energy Labelling) 2023 (Ecodesign)
PO3 – Dismantling and Recycling	ECODESIGN • All Base Cases/Drier types: Dismantlability features[29] for materials and components referred to in Annex VII to Directive 2012/19/EU	2021
PO4 – Reparability and durability	ECODESIGN • All Base Cases/Drier types: Critical spare parts[30] shall be available for at least 10 years after placing the last unit of the model on the market, and manufacturers should ensure a maximum delivery time of 15 working days after having received the order + Provision of disassembly and repair information to all professionals of critical components (in product manual) [31]	2021

The potential impacts of the proposed policy options were estimated using six indicators including energy consumption during use. Figure 10 shows the total energy consumption in the use phase for tumble driers when implemented by the different policy options.

[29] For example: "Manufacturers shall ensure that joining or sealing techniques do not prevent the dismantling of materials and components referred to in Annex VII to Directive 2012/19/EU."
[30] As defined in section 3.2.2, the critical parts of tumble driers are pumps, motors, fans and heating elements.
[31] For example: "Dismantling of these components shall be ensured by making an exploded diagram of the tumble drier with the location of the materials and components available in technical documentation, and the sequence of dismantling operations needed to access and remove the materials and components, including: type of operation, type and number of fastening technique(s) to be unlocked, tool(s) required, safety requirements and risks (if any) related to the disassembly operations." A caution warning should be included in product manual advising consumers to not disassembly without the help of a professional and an indication made about this preventing any warranty claim. The list of critical parts and the procedure for ordering them shall be publicly available on the free access website of the manufacturer, importer or authorised representative, at the latest two years after the placing on the market of the first unit of a model and until the end of the period of availability of these spare parts.

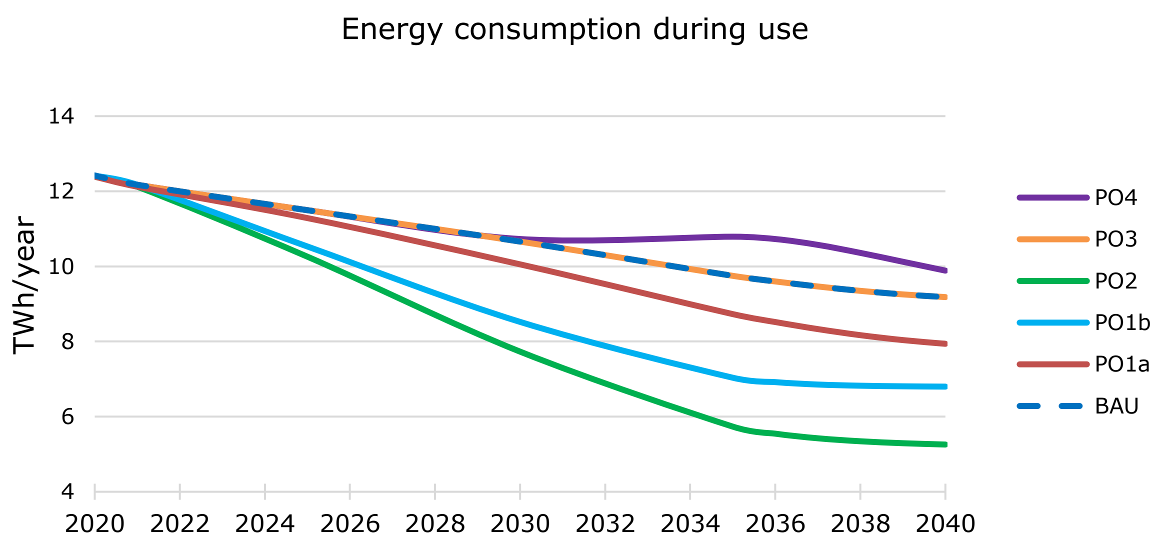

Figure 10: Energy consumption during use from 2020 to 2040

PO1a can potentially save 1.2 TWh/year in 2040, which is a reduction of ~14% of the total energy consumption compared to BAU. PO2 is estimated to save 4.0 TWh/year in 2040, which corresponds to a reduction of 42% of the total energy consumption compared to BAU. PO2 results in higher energy savings than PO1a due to the more stringent ecodesign requirement. PO1b shows the effect of a stringent ecodesign requirement only. In 2030, this corresponds to energy savings of 2.4 TWh/year. The effect of removing all heating element driers is thus larger than just imposing new energy label intervals.

In order to properly evaluate the effect of the policy options, the year 2040 is more relevant as a reference year than 2030. This is due to the long lifetime of household tumble driers and their replenishment before an effect can be observed in the EU market. Nevertheless, both 2030 and 2040 are shown in Table ix and Table x.

The largest savings in 2040 on energy, GHG and user expenditure, and the largest increase on retail turnover and jobs, are achieved with PO2, even at the initial high cost of consumers' average expenditure, which starts getting counterbalanced by the energy savings at year 2029. This is because it is cheaper using a heat pump drier with the usage patterns identified in Task 3 than using a heating element drier when evaluated over the whole lifetime. This holds true, even though the heat pump driers are significantly more expensive than the heating element driers.

Table ix: Results of each policy option, evaluated by the differences compared to BAU values in 2030 (a negative number means a reduction of the parameter compared to BAU)

Differences compared to BAU, 2030						
	Energy consumption [TWh/year]	GHG [mt. CO2 eq./year]	User expenditure [bln. EUR/year]	Retail turnover [bln. EUR/year]	Embedded Energy [PJ/year]	Jobs
PO1a	-0.61	-0.21	0.05	0.18	-	35
PO1b	-2.14	-0.67	-0.13	0.32	0.09	62
PO2	-2.93	-0.94	-0.08	0.54	0.09	104
PO3	-	-0.07	-	-	-0.18	-
PO4	0.07	-0.11	0.03	-0.04	-0.02	23

Table x: Results of each policy option, evaluated by the differences compared to BAU values in 2040 (a negative number means a reduction of the parameter compared to BAU)

Differences compared to BAU, 2040						
	Energy consumption [TWh/year]	GHG [mt. CO2 eq./year]	User expenditure [bln. EUR/year]	Retail turnover [bln. EUR/year]	Embedded Energy [PJ/year]	Jobs
PO1a	-1.24	-0.37	-0.09	0.18	-	35
PO1b	-2.38	-0.66	-0.19	0.32	0.09	62
PO2	-3.93	-1.12	-0.30	0.54	0.09	104
PO3	-	-0.09	-	-	-0.18	-
PO4	0.70	0.03	-0.09	-0.56	-0.32	63

Condenser driers (BC1 and BC2) present the largest contributions with these savings, as it can be seen in Table 69, Table 71, Table 73 and Table 75. This is obvious because condenser driers represent the current and future dominant technologies in the market, but also because there is more room for design improvements as it was explained in previous section.

It is estimated that air-vented tumble driers will continue to decrease in sales, and that gas-fired products will continue to be a niche product responsible for a very low percentage of the total market. That being said, it is not recommended to exclude them from the current scope as there is no indication they will disappear from the market.

As the gas driers are able to reach the EEI levels of heat pump driers due to the current conversation factor between gas and electricity, they are currently considered quite efficient, and the current models will be able to stay on the market even after imposing the most stringent proposed ecodesign requirements. Excluding them from the scope would not be recommended – even considering the low sales – as they are still considered a good option when replacing a heating element air-vented drier. Excluding them would mean removing the energy label from them, and thus making it harder for consumers to identify the real efficiency of a gas fired drier.

Recommendations

Based on the discussion and analysis throughout the report, the following concrete recommendation are given:

- Change the EEI calculation method from using energy consumption per year, to using energy consumption per cycle.
    - Scale the reference energy consumption per cycle (SEc) according to the available data based on the current technological progress and market share of each tumble drier type. This will ensure a lower dependency between the rated capacity and the energy consumption per cycle.
- Rescale the energy class intervals from A to G, making sure that:
    - The A class is empty
    - The energy class intervals are placed, as much as possible, evenly so consumers get a better understanding of the differences between classes.
- Rescale the condensation efficiency classes, distributing tumble driers in 4 classes instead of 3, and revise the condensation efficiency requirement to 80% (up from 70%), which would exclude 5% of driers on the market.
- Do not exclude gas fired driers from the scope.
- Change the weighting between full and half-loaded cycles when calculating E_c and T_c to 62% of the rated capacity, instead of the current 71% by changing the calculation formula
- Remove tumble driers from the horizontal standby regulation and add specific standby requirements to the new tumble drier ecodesign regulation. Set proposed maximum consumption levels for low power modes.
- Set ambitious ecodesign limits that ensures that cost effective savings potentials are utilized by removing all heating element driers from the market as they present the largest potential savings.
- Ensure that critical spare parts are available for at least 10 years after the production of a model ceases, to promote a longer average lifetime of the product.
- Technical information on how to disassembly critical components (for repair) and dismantle materials and components (for end-of-life) should be available in booklet/technical documentation.

1. Scope

Task 1 follows the MEErP methodology and the specific items requested by the European Commission. It includes the following:

1. Product scope: Identification and description of relevant product categories and definition of the product scope and categorisation based on Regulations, previous studies and market terms.
2. Legislation: Update of relevant legislation on EU, Member State and third country level.
3. Test standards: Update and description of relevant test and measurement standards on EU, Member State and third country level, including those on resource efficiency aspects.

The review of legislation and test standards include those relevant to the Ecodesign and Energy Labelling Regulations on tumble driers[32].

1.1 Product scope

The current scopes of both the Commission Regulation (EU) No 932/2012 and the Commission Delegated Regulation (EU) No 392/2012 cover electric mains-operated and gas-fired household tumble driers and built-in household tumble driers, including those sold for non-household use.

The definition of tumble driers is presented and discussed in the next sub-section.

1.1.1 Definitions from the Regulations

The tumble drier Ecodesign Regulation (EU) No 932/2012 and Energy Labelling Regulation (EU) 392/2012 employ identical definitions for household tumble driers, which are listed below.

Products within the scope of the Regulations are defined as:

Household tumble drier means an appliance in which textiles are dried by tumbling in a rotating drum through which heated air is passed and which is designed to be used principally for non-professional purposes.

[32] Commission Regulation (EU) No 932/2012, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0932&from=EN and Commission Delegated Regulation (EU) No 392/2012, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0392&from=EN

Built-in household tumble drier means a household tumble drier intended to be installed in a cabinet, a prepared recess in a wall or a similar location, requiring furniture finishing.

Air-vented tumble drier means a tumble drier that draws in fresh air, heats it up, and passes it over the textiles and vents the resulting moist air into the room or outside.

Condenser tumble drier means a tumble drier which includes a device (either using condensation or any other means) for removing moisture from the air used for the drying process.

Automatic tumble drier means a tumble drier which switches off the drying process when a certain moisture content of the load is detected, for example through conductivity or temperature sensing.

Non-automatic tumble drier means a tumble drier which switches off the drying process after a predefined period, usually controlled by a timer, but which may also be manually switched off.

Defined products not within the scope of the Regulations:

Household combined washer-drier means a household washing machine which includes both a spin extraction function and also a means for drying the textiles, usually by heating and tumbling.

Household spin-extractor, also known commercially as 'spin-drier', means an appliance in which water is removed from the textiles by centrifugal action in a rotating drum and drained through an automatic pump and which is designed to be used principally for non-professional purposes.

Other important definitions are:

Programme means a series of operations that are predefined, and which are declared by the manufacturer as suitable for drying certain types of textiles

Cycle means a complete drying process, as defined for the selected programme.

Programme time means the time that elapses from the initiation of the programme until the completion of the programme, excluding any end-user programmed delay

Rated capacity means the maximum mass in kilograms, indicated by the manufacturer in 0,5 kilograms increments of dry textiles of a particular type, which can be treated in a household tumble drier with the selected programme, when loaded in accordance with the manufacturer's instructions.

Partial load means half of the rated capacity of a household tumble drier for a given programme.

Condensation efficiency means the ratio between the mass of moisture condensed by a condenser tumble drier and the mass of moisture removed from the load at the end of a cycle.

Off-mode means a condition where the household tumble drier is switched off using appliance controls or switches accessible to and intended for operation by the end-user during normal use to attain the lowest power consumption that may persist for an indefinite time while the household tumble drier is connected to a power source and used in accordance with the manufacturer's instructions; where there is no control or switch accessible to the end-user, 'off-mode' means the condition reached after the household tumble drier reverts to a steady-state power consumption on its own.

Left-on mode means the lowest power consumption mode that may persist for an indefinite time after completion of the programme without any further intervention by the end-user besides unloading of the household tumble drier. Starts after the completion of any options that has been selected by the consumer.

Equivalent household tumble drier means a model of household tumble drier placed on the market with the same rated capacity, technical and performance characteristics, energy consumption, condensation efficiency where relevant, standard cotton programme time and airborne acoustical noise emissions during drying as another model of household tumble drier placed on the market under a different commercial code number by the same manufacturer.

Standard cotton programme means the cycle which dries cotton laundry with an initial moisture content of the load of 60 % up to a remaining moisture content of the load of 0 %.

1.1.2 Definitions from preparatory study

Besides the above definitions from the Regulations, the preparatory study sets out a number of relevant definitions, which defines tumble driers across the above categories:

Electric tumble drier: the drier generally uses a coiled wire heated with electric current. The amount of electric current is varied to adjust the temperature.

Gas tumble drier: a gas burner is used to heat the air. The air temperature can be altered by adjusting the size of the gas flame or, more commonly, by merely extinguishing and relighting it.

Air condenser drier: The ambient room air is used as a heat sink. It is blown across the outside of the heat exchanger to cool and dehumidify the warm air used for the drying process. This was the most common type of condenser drier in the market at the time of the preparatory study[33].

Water condenser drier: Water is used to cool the warm air and condense the moisture. At the time of the preparatory study there was no tumble drier on the market using this technology, but for washer-driers this technology was prevalent.

Heat pump condenser drier: The heating and condensing is performed by the hot and cold plates of a heat pump. At the time of the preparatory study there were only a few models of tumble driers available on the market based on this technology.

1.1.3 Definitions in EN 61121:2013 standard – Tumble driers for household use – Methods for measuring the performance

This EN standard provides some additional definitions which are also relevant to the aims of this study, listed below:

Test load means textiles load used for testing.

Pre-treatment means processing of a new test load prior to its first use to avoid rapid changes of characteristics during tests.

Conditioning means brining the test load into thermodynamic equilibrium with the defined ambient air conditions of temperature and humidity; Note: The process of conditioning is not the same as "wetting".

Test run means single performance assessment.

Test series means group of test runs on a tumble drier which, collectively, are used to assess the performance of that tumble drier.

Operation means each performance of a function that occurs during the tumble drier drying process such as heating up, drying, cooling, anti-creasing.

[33] Ecodesign of Laundry Dryers - Preparatory studies for Ecodesign requirements of Energy-using-Products (EuP) Lot 16. Final Report. March 2009. PriceWaterHouseCoopers.

End of the programme means moment in time when the tumble drier indicates the programme is complete and the load is accessible to the user[34].

Cycle time means period of time from the initiation of the programme (excluding any user programmed delay) until all activity ceases. Activity is considered to have ceased when the power consumption reverts to a steady state condition that persists indefinitely without user intervention. If there is no activity after the end of the programme, the cycle time is equal to the programme time[35].

Normalization means processing of a test load after a pre-determined number of cycles to bring the test load to a normal state prior to testing.

Test load mass means actual mass of the test load.

Nominal test load mass means mass of dry textiles of a particular type for which the performance of the tumble drier will be tested (rated capacity or part load). Target value toward which the conditioned test load mass will be adjusted.

Moisture content means ratio of the difference between test load mass and the conditioned test load mass to the conditioned test load mass expressed in percent.

Initial moisture content means moisture content of a test load prior to a test run.

Final moisture content means moisture content of a test load at the end of a test run.

Rated voltage means voltage assigned to the appliance by the manufacturer.

1.1.4 PRODCOM categories

The PRODCOM database is the official source of data regarding production and sales of products in the EU according to the MEErP methodology. For tumble driers, the first data entry in the database was in 1995 and the latest in 2016. From 2008 the PRODCOM database switched from the NACE Rev. 1.1 (Statistical Classification of Economic Activities in the European Community, Revision 1.1) nomenclature to the NACE Rev. 2.0[36], which

[34] **Note 1**: Where there is no such indicator and the door is locked during operation, the programme is deemed to be completed when the load is accessible to the user. Where there is no indicator and the door is not locked during operation, the programme is deemed to be completed when the power consumption of the appliance drops to a steady state condition and it is not performing any function. For non-automatic tumble dryers, the programme is deemed to be completed when it is stopped by the operator. **Note 2**: An indication of the end of the programme may be in the form of a light (on or off), a sound, an indicator shown on a display or the release of a door or latch. In some tumble dryers there may be a short delay from an end of the programme indicator until the load is accessible by the user.

[35] **Note**: Cycle time includes any activity that may occur for a limited period after the end of the programme. Any cyclic event that occurs indefinitely is considered to be steady state.

[36] http://ec.europa.eu/eurostat/web/nace-rev2/transition

meant that most product categories were rearranged. The Product categories relevant for this review from both versions of the database are shown in Table 1.

Table 1: Product categories used in the PRODCOM database

NACE Rev 1.1 (1995-2007)	
29.71	Manufacture of electric domestic appliances
└29.71.13	Cloth washing and drying machines, of the household type
└29.71.13.70	Drying machines of a dry linen capacity ≤ 10 kg
NACE Rev 2.0 (2008-2016)	
27.51.13.00	Cloth washing and drying machines, of the household type

As seen from Table 1, the NACE rev. 1.1 clearly differentiates between washing machines and drying machines, which has a specific category. Machines that both wash and dry are grouped with washing machines. From 1995 to 2002 the data was only collected for the EU-15 countries, and hence for other countries who joined the EU afterwards, data is available from 2003 and forward.

In the NACE rec. 2.0 there is only one category for household washing and drying machines, and collection of separate data in the specific categories has been discontinued. It is therefore not possible to single out the tumble driers from this aggregated category in the NACE Rev 2.0 dataset, which therefore cannot be used for market analysis in this review study.

In both versions of the database there are also categories for washing and drying machines intended for manufacturing or industrial purposes, which are not mentioned here as they are not relevant for this study. Neither of the classifications allow to differentiate between all relevant product groups such as the different tumble drier technologies defined in the Regulations.

1.1.5 Description of products

The primary distinction between tumble driers is the technology that they use, which is also reflected by the categorisation used in the Regulations. In the below sections, the two main types of tumble driers, as well as the heating technology they typically use, are described in more detail to provide explanation of the terms used in the report.

Air-vented tumble driers

Air-vented tumble driers, as shown in Figure 11 are the traditional type of drier, which draws in air from its surrounding room and then heats it and blow it through the clothes to remove moisture from it. The humid air is then exhausted through a ventilation duct in the wall to the outdoors. Hence the vented driers have to be fitted with a hose connected to a wall or window through which the humid air from the drum can be exhausted.

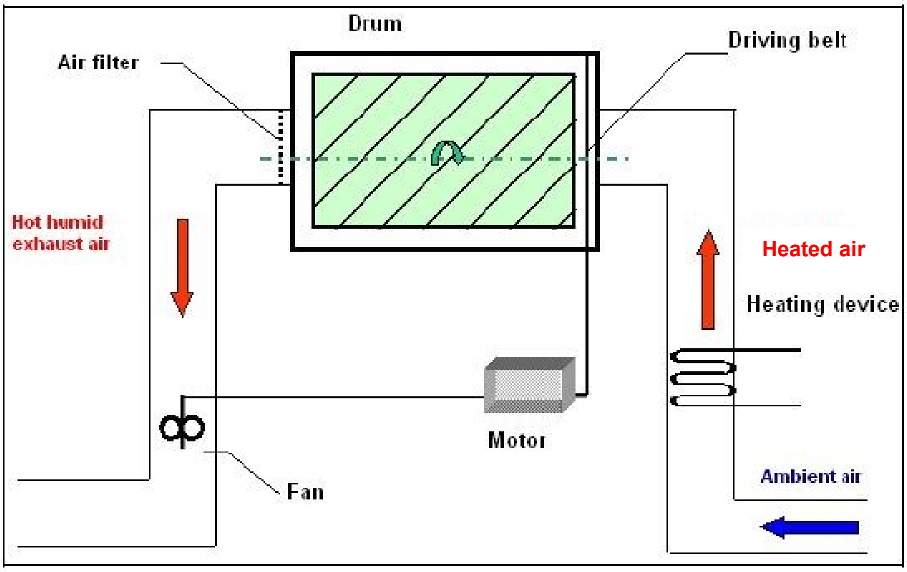

Figure 11: Air-vented tumble drier. Source: Adapted by PWC (2009)[37] from (Essaoui, 2001)[38]

Condenser tumble driers

Condenser tumble driers work through a condensation process where air is recirculated rather than released to the outdoors. The water is condensed out of the moist air coming from the drum by cooling it down in a heat exchanger (using ambient air as heat sink) and the air is reheated and recirculated back to the drum, as shown in Figure 12. The water is either deposited in a container, which should then be emptied by the user, or the drier is connected to a drain to which the water is released. The condenser tumble drier does therefore not have to be placed near a wall, but it is convenient to place them near a drain.

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[37] PWC: Ecodesign of Laundry Driers, Preparatory studies for Ecodesign requirements of Energy-using-Products (EuP) – Lot 16, Final Report, March 2009
[38] Essaoui: Présentation du sèche-linge, Fagor-Brandt internal documentation, 2001

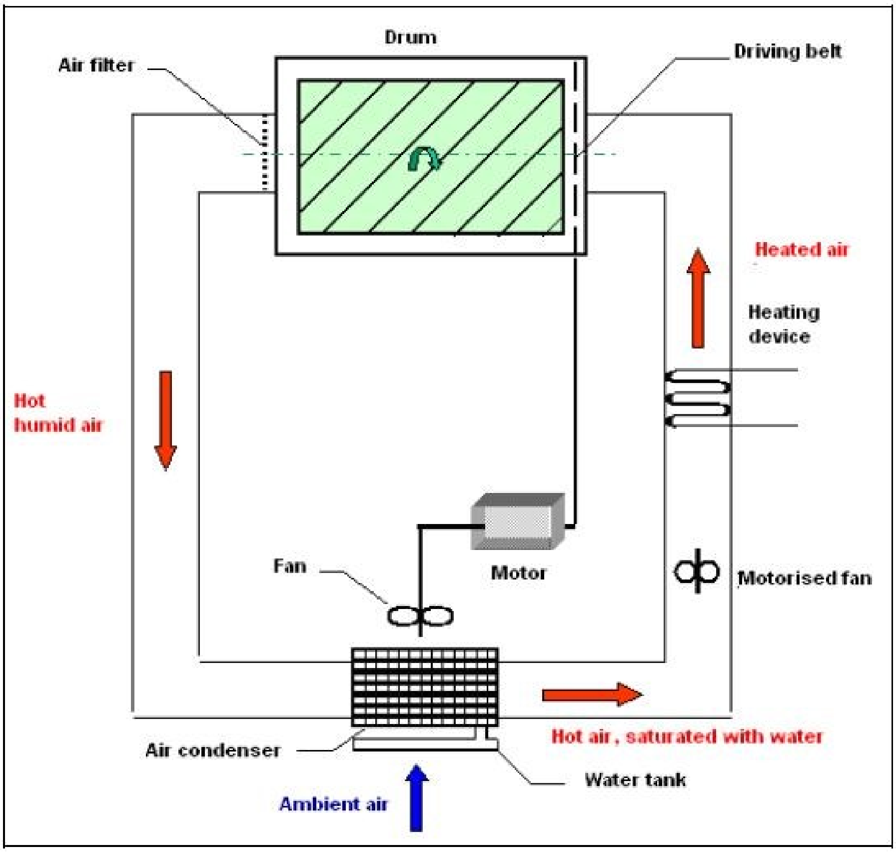

Figure 12: Condenser tumble drier. Adapted by PWC (2009) from (Essaoui, 2001)

Heat element heating technology

Heat element tumble driers use a standard electric heat element to heat the air going into the drum. The heat element can be used in both air-vented and condenser driers and is often a metal coil or plate as seen in Figure 13. The heat element heats up the air as it passes through.

Figure 13: Example of a plate heating element

Heat pump heating technology

In heat pump driers, the hot moist air from the drum is passed through a heat pump. The heat pump removes the heat from the hot moist air causing the water in it to condense, and the removed heat is recycled to re-heat the now dry air before it goes back in the drum. The heating and cooling is achieved through a compression-expansion cycle, which requires electricity and utilises a refrigerant in a closed-loop to transfer the energy. This cycle is shown in Figure 14.

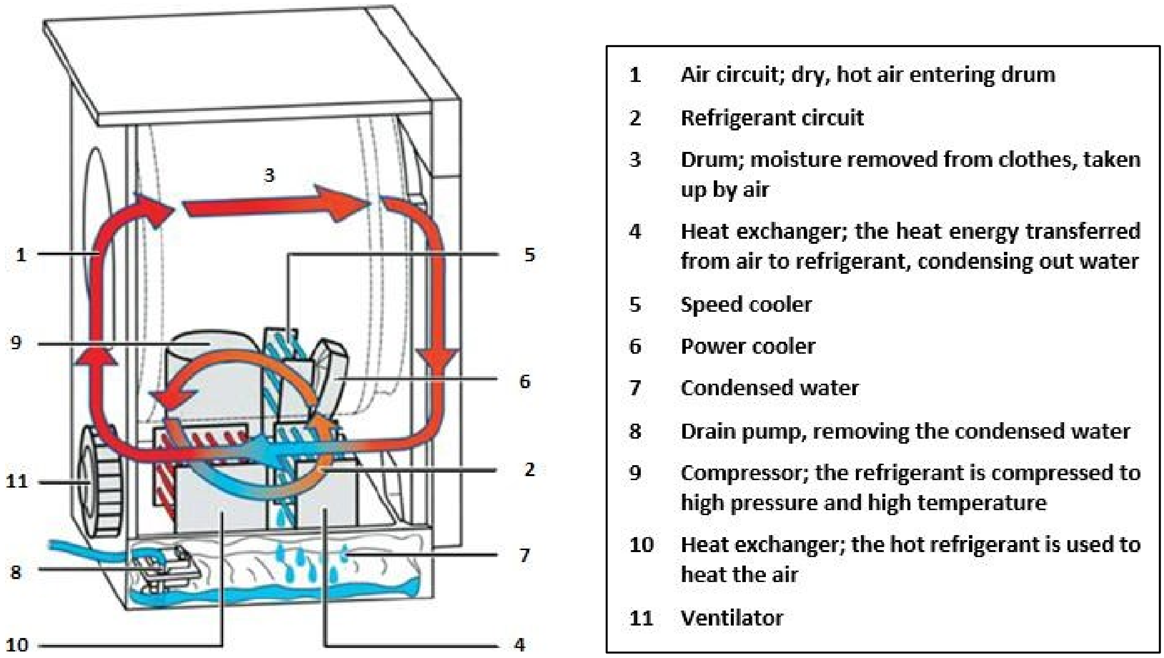

Figure 14: Heat pump drier. Source: ResearchGate (2012)[39]

Gas-fired heating technology

The gas tumble drier technology is very similar to the heating element air-vented technology, except the electric heating element is replaced by a gas flame. Gas tumble driers are always air-vented (i.e. cannot use condensing technology) due to the combustion gases.

1.1.6 Summary of scope

The overall scope of this review study is proposed to remain the same as the scope of the current Regulations. The different tumble drier categories can be seen in Figure 15.

The driers can be classified either based on the heating technology (gas, heat element or heat pump) or on the mechanism used to remove the clothes' moisture (i.e. drier technology, which can be air-vented or condensing). In the case of heat element driers, the categories overlap (see Figure 15).

In the Ecodesign Regulation (EU) No 932/2012, the requirements are more stringent for condenser tumble driers than for air-vented driers, and therefore the product classification is only relevant at drier technology level by defining clearly the differences

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[39] https://www.researchgate.net/figure/254334342_fig2_FIG-2-Schematic-of-a-heat-pump-drying-system-1-process-circuit-2-compressor-3 and https://www.researchgate.net/publication/254334342_Advancements_in_Drying_Techniques_for_Food_Fiber_and_Fuel (courtesy of Bosch Siemens Inc., Germany)

between air-vented and condenser tumble driers. However, the methodology for calculating the weighted energy consumption is different for gas-fired household tumble driers (same in Energy Labelling Regulation (EU) 392/2012). Because of this, it is necessary to make a distinction between the heating technologies.

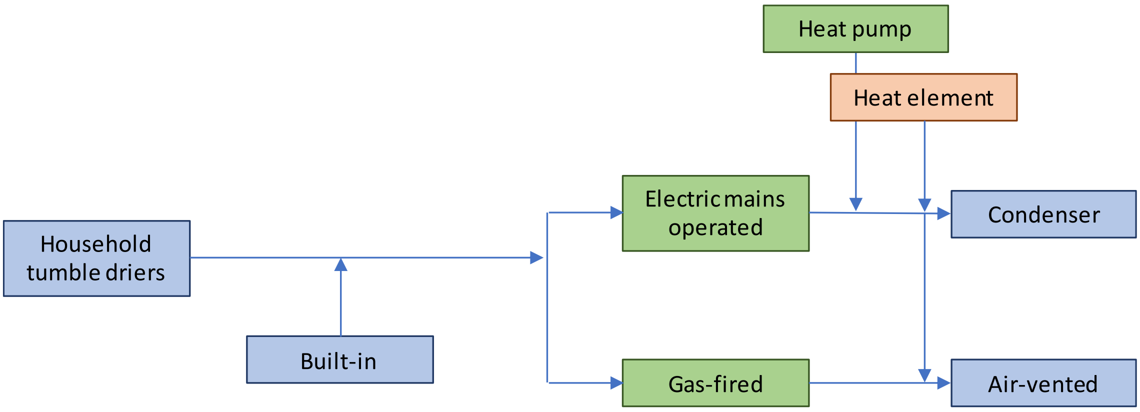

Figure 15: Overview of tumble driers classification

Heating technologies are important to consider for the assessment of technologies. They have a strong influence on the driers' energy efficiency, as well as on the resource efficiency, since they influence the materials used.

1.2 Review of relevant legislation and voluntary schemes

1.2.1 EU Directive 2009/125/EC – Ecodesign for Energy-Related Products[40]

The Ecodesign Directive provides consistent EU-wide rules for improving the environmental performance of energy-related products placed on the EU market. This EU-wide approach ensures that Member States follow the same implementing measures so that potential barriers to internal EU trade are removed.

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

The Ecodesign Directive is a framework Directive, meaning that it does not directly set minimum requirements. Rather, the goals of the Directive are implemented through

[40] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0125&from=EN

product-specific Regulations, which are directly applicable in all EU Member States. For a product to be covered under the Ecodesign Directive it needs to meet the following criteria:

- have a volume of sales that exceeds 200 000 units per year throughout the internal European market
- have a significant environmental impact within the internal market
- present significant potential for improvement in environmental impact without incurring excessive costs

Commission Regulation (EU) No 932/2012[41] regarding ecodesign requirements for household tumble driers, establishes energy efficiency requirements for electric mains-operated and gas-fired household tumble driers and built-in household tumble driers, including those sold for non-household use. The Regulation does not apply to household combined washer-driers and household spin-extractors. The requirements in the Regulation have been introduced in two tiers which are:

- From 1 November 2013:
  - The energy efficiency index (EEI) shall be < 85 for all household tumble driers
  - The weighted condensation efficiency shall be ≥ 60% for condenser household tumble driers
- From 1 November 2015, for condenser household tumble driers:
  - The energy efficiency index (EEI) shall be < 76
  - The weighted condensation efficiency shall be ≥ 70%

Besides these specific requirements, the Regulation sets out some generic requirements. These are requirements regarding the use of standard programme for the different calculations as well as information requirements.

- The basis for calculating the energy consumption and other parameters, are set to a cycle that dries cotton laundry with an initial moisture content of 60%, down to a moisture content of 0%
- This cycle shall be clearly identifiable on the programme selecting device as the "Standard cotton programme".
- This cycle shall be set as the default cycle for tumble driers with automatic programme selection functions.
  - If the program is selected automatically with switching on the drier, then the standard cotton cycle shall be preselected at switch on automatically.

[41] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0932&from=EN

Furthermore, requirements for the booklet of instructions provided by manufacturers shall include:

- Information about the "standard cotton programme", and that it is the most efficient programme for drying wet cotton laundry
- The power consumption of the off-mode and left-on mode
- Indicative information on the programme time and energy consumption for the main drying programmes at full, and, if applicable, partial load.

The tolerance-levels determined in Regulation 932/2012 for the purpose of verification of compliance, are set to 6% for all parameters listed in the Regulation, except for power off and power left-on modes with a power consumption of less than or equal to 1,00W where it shall not be more than 0.1W of the rated value. These are:

- weighted annual energy consumption
- weighted energy consumption
- weighted condensation efficiency
- weighted programme time
- power consumption in off-mode and left-on mode
- duration of the left-on mode

Commission Regulation (EU) No 2016/2282[42] with regard to the use of tolerances in verification procedures specifies that the tolerance-levels determined for the purpose of verification of compliance, are only allowed to be used by market surveillance authorities in the context of reading measurement results, rather than by producers or suppliers for the purpose of establishing values for the technical documentation or in interpreting these values with a view to achieving compliance.

Commission Regulation (EC) No 640/2009[43] **incl. amendment (EU) No 4/2014** with regard to ecodesign requirements for electric motors and its amendment Commission Regulation (EU) No 4/2014[44]. The current scope includes electric one- or three-phase AC motors with output in the range 0.75-375 kW. This means that motors in tumble driers are currently not covered by the electric motor regulation[45] (specifically, the motors for driving

[42] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R2282&from=EN
[43] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R0640&from=EN and http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0004&from=EN
[44] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0004&from=EN
[45] A motor size of around 200W is assumed to be the typical used in tumble driers considering stakeholders input and the information available at preparatory study for the fan/drum motor.

the drum and the fans for the hot and cooling air). Electric motors in the compressors for heat pump driers are not covered by the electric motor regulation, cf. article 1 (point 2(b)).

The most recent results from Lot 11 and Lot 30 study[46] show that the scope of the foreseen revised electric motor regulation will probably include single speed motors with rated outputs from 0.12kW to 1000kW, as well as including motors equipped with variable speed drives. This would include some motors used in drum drives and fans in tumble driers in the foreseen new Motor Regulation. In this case the motors used in tumble driers would have to comply with the IE3 efficiency levels, shown in Annex 1 in the current Motor Regulation.

Commission Regulation (EU) No 1275/2008[47] regarding ecodesign requirements for standby and off mode, and networked standby, electric power consumption of electrical and electronic household and office equipment.

EU ecodesign requirements are mandatory for all manufacturers and suppliers wishing to place on the market products consuming electric power in standby and off mode in the EU. A wide range of products, e.g. computers, TVs, audio and video equipment, white goods and electric toys can have standby modes, so the Regulation is horizontal and covers many products. The complete list of products is presented in Annex I of the Regulation, where clothes driers are explicitly mentioned. The Regulation is entering into force in stages, and all but the last stage (in 2019) is currently active. The requirements for products listed in Annex I is:

- Standby and off mode ≤ 0.5 Watts
- Standby with display ≤ 1 Watts
- Networked standby ≤ 3 Watts

Standby is here defined as a condition where the equipment is connected to the mains power source, depending on energy input from the mains power source to work as intended and provides only the following functions, which may persist for an indefinite time:

1. Reactivation function, or reactivation function and only an indication of enabled reactivation function, and/or:
2. Information or status display.

[46] https://www.eceee.org/ecodesign/products/electricmotors/ and https://www.eceee.org/ecodesign/products/special-motors-not-covered-in-lot-11/
[47] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02008R1275-20170109&from=EN

Off mode is here defined as a condition in which the equipment is connected to the mains power source and is not providing any function; the following shall also be considers as off mode:

1. Conditions providing only an indication of off-mode condition
2. Conditions providing only functionalities intended to ensure electromagnetic compatibility pursuant to Electromagnetic Compatibility Directive 2004/108/EC of the European Parliament and of the Council.

From 2017, all covered appliances are required to have a power management system which turns the equipment into standby or off-modes after the shortest possible period of time, when the equipment is not providing the main function.

For appliances connected to the internet, an option for deactivating the wireless network connection shall be included. Furthermore, a power management system for the network capabilities of the appliance, should be included as well. This system should switch the appliance into networked standby before 20 minutes after use. This is relevant for some of the newer tumble drier models, which are equipped with network capabilities for remote start operation.

Tumble driers do in some models offer "delayed start" options. These modes are not covered in the standby Regulation, as this mode does not last for an indefinite time. Similarly, tumble driers have a left-on mode, after operation. This mode is also not covered in the Regulation, as the mandatory power management system turns the appliance off after a set amount of time. Furthermore, the definition of left-on mode says there should not be further user intervention by the end-user, which happens when appliances are on standby, due to reactivation.

Left-on mode and off mode are indirectly regulated in the ecodesign and energy labelling Regulations of tumble driers as they are included in the EEI calculation.

The Standby Regulation is currently under revision where the scope and some of the requirements may be amended[48].

Commission Regulation (EU) No 206/2012[49] regarding air conditioners and comfort fans. The energy requirements set here are not applicable to heat pump tumble driers, as

[48] https://www.eceee.org/ecodesign/products/standby/
[49] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0206&from=EN

the temperature levels and system designs of an air conditioning system are very different from a drying process and should hence not be compared.

F-gas Regulation - (EU) No 517/2014[50]**,** which was adopted in 2006 and succeeded in stabilising EU F-gas emissions at 2010 levels. A new regulation, which replaces the first and applied from 1 January 2015, strengthened the existing measures and introduced a number of far-reaching changes. By 2030 it will cut the EU's F-gas emissions by two-thirds compared with 2014 levels. However, the F-Gas Regulation does not apply to tumble driers because heat pumps used in tumble driers do not fit the definition of 'stationary heat pumps'[51], and the tumble driers are hermetically sealed and do not contain more than, or equal to 10 tonnes of CO_2-equivalent in fluorinated greenhouse gases.

1.2.2 EU Regulation 2017/1369[52] setting a framework for energy labelling and replacing Directive 2010/30/EU

Regulation 2017/1369 sets a framework for energy labelling of energy-related products and replaces Directive 2010/30/EU. The Directive required producers to label their products in terms of energy consumption on a scale of A – G, as well as inform of a number of other parameters, so that consumers could compare the efficiency of one product with that of another. The current energy labelling requirements for household tumble driers (Regulation 392/2012) are set in relation to Directive 2010/30/EU. The revised rules for energy labelling of household tumble driers will be issued under the new framework Regulation.

In the future, all products will be labelled on a new, updated and clearer scale from A (most efficient) to G (least efficient). This system will gradually replace the current system of A+++ to G labels, which as a result of the technological development towards more energy efficient products in recent years no longer enables consumers to distinguish clearly between the most energy efficient items.

The new A – G scales for the different product categories will be issued through new, product-specific delegated Regulations, and these new scales shall be adopted by 2 August 2023 according to Article 11(4) of the framework Regulation (EU) 2017/1369[53]. For the present study, this means that a rescaling must be performed for the products in scope, transferring them from the current A+++ – G scale to an A – G scale. As Regulation 2017/1369 stipulates, in order to encourage technological progress, the top class should be left empty at the moment of rescaling. In exceptional cases, where technology is

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[50] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0517&from=EN

[51]

[52] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1369&from=EN

[53] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1369&from=EN

expected to develop more rapidly, the two top classes should be left empty at the moment of introduction of the newly rescaled label.

The subject is addressed later in this report, where calculations for the rescaling of tumble driers are performed.

Commission Delegated Regulation (EU) No 392/2012[54] supplementing Directive 2010/30/EU regarding energy labelling of household tumble driers, establishes labelling and information requirements to tumble driers that are within the scope of Ecodesign Regulation 932/2012. Thus, requirements in the Regulation are set to air-vented, condenser and gas-fired household tumble driers, respectively.

In terms of energy efficiency, the following distribution of energy efficiency classes based on the energy efficiency index (IEE) is made in the Regulation. This distribution applies for all three types of tumble driers.

Table 2: Energy efficiency classes in Regulation 392/2012

Energy efficiency class	**Energy efficiency index (IEE)**
A+++ (most efficient)	EEI < 24
A++	24 ≤ EEI < 32
A+	32 ≤ EEI < 42
A	42 ≤ EEI < 65
B	65 ≤ EEI < 76
C	76 ≤ EEI < 85
D (least efficient)	85 ≤ EEI

The EEI is calculated as specified in the Regulation.

For condenser tumble driers, requirements are also made for condensation efficiency. The condensation efficiency class is determined on the basis of the weighted condensation efficiency (C_t), which is calculated as specified in the Regulation. The distribution of condensation efficiency class according to the weighted condensation efficiency (C_t) made in the Regulation can be seen in Table 3.

[54] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0392&from=EN

Table 3: Condensation efficiency classes in Regulation 392/2012

condensation efficiency class	weighted condensation efficiency
A (most efficient)	$C_t > 90$
B	$80 < C_t \leq 90$
C	$70 < C_t \leq 80$
D	$60 < C_t \leq 70$
E	$50 < C_t \leq 60$
F	$40 < C_t \leq 50$
G (least efficient)	$C_t \leq 40$

The Regulation also makes several information requirements. The information required to appear on the energy labels for all three categories of tumble driers is the following:

- supplier’s name or trade mark
- supplier’s model identifier, meaning the code, usually alphanumeric, which distinguishes a specific household tumble drier model from other models with the same trade mark or supplier’s name
- the energy efficiency class, as defined in the Regulation (see Table 2)
- the head of the arrow containing the energy efficiency class of the household tumble drier shall be placed at the same height as the head of the arrow of the relevant energy efficiency class
- weighted annual energy consumption (AE_C) in kWh/year, rounded up to the nearest integer and calculated as specified in the Regulation
- information on the type of household tumble drier
- cycle time corresponding to the standard cotton programme at full load in minutes and rounded to the nearest minute
- rated capacity, in kg, for the standard cotton programme at full load, and
- the sound power level (weighted average value — L_{WA}), during the drying phase, for the standard cotton programme at full load, expressed in dB, rounded to the nearest integer.

Apart from these, the energy labels of condenser tumble driers must also include the condensation efficiency class, as defined in the Regulation (see Table 3).

The design of the energy labels for air-vented, condenser and gas-fired household tumble driers, respectively, as determined in Regulation 392/2012, can be seen in Figure 16.

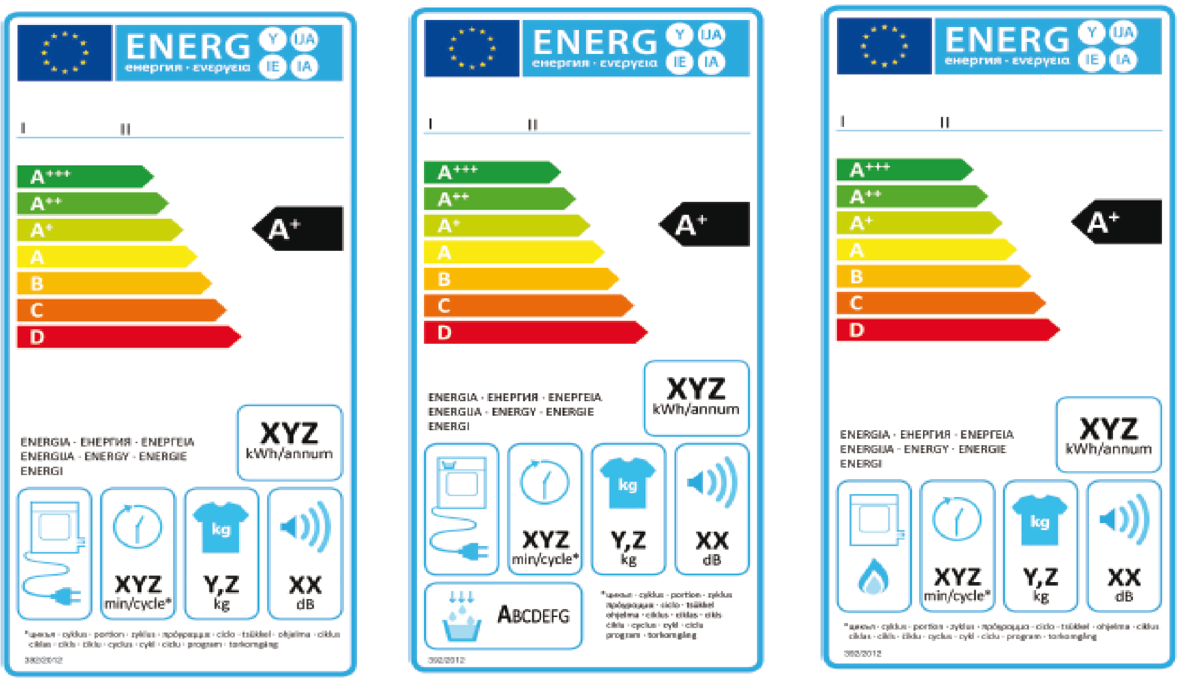

Figure 16: From left to right: the design of the energy labels for air-vented, condenser and gas-fired tumble driers as specified in Commission delegated Regulation (EU) No 392/2012

Apart from information requirements for the energy label itself, Regulation 392/2012 sets out requirements for information, which are listed below:

A. Information on Product fiche

1. The information in the product fiche of household tumble driers shall be given in the following order and shall be included in the product brochure or other literature provided with the product:
    a. Supplier's name or trade mark
    b. supplier's model identifier, which means the code, usually alphanumeric, which distinguishes a specific household tumble drier model from other models with the same trade mark or supplier's name;
    c. rated capacity in kg of cotton laundry for the standard cotton programme at full load;
    d. whether the household tumble drier is an air-vented, condenser or gas-fired household tumble drier;
    e. energy efficiency class in accordance with point 1 of Annex VI in the Regulation;
    f. for electric mains-operated household tumble drier:

the weighted Annual Energy Consumption (AEc) rounded up to one decimal place; it shall be described as: 'Energy consumption "X" kWh per year, based on 160 drying cycles of the standard cotton programme at full and partial load, and the consumption of the low-power modes. Actual energy consumption per cycle will depend on how the appliance is used.';

for household gas-fired tumble drier: the weighted Annual Energy Consumption (AEC(Gas)) rounded up to one decimal place; it shall be described as: 'Energy consumption "X" kWh-Gas per year, based on 160 drying cycles of the standard cotton programme at full and partial load. Actual energy consumption per cycle will depend on how the appliance is used'; and the weighted Annual Energy Consumption (AEC(Gas)el) rounded up to one decimal place; it shall be described as: 'Energy consumption "X" kWh per year, based on 160 drying cycles of the standard cotton programme at full and partial load, and the consumption of the low-power modes. Actual energy consumption per cycle will depend on how the appliance is used.

g. whether the household tumble drier is an 'automatic tumble drier' or 'non-automatic tumble drier
h. where the household tumble drier has been awarded an 'EU Ecolabel award' under Regulation (EC) No 66/2010, this information may be included;
i. the energy consumption (Edry, Edry½, Egdry, Egdrya½, Egdry, a, Egdry½, a) of the standard cotton programme at full and partial load;
j. the power consumption of the off-mode (Po) and of the left-on mode (Pl) for the standard cotton programme at full load;
k. if the household tumble drier is equipped with a power management system, the duration of the 'left-on mode';
l. indication that the 'standard cotton programme' used at full and partial load is the standard drying programme to which the information in the label and the fiche relates, that this programme is suitable for drying normal wet cotton laundry and that it is the most efficient programme in terms of energy consumption for cotton;
m. the weighted programme time (Tt) of the 'standard cotton programme at full and partial load' in minutes and rounded to the nearest minute as well as the programme time of the 'standard cotton programme at full load' (Tdry) and the programme time of the 'standard cotton programme at partial load' (Tdry½) in minutes and rounded to the nearest minute;

n. if the household tumble drier is a condenser tumble drier, the condensation efficiency class in accordance with point 2 of Annex VI, expressed as 'condensation efficiency class 'X' on a scale from G (least efficient) to A (most efficient)'; this may be expressed by other means provided it is clear that the scale is from G (least efficient) to A (most efficient);
o. if the household tumble drier is a condenser tumble drier, the average condensation efficiency Cdry and Cdry½ of the standard cotton programme at full load and partial load and the weighted condensation efficiency (Ct) for the 'standard cotton programme at full and partial load', as a percentage and rounded to the nearest whole percent;
p. the sound power level (weighted average value — LWA) expressed in dB and rounded to the nearest integer for the standard cotton programme at full load;
q. if the household tumble drier is intended to be built-in, an indication to this effect.

2) One product fiche may cover a number of household tumble drier models supplied by the same supplier. The information contained in the fiche may be given in the form of a copy of the label, either in colour or in black and white. Where this is the case, the information listed in point 1 not already displayed on the label shall also be provided.

B. Information to be provided in cases where end-users cannot be expected to see the tumble drier displayed:

1. The information referred to in Article 4(b) shall be provided in the following order:
   a. the rated capacity in kg of cotton, for the standard cotton programme at full load;
   b. whether the household tumble drier is an air-vented, condenser or gas-fired household tumble drier;
   c. the energy efficiency class as defined in point 1 of Annex VI;
   d. for electric mains-operated household tumble drier:

      the weighted Annual Energy Consumption (AEc) rounded up to the nearest integer, to be described as: 'Energy consumption "X" kWh per year, based on 160 drying cycles of the standard cotton programmes at full and partial load, and the consumption of the low-power modes. Actual energy consumption per cycle will depend on how the appliance is used.';

      for household gas-fired tumble drier: the weighted Annual Energy Consumption (AEC(Gas)) rounded up to one decimal place; it shall be described as: 'Energy consumption "X" kWh-Gas per year, based on 160 drying cycles of the standard cotton programme at full and partial load. Actual energy consumption per cycle will depend on how the appliance is used'; and the weighted Annual Energy Consumption (AEC(Gas)el) rounded up to one decimal place; it shall be described as: 'Energy consumption "X" kWh per year, based on 160 drying cycles of the standard cotton programme at full and partial load, and the consumption of the low-power modes. Actual energy consumption per cycle will depend on how the appliance is used'

e. whether the household tumble drier is an 'automatic tumble drier' or 'non-automatic tumble drier'
f. the energy consumption (Edry, Edry½, Egdry, Egdry½, Egdry, a, Egdry½, a) of the standard cotton programme at full and partial load, rounded up to two decimal places and calculated in accordance with Annex VII;
g. g) the power consumption of the off-mode (Po) and the left-on mode (Pl) for the standard cotton programme at full load;
h. (h) the programme time of the 'standard cotton programme at full load' (Tdry) and the programme time of the 'standard cotton programme at partial load' (Tdry½), in minutes and rounded to the nearest minute, calculated in accordance with Annex VII;
i. (i) if the household tumble drier is a condenser tumble drier, the condensation efficiency class in accordance with point 2 of Annex VI;
j. (j) the sound power level (weighted average value — LWA) for the standard cotton programme at full load, expressed in dB and rounded to the nearest integer; (k) if the household tumble drier is intended to be built-in, an indication to this effect.

2. Where other information contained in the product fiche is also provided, it shall be in the form and order specified in Annex II.
3. The size and font in which all the information referred in this Annex is printed or shown shall be legible.

Commission Delegated Regulation (EU) No 2017/254[55] with regard to the use of tolerances in verification procedures, replaces Annex V of Regulation 392/2012. The new Annex V specifies, that the tolerance-levels determined for the purpose of verification of compliance, are only allowed to be used by market surveillance authorities in the context of reading measurement results, rather than by producers or suppliers for the purpose of

[55] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R0254&from=EN

establishing values for the technical documentation or in interpreting these values with a view to achieving compliance.

Commission Regulation (EU) No 518/2014[56] with regard to labelling of energy-related products on the internet, adds a number of information requirements to Regulation 392/2012 regarding an electronic label and an electronic product fiche in cases where tumble driers are offered for sale on the internet. These include changes to Article 3 where following points are added:

- An electronic label an electronic label in the format and containing the information set out in Annex I of Regulation No 392/2012 is made available to dealers for each household tumble drier model placed on the market from 1 January 2015 with a new model identifier. It may also be made available to dealers for other household tumble drier models
- An electronic product fiche as set out in Annex II of Regulation No 392/2012 is made available to dealers for each household tumble drier model placed on the market from 1 January 2015 with a new model identifier. It may also be made available to dealers for other household tumble drier models

Article 4, point (b) of Regulation No 392/2012 is replaced by

- Household tumble driers offered for sale, hire or hire-purchase where the end-user cannot be expected to see the product displayed, as specified in Article 7 of Directive 2010/30/EU, are marketed with the information provided by suppliers in accordance with Annex IV to this Regulation. Where the offer is made through the internet and an electronic label and an electronic product fiche have been made available in accordance with Article 3(f) and 3(g) the provisions of Annex VIII shall apply instead.

Annex VIII is added with information to be provided in the case of sale, hire or hire-purchase through the internet.

On May 9th, 2012, a **Corrigendum to Commission Delegated Regulation (EU) No 392/2012**[57] has been published. The corrigendum revises a number of dates indicated in Regulation 392/2012, but makes no substantive changes in the Regulation otherwise.

[56] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0518&from=EN
[57] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0392R(01)&from=EN

1.2.3 EU Directive 2014/35/EU – Low Voltage Directive[58]

The new Low Voltage Directive (LVD) has come into force on the 20th of April 2016. The LVD ensures that electrical equipment that operates within certain voltage limits, provides a high level of protection. The LVD Directive covers all health and safety risks of electrical equipment operating with a voltage of between 50 and 1000 volts for alternating current and between 75 and 1500 volts for direct current. Consumer goods with a voltage below 50 for alternating current or 75 for direct current are covered by the General Product Safety Directive (GPSD) (2001/95/EC).

Household appliances, hereunder tumble driers, fall under the scope of the LVD Directive.

1.2.4 EU Directive 2012/19/EU – The WEEE Directive[59]

The Waste Electrical and Electronic Equipment (WEEE) Directive implements the principle of "extended producer responsibility" where producers of EEE are expected to take responsibility for the environmental impact of their products at the end of life. As such, the WEEE Directive aims to reduce environmental impacts through setting targets for the separate collection, reuse, recovery, recycling and environmentally sound disposal of WEEE.

As EEE, tumble driers fall under the scope of the WEEE Directive. Ecodesign requirements for tumble driers could therefore be used to assist the WEEE Directive aims via the introduction of product design requirements that enhance reuse, material recovery and effective recycling.

1.2.5 EU Regulation 1907/2006/EC – REACH Regulation[60]

The Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) 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 determined "substances of very high concern (SVHC)" due to their large potential negative

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[58] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0035&from=EN
[59] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=DA
[60] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006R1907-20140410&from=EN

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.

As REACH applies to all chemical substances, it also applies to chemicals that may be used in household tumble driers, for instance refrigerants in heat pump tumble driers.

1.2.6 EU Directive 2011/65/EU – RoHS Directive[61]

The Restriction of Hazardous Substances (RoHS) Directive aims to reduce hazardous substances from electrical and electronic equipment (EEE) 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.

1.2.7 Third country national legislation - Switzerland

In Switzerland, national Minimum Energy Performance Standards (MEPS) have been issued in 2012, banning all non-heat pump driers from the Swiss market. These MEPS have been further tightened in 2015, allowing only driers classified A+ or better to remain on the market[62].

1.2.8 Voluntary agreements

ENERGY STAR[63]

In the US, the ENERGY STAR program has established requirements for clothes driers in May 2014. The criteria include requirements for energy efficiency and cycle time. Only gas, electric, and compact clothes driers meeting the ENERGY STAR definitions for an electric or gas clothes driers are eligible to earn ENERGY STAR certification in the US. In the EU, the ENERGY STAR program does not include requirements for white goods.

The following table lists the efficiency requirements made for products to be eligible to earn ENERGY STAR certification.

Table 4: US ENERGY STAR requirements for tumble driers[64]

Product type	Combined Energy Factor (kg/kWh)
Vented Gas	1.58
Ventless or Vented Electric, Standard (≥124.6 litre capacity)	1.78

[61] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0065&from=EN
[62] http://www.topten.eu/uploads/File/EEDAL15_Eric_Bush_Heat_Pump_Tumble_Driers.pdf
[63] https://www.energystar.gov/products/appliances/clothes_dryers/key_product_criteria
[64] Units are converted from the original version given in Imperial system to the SI-system

Ventless or Vented Electric, Compact (120V) (<124.6 litre capacity)	1.72
Vented Electric, Compact (240V) (<124.6 litre capacity)	1.56
Ventless Electric, Compact (240V) (<124.6 litre capacity)	1.22

The Combined Energy Factor (CEF) is the quotient of the test load size, 3.83 kg for standard driers and 1.36 kg for compact driers, divided by the sum of the machine electric energy use during standby and operational cycles. The equation is shown here:

$$CEF = \frac{CEF\ (kg)}{E_{on} + E_{standby}}$$

The units are kg loaded clothes per kWh, the higher the value, the more efficient the clothes drier is.

Nordic Ecolabelling of White Goods

Background document Version 5.2, February 2017

The Nordic Ecolabel *("Svanemærket")* uses the EU energy labelling scheme as basis for setting energy efficiency requirements for white goods including tumble driers. It covers both electric mains and gas fired household tumble driers, but not combined washer-driers or spin driers.

For a tumble drier to pass the Nordic Ecolabel requirement, numerous requirements are set:

- Energy efficiency class of at least A^{+}
- Condensation efficiency class of at least B
- Maximum airborne noise emission of 65dB (tested according to EN 60704)
- For heat pump driers: The refrigerants must not have a GWP_{100}>2000. For refrigerants with a GWP_{100}>100, the heat pump shall be pressure tested on the production site to prevent leakage, and it should be marked according to EN14511-4.

Furthermore, additional requirements are set for the use of chemical substances (e.g. phthalates), manufacturing processes, packaging, waste, and content of flame retardants.

1.2.9 Summary of relevant[65] legislations and voluntary agreements

A summary of the relevant legislation and voluntary agreements to the revision of the ecodesign and energy labelling Regulations is presented in Table 5.

Table 5: Summary of relevant legislations other than ecodesign and energy labelling Regulations of tumble driers and of relevant voluntary agreements

Relevant for	Name	Relevance to current review study	Aim of Regulation/Agreement	Applicable from	Specific relevant requirements
Ecodesign	Commission Regulation (EU) No 2016/2282	Tolerances for verification procedures in ecodesign Regulation	Amend numerous ecodesign Regulations (incl. tumble driers) with regard to the use of verification tolerances.	2016	The verification procedure in Annex III of Regulation 932/2012 is replaced by procedure in Annex XIII of Regulation 2016/2282
	Commission Regulation (EC) No 640/2009	Ecodesign efficiency requirements that may be applicable for the electric motors driving the fans and the drum in tumble driers	Set ecodesign requirements for electric motors (under revision, incl. scope of the requirements)	2009	Minimum efficiencies for electric motors related to rated power consumption
	Commission Regulation (EU) No 1275/2008 (including four amendments)	Ecodesign energy requirements for off mode and networked standby as well as power management function	Set ecodesign requirements for standby, networked standby and off modes including power management	2013	Power consumption requirements: Off mode ≤0.5W and Networked standby ≤3W Equipment shall offer a power management function switching equipment after the shortest period of time into off-mode
Energy labelling	Commission Delegated Regulation (EU) No 2017/254	Tolerances for verification procedures in energy labelling Regulation	Amend numerous energy labelling Regulations (incl. tumble driers) with regard to the use of verification tolerances	2017	The verification procedure in Annex V of Regulation 392/2012 is replaced by procedure in Annex VI of Regulation 2017/254
	Commission Regulation (EU) No 518/2014	Availability of tumble driers energy label and fiche online	Amend numerous energy labelling Regulations (incl. tumble driers) with regard to labelling on the internet	2014	Articles 3 and 4 of Regulation 392/2012 are amended according to article 6 of Regulation 518/2014
	EU Regulation 2017/1369	Setting a new framework for energy classes	Replace Energy labelling Directive 2010/30/EU	2017	New rules for rescaling energy classes
Voluntary agreements	ENERGY STAR for electric and gas clothes driers	Setting combined energy factor requirements (kg load/kWh) requirements for electric and gas-fired vented and compact driers	Set energy efficiency requirements for these drier types in the US	2014	Combined energy factor requirements specific for Vented Gas, Ventless Gas, Vented Electric and Ventless Electric both Standard and Compact sizes typically used in the US

[65] Only those legislations having a direct impact to tumble driers have been reviewed, i.e. those which set requirements on products, services, materials and/or substances that are used in tumble driers. No Ecolabel nor Green Public Procurement criteria exist for tumble driers.

Relevant for	Name	Relevance to current review study	Aim of Regulation/Agreement	Applicab le from	Specific relevant requirements
	Nordic Ecolabelling of White Goods	Setting requirements for energy efficiency and condensation efficiency classes, noise and use of refrigerants	Setting requirements for white goods, incl. tumble driers, referencing the Energy Labelling regulation	2017	Energy and condensation efficiency, noise and use of refrigerants requirements

1.3 Review of relevant standards

1.3.1 European and international standards

European (EN) standards are documents that have been ratified by one of the three European Standards Organizations (ESOs), **CEN** (the European Committee for Standardization), **CENELEC** (the European Committee for Electrotechnical Standardization) or **ETSI** (European Telecommunications Standards Institute). Many result from the adaptation of international standards (**IEC** and **ISO**), to ensure that they are appropriate to European conditions, etc.

CEN, CENELEC and ETSI deal with different fields of activity, but cooperate in a number of areas of common interest. They also share common policies on issues where there is mutual agreement.

The CEN/CENELEC Internal Regulations, Part 2, state that the EN 'carries with it the obligation, to be implemented at national level, by being given the status of a national standard and by withdrawal of any conflicting national standards'. Therefore, a European Standard automatically becomes a national standard in each of the 34 CEN-CENELEC member countries.

The international standards mentioned in this report are **ISO** (International Organization for Standardization) standards and **IEC** (International Electrotechnical Commission) standards.

Measurement and performance standards

EN 61121:2013 *Tumble Driers for household use – methods for measuring the performance* (Modified from IEC 61121:2012)
Defines test methods for measuring performance characteristics of electric tumble driers regarding the drying performance, evenness of drying, condensation efficiency (for condenser driers), water and electric energy consumption and programme time are described in this standard. It covers household electric tumble driers, both automatic and non-automatic. Gas fired tumble driers are not covered in this standard.

The standard supersedes EN 61121:2005 which was valid during the preparatory study. The major changes include:

- Testing procedures for partial load operation (i.e. half of the maximum capacity)

- Testing procedures for power consumption in low power modes (i.e. by including a revised formula for calculating total energy consumption based on these numbers):
  - Low power modes include left-on mode and off mode
  - The left-on modes are differentiated between "unstable left-on mode" (LU) which is 30 minutes after the door has been opened post programme, and the "left on mode" (LO) which starts after the LU has finished.

The energy consumption during use is calculated based on 7 runs where 3 is with full capacity, and 4 is with partial load. The annual energy consumption (AEc) is based on the energy consumption during use, and its power consumption in off modes, as follows:

$$AE_c = E_t \times 160 + \left\{\frac{P_o + P_{LO}}{1.000} \times \left[\frac{525600 - (t_t + t_{mLU}) \times 160}{2 \times 60}\right]\right\} + \left(\frac{P_{LU}}{1.000} \times \frac{t_{mLU} \times 160}{60}\right)$$

With:

$\mathbf{E_t}$ being the average total energy consumption of the active mode, $\mathbf{P_{LU}}$ **/** $\mathbf{P_{LO}}$ being the power consumption doing the left-on modes, $\mathbf{P_O}$ being the power consumption in off-modes, $\mathbf{t_t}$ being the programme time, $\mathbf{t_{mLU}}$ being the time of the LU left-on mode, and **160** is the number of standard drying cycles per year.

The first part of the equation is hence the energy consumption of 160 drying cycles, and the rest is the power consumption of the left-on and off-modes.

This is slightly different from the AE_c calculation in Regulation No 392/2012, which doesn't differentiate between the left on modes. The AE_c calculation method defined in the standard, in comparison to what defined in the Ecodesign and Energy Labelling Regulations for tumble driers, splits the left-on mode in stable (L_O) and unstable (L_U), while in the Regulations, left-on mode is only measured as the minimum power consumption in this mode after the completion of the programme, once the consumption has been stabilized. Therefore, the calculation of AE_c in the standard, results in higher power consumption in the case the unstable left-on mode is also quantified. It is the method in the Regulations which is used to calculate the AEc for Ecodesign and Energy Labelling purposes.

The energy efficiency index (EEI) is defined as the ratio of the annual energy consumption, and the standard annual energy consumption (SAEc):

$$EEI = \frac{AEc}{SAEc} \times 100$$

With SAEc for condenser driers in kWh/year being defined as

$$SAEc = 140 \times c^{0.8} \frac{kg}{cycle}$$

With **c** being the rated capacity for the cotton drying program. 140 is an arbitrary scaling factor, and the exponent "0.8" is to correct the non-linear relationship between total energy consumption and drying load.

For vented driers, a correction factor for the lost energy in the vented air, is added as

$$SAEc = 140 \times c^{0.8} - 30 \times \frac{t_t}{60}$$

With $\mathbf{t_t}$ being the cycle time in minutes.

The testing sequence EN 61121:2013 is based on that one given in the standard IEC 61121:2012 but modified with respect to reflecting the requirements of the European regulations 392/2012 on energy labelling of household tumble driers and 932/2012 on ecodesign requirements of household tumble driers.

The testing sequence according IEC 61121:2012 is generally very thorough, and the overall procedure is to run a drying sequence until 5 valid runs are achieved. The mean value of these runs is then used as the final figure. The validity of the sequence is based on the final moisture content in laundry. The laundry used is cotton with 60% initial humidity or synthetics with 50% initial moisture, and the final moisture level is either 0% (cupboard dry), 12% (iron ready), or 2% (Synthetic/blends textiles). The programme used is determined before the test series. The selected programme is used for all 5 testing runs.

The modifications of EN61121:2013 in comparison to IEC 61121:2012 are as follows:

The program defined for the energy label testing procedure is selected to cotton cupboard dry, a program that must be able to dry a standard cotton load from an initial moisture content of 60% to a final moisture content of 0%. This program is used with the treatments 'full', which is run 3 times with rated cotton capacity, and the treatment 'half', which is run 4 times with half the rated cotton capacity. In addition, the power consumption is measured in the 'left-on-mode' as well as in the 'off-mode'.

There are no restraints on time consumption or the amount of wear on the laundry during the drying cycle.

One major item to note, is the water quality used for wetting the laundry. Automatic tumble driers, which are units that stop after a certain amount of moisture content in the load is reached, are very dependent on the water quality used for testing. This is because the sensors used to measure the moisture content in the laundry are dependent on the conductivity of the fabric, which can be influenced by the water hardness, alkalinity, and pH level. The water is treated according to IEC 60734:2012, which makes sure that the water used in all household appliances are of equal standard, but it may not reflect the everyday user setup. If the automatic tumble driers are used where water properties differ by a large extent from the reference values, the driers may not be able to stop drying even though the desired moisture content is reached. This can lead to increased energy consumption or undesired drying results. In this way the reported values on the energy label might differ when used with water having properties varying from these values.

Recent developments of standardisation work by TC59X/SWG1.9 on EN 61121:2013

The ongoing standardisation work proposes numerous changes to the standard with varying extend. The major changes proposed by the working group as of November 2017 includes:

- A need for a more precise verification procedure than given in the Regulation.
- Definition of "combined test series" to be added.
- A revised calculation method for condensation efficiency
    - Currently measurement overrepresents partial load, and underrepresents full loads → From weighted average, to a summation of whole test series.

EN 1458-2:2012 *Domestic gas fired tumble driers of types B22D and B23D, of nominal heat input not exceeding 6 kW – Part 2: rational use of energy*

Part 2 of this standard specifies the requirements and test methods for rational use of energy for domestic gas fired tumble driers of types B22D and B23D of nominal heat input not exceeding 6 kW.

The tumble drier shall have a gas energy consumption not exceeding 1.11 kWh/kg of standard load.

The electrical energy consumption is measured in accordance with EN 61121. The gas energy consumption E_g is determined in kWh as

$$E_g = 0.278V_c \times H_s$$

With V_c being the volume of dry gas consumed, and H_s being the gross calorific value of the dry gas under reference conditions (15°C and 1013.25 mbar). The volume of gas is measured with a gas meter.

In Regulation No 392/2012, this energy consumption is then divided by a factor of 2.5 (in order to convert between the value of primary and electric energy) and added the auxiliary electric consumption, in order to give the weighted energy consumption E_t, used in the calculation of the EEI.

EN 60704-2-6:2012 (IEC 60704-2-6:2012) *Household and similar electrical appliances – Test code for the determination of airborne acoustical noise – Part 2-6: Particular requirements for tumble driers*

Defines methods of determination of airborne acoustical noise. Part 1 states general requirements, Part 2-6 specifies particular requirements for tumble driers, Part 3 defines the procedure for determining and verifying declared noise emission values. This harmonised standard constitutes the method for measuring sound power level in Regulation 392/2012[66].

EN 50564:2011 (IEC 62301-1:2011) ***Electrical and electronic household and office equipment. Measurement of low power consumption***

Defines methods for measuring the electrical power consumption in standby mode. Applicable to mains powered electrical household appliances and to the mains powered parts of appliances that use other fuels such as gas or oil.

Safety standards

EN 1458-1: 2012 ***Domestic gas fired tumble driers of types B_{22D} and B_{23D}, of nominal heat input not exceeding 6 kW***

Part 1 of this standard specifies safety requirements for domestic gas fired tumble driers of types B_{22D} and B_{23D} of nominal heat input not exceeding 6 kW.

EN 60335-1:2012+A11:2014 (IEC 60335-1:2010+A1:2013+A2:2016) ***Household and similar electrical appliances – Safety.***

Part 1 of this standard states general safety requirements. Parts 2-11 specify requirements for tumble driers intended for household and similar purposes. Parts 2-43 deal with the safety of electric clothes driers for drying textiles on racks located in a warm airflow and to electric towel rails, for household and similar purposes, with rated voltage not exceeding 250V. Parts 2-102 specify requirements for gas, oil and solid-fuel burning appliances having electrical connections.

Substances, materials and end-of-life standards

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

Specifies a system of uniform plastic material marking. 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***

[66] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014XC0516(03)&from=EN

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)***

Product marking requirements needed to ensure compliance with the WEEE Directive and 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***

Part of a series of standards requested in Commission Mandate M/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-depolluted WEEE and fractions

  - Storage of fractions
  - 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 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 (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.

Other standards

EN 61000 (IEC 61000) *Electro Magnetic Compatibility (EMC) standards*
Deals with different aspects regarding electro-magnetic compatibility and sets the basis for the European EMC legislation. Part 1 states general considerations, part 2 describes and classifies the environment and specifies compatibility levels, part 3 specifies emission and immunity limits, part 4 defines testing and measurement techniques, part 5 defines installation and mitigation guidelines and part 6 defines generic standards.

EN 62233:2008 *Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure*
Seeks to limit the electro-magnetic fields (EMF) produced by electrical household appliances in order to protect human beings.

IEC 62430:2009 *Environmentally conscious design (ECD) for electrical and electronic products and systems*

Specifies requirements and procedures to specify generic procedures to integrate environmental aspects into design and development processes of electrical and electronic products including combination of products, and the materials and components of which they are composed.

1.3.2 Mandates issued by the EC to the European Standardization Organizations

M/495 - Standardisation mandate to CEN, CENELEC and ETSI under Directive 2009/125/EC relating to harmonised standards in the field of Ecodesign

Mandate/495 is of generic and horizontal nature. The objective of the mandate is to provide European standards to enable the implementation of the Ecodesign Directive 2009/125/EC and its implementing measures. When Energy labelling requirements are introduced together with Ecodesign requirements, the mandate also aims at providing European standards to enable the implementation of the Energy Labelling Directive 2010/30/EU and its supplementing measures.

Standardisation needs for relevant products are included in annex B to the mandate. Annex B is updated regularly, when the ecodesign work progress on a product group allows the Commission to precisely specify the standardisation needs.

For the time being there is no standardisation requests under Mandate M/495 for tumble driers and no needs are foreseen to arise from the ongoing revision of the ecodesign and energy labelling regulations for household tumble driers.

M/544 – Standardisation mandate to the European standardisation organisations as regards ecodesign requirements for networked standby in support of Regulation (EC) No 1275/2008 and Regulation (EC) No 642/2009

This mandate allows the introduction of network standby in a future revision of the standard EN50564:2011 – Electrical and electronic household and office equipment - Measurement of low power consumption.

If networked standby is to be taken into account then tumble driers fit the definition of edge equipment in the draft version prEN 50643, which is: "networked equipment that can be connected to a network and interact with that network or other equipment and that does not have, as its primary function, the passing of network traffic to provide a network."

Regarding networked standby there are some useful definitions in Regulation (EC) No 1275/2008[67]:

Network means a communication infrastructure with a topology of links, an architecture, including the physical components, organisational principles, communication procedures and formats (protocols).

Networked equipment means equipment that can connect to a network and has one or more network ports.

Networked standby means a condition in which the equipment is able to resume a function by way of a remotely initiated trigger from a network connection.

M/543 – Material Efficiency

In December 2015, the EC published a standardisation request to the ESOs covering ecodesign requirements on material efficiency aspects for energy-related products in support of the implementation of Directive 2009/125/EC.[68] It was noted in the mandate, that the absence of adequate metrics is one of the reasons for the relative lack of ecodesign requirements related to material efficiency in previous ecodesign implementing measures. The mandate therefore requests that the ESOs draft new European standards and European standardisation deliverables on material efficiency aspects for energy-related products in support of the ecodesign Directive 2009/125/EC. This standardisation request clarifies that the following material efficiency aspects should be covered:

- Extending product lifetime.
- Ability to re-use components or recycle materials from products at end-of-life.
- Use of re-used components and/or recycled materials in products

Several prEN standards have been developed in light of this mandate. They are described in section 1.4.

1.3.3 Summary of relevant standards

A summary of the relevant standards to the reviewed ecodesign and energy labelling Regulations is presented in Table 6.

[67] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02008R1275-20170109&from=EN
[68] http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=564

Table 6: Summary of relevant standards for ecodesign and energy labelling Regulations

Name	Relevance to current review study	Aim of standard	Valid from	Replacing / Expanding standard
EN 61121:2013	Yes	Methods for measuring the performance of electric mains TDs	2013	Supersedes EN 61121:2005
EN 1458-2:2012	Yes	Methods for measuring performance for gas-fired TDs	2012	Supersedes EN 1458-2:2001
EN 60704-2-6:2012 (IEC 60704-2-6:2012)	Yes	Methods for determining airborne acoustical noises for TDs	2012	No
EN 50564:2011 (IEC 62301-1:2011)	Yes	Methods for measuring energy consumption in standby modes (Both electric and gas fired)	2011	No
EN 1458-1: 2012	Yes	Safety requirements for gas fired tumble driers	2012	No
EN 60335-1:2012+A11:2014 (IEC 60335-1:2010+A1:2013+A2: 2016)	No	General safety requirements for electric connections in appliances.	2012 /2014	No
ISO 11469:2016	No	General identification and marking of plastic products	2016	No
EN ISO 1043-2:2011	No	Defines abbreviated terms and symbols for basic polymers used in components	2011	No
IEC TR 62635:2012	Yes	Guidelines for end-of-life information provided by manufacturer/recyclers.	2012	No
EN 50419:2006	No	Marking of electrical and electronic equipment	2006	No
EN 50625-1:2014	Yes	Implementation and effectiveness of WEEE	2014	No
EN 62321	No	Test methods for determining levels of certain substances in electrotechnical products		No
EN 50581:2012	No	Evaluation of electrical and electronic products regarding hazardous substances.	2012	No
EN 61000 (IEC 61000)	No	Electromagnetic compatibility standards		No
EN 62233:2008	No	Measurement methods for EMF produced by household appliances	2008	No
IEC 62430:2009	No	ECD for electrical systems	2009	No

1.4 Review of relevant legislation, standards and voluntary agreements on resource efficiency

Within the past 10 years the awareness of resource depletion has increased, and the ideas of circular economy have been widely accepted as a solution that can improve the resource efficiency. The European Commission published in 2015 a circular economy package that included an action plan to promote circular economy[69]. The areas of actions that are most relevant in connection with ecodesign is the general measures on product design.

Product design is key to facilitating recycling, repair and refurbishment, but also more durable products. All measures hold the potential to reduce the consumption of virgin materials (including critical raw materials) and reduce the environmental burden of products.

To reach better design of products the Commission will:

- *"Support reparability, durability, and recyclability of products in product requirements under the Ecodesign Directive, taking into account specific requirements of different products. The Ecodesign working plan 2015–2017 will identify product groups that will be examined to propose possible eco-design and/or energy labelling requirements. It will set out how ecodesign can contribute to the objectives of the circular economy. As a first step, the Commission will propose requirements for electronic displays, including requirements related to material efficiency."*
- *"Propose the differentiation of financial contributions paid by producers under the Extended Producer Responsibility scheme on the basis of the end-of-life management costs of their products. This provision under the revised legislative proposal on waste creates economic incentives for the design of products that can be more easily recycled or reused."*
- *"Examine options and actions for a more coherent policy framework for the different strands of work on EU product policy in their contribution to the circular economy."*

The Ecodesign Working Plan 2016-2019[70] contributes to the Commissions Circular Economy agenda. The Working plan states that Ecodesign should make a much more significant contribution to the circular economy, and that the Commission in Regulations due for review in the Working Plan period will examine how aspects relevant to circular economy, such as resource efficiency, reparability, recyclability and durability can be taken into account in revised measures. Subsequently the above-mentioned aspects are analysed in all new review studies including for household tumble driers.

The possibilities for establishing requirements supporting the circular economy are also explored in preparatory studies for new product groups.

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[69] https://ec.europa.eu/growth/industry/sustainability/circular-economy_en
[70] Ecodesign Working Plan 2016-2019. COM(2016 773 final

Besides the circular economy work package there is also a number of relevant legislations, standards and voluntary agreements on resource efficiency, which are briefly described below.

M/543 – Material Efficiency

- Resulting from the standardisation mandate M/543 on Material efficiency, several prEN standards have been developed. They are explained in next sections.

prEN 45558

This European Standard is currently under development. The aim of the standard is to develop a method so information on critical raw materials can be exchanged up and down in the supply chain of energy related products. Though, it does not provide any specific method to capture this information. How organisations will capture the data is individually which allow more flexibility.
The standard e.g. allows organisations to

- to assess the use of critical raw materials in energy related products
- to support collection and recycling processes, so the critical raw materials can be extracted End-of-Life
- to use information on critical raw materials in life-cycle management

Furthermore, this standard can support policy makers regarding policy around the import of critical raw materials. It can also prove to be valuable in connection with Ecodesign studies as more information about the materials are available. This can lead to more precise estimations of both the value and impact of critical raw materials in energy related products, but also measures that can improve the recycling of critical raw materials.

prEN 45553

This European Standard is currently under development and deals with the assessment regarding the ability to remanufacture energy related products. The aim is to ensure a general method for assessing the ability to remanufacture energy related products. The aspects considered are among others:

- Assessment of accessibility (Including a formula that can evaluate the accessibility)
- Assessment of the ability to re-/disassemble (Including disassembly sequence, disassembly index, time for disassembly and different formulas)

This standard may allow requirements regarding disassembly in ecodesign as this standard creates a common framework for documenting the disassembly. Without any standard it is difficult for the market surveillance authorities to control such measures.

prEN 45556

This European Standard is currently under development. The aim is to ensure a general method for assessing the proportion of reused components in energy related products. The aspects considered are among others:

- Calculation of reused component index
- Quality assurance (maintain records of previous quality control)
- Marking and Instructions (e.g. ensure traceability of the reused component)

prEN 45557

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 45554

This European Standard is currently under development and deals with methods for assessing the recyclability and recoverability of energy-related products. This standard suggests a horizontal approach for all energy related products. However, the standard also states that a correct assessment can only be done in a product-specific way, taking into account specific parameters of a specific product group. This standard defines a series of parameters which may be considered to calculate product specific recycling and recoverability rates.

The standard provides a general methodology for:

- Assessing the recyclability of energy related products
- Assessing the recoverability of energy related products
- Assessing the ability to access or remove certain components of interest to facilitate better recycling and recovery operations.
- Assessing the recyclability of critical raw materials from energy related

prEN 45555

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.

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.

prEN 50614

This European Standard is currently under development (within the standardisation mandate M/518). The purpose of the standard is to facilitate the preparation for re-use of equipment and support the WEEE Directive. The standards include measures on how to check, clean or perform repair recovery operations, so components of discarded products (waste) are prepared so they can be reused without any other pre-processing. The standard also provides relevant description of quality, safety and environmental requirements that a reuse operator should adopt to ensure safe products for the consumer and also to protect the brand of the product (avoid faulty and dangerous remanufactured products) as consumers still may connect a remanufactured product with the brand of the appliances which not necessarily is the case.

Standard BS 8887-211

This standard focus on design for manufacture, assembly, disassembly and end-of-life processing (MADE) of computing hardware. So, this standard is not related to household appliances but some of the requirements could be used across all electronic products. The standard describes the different types of products that potentially could re-enter the production. Examples of products that can re-enters the production are:

- Non-working products (out-of-the-box)
- Products that needs repair within the warranty period (returned to the OEM)
- Unsold products (factory overstock, demonstration models, “try before buy – offer”
- Return of used products (e.g. lease or “trade-in-offers” – relevant in connection with circular economy)

Standard VDI 2343

This standard is providing a common framework for the different definitions on reuse which is crucial to reach a common understanding on the different definitions. Definitions are also crucial in connection with interpretation of Regulation and without any clear definitions any requirements towards reuse/remanufacturing/refurbishment will be invalidated. In general, refurbishment is not clearly defined in most EU Regulation (e.g. fully refurbishment is defined in the Regulation on medical devices71). The standard defines different levels of reuse such as:

- Repair – restores defective product
- Refurbishing – restores used product to a certain quality
- Remanufacturing – restores used product to 'as good as new' through new and reconditioned components and parts;
- Upgrading – improving the functions/properties of the original product

Definitions are very important in connection with the liability of the product. At which level of repair/reuse is the original manufacturer (brand on the appliance) responsible for the product.

Standard ONR 192102

Standard ONR 192102 is an Austrian standard that establishes a label for electronic products designed for easy repair.

The standard/label established both obligatory requirements that should be followed by anyone claiming the label, but also a set of voluntary requirements. If the also follow the voluntary criteria they are awarded with a score. The score is dependent on the number of criteria the product complies with and an overall reparability score is awarded which are either 'good', 'very good' or 'excellent'.

- Examples of the requirements and criteria are:
- Information relevant for disassembly (e.g. instructions, break down plan)
- Requirements on information for repair (e.g. instructions and exploded views)
- Easiness of disassemble (e.g. possibility of breaking down the product and accessibility to inner parts (cable lengths, space for mounting, welding, screw orientation and size, scale of design)

[71] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L:2017:117:FULL&from=EN

Such standards and labels are very important for both manufacturer designing products for the circular economy, but also regarding requirements. European standard can be developed in line with ONR 192102, which makes any requirements towards improvement resource efficiency (design for easy disassemble etc.) more robust and makes it possible for the market surveillance authorities to control such requirements.

2. Market and stock

2.1 Sales

The MEErP recommends using Eurostat data on production (PRODCOM) and calculate the EU sales and trade as "EU Production + EU import – EU export". However, experience from other studies and also the MEErP guidance document itself, finds the PRODCOM data not very reliable for the analysis of individual products. This also applies to tumble driers, especially for the NACE rev. 2.0, since the PRODCOM categories have a broader scope than the Regulations and the data therefore cannot be used directly to represent the market of products in scope of the Regulations or the study. As the PRODCOM data is still the official source for EU policies, the sales and trade data were collected from the database and shown in this task, but the GfK data will be used for all further calculations and analyses.

The sales volumes of tumble driers within the EU is therefore based on purchased market data from the large international market research institute GfK, who provided point of sales tracking data on tumble driers for 21 countries (see Annex I). The sales and trade data for tumble driers was not available for seven of the EU-28 countries (Czech Republic, Romania, Slovenia, Slovakia, Bulgaria, Cyprus and Malta), representing a total of 9% of the EU population and 3.6% of the gross domestic product (GDP)[72]. Based on the population of these countries and GfKs coverage of each country (see Annex I), an overall EU market coverage of the GfK tumble drier data has been calculated resulting in 78.8%.

The GfK data were scaled to 100% for each of the 21 countries covered by GfK's data collection programme. To achieve a representation of 100% of the EU market, GfK's data were scaled up to cover the total EU market.

GfK collects point-of-sales data on different types of tumble driers, very much in line with the definitions in the Regulation. Data is available on each product type specifically, including data on all label parameters and nominal annual energy consumption for each product type. This level of detail is much higher than the data available from PRODCOM, and therefore only the overall sales are compared between GfK data and PRODCOM data in Table 7.

[72] https://europa.eu/european-union/about-eu/countries_en

Table 7: Comparison of tumble drier sales data from GfK and PRODCOM, shown as million units

Sales, millions	1995	2000	2002	2005	2006	2010	2015	2016
GfK, scaled	-	-	3.91	4.04	4.43	3.99	4.74	5.05
PRODCOM	2.53	3.50	3.60	4.71	5.56	21.05	19.36	18.97
Difference	-	-	3%	15%	23%	136%	121%	116%

As seen in Table 7, the GfK data is not available before 2002[73], which is the first year of comparison. In 2002 the data from PRODCOM was collected according to the NACE Rev 1.1 definitions[74] (see section 1.1.4), and the difference between the two datasets is 93,000 units or 3%. Also, this is the only year in the data set where the GfK data shows higher sales than the PRODCOM data, even though the difference is small. The increasing difference between the two datasets towards 2007 (end of NACE rev. 1.1), is ascribed to the increased quality of collection from Member States in the PRODCOM database, and since the product categories are broader, the PRODCOM sales data is generally higher.

From 2008 and onwards, only the NACE Rev 2.0 data is available, which means only aggregated data for washing machines and driers (including combined washer-driers). Since the penetration rate is larger for washing machines than tumble driers, the majority of the sales are expected to be washing machines which is why the PRODCOM data deviates between 120-140% from the GfK data in the years after introduction of NACE rev 2.0.

It is clear that the data from PRODCOM after 2007 (NACE rev. 2.0) is not at the level of detail required, enough to be used in this study, and neither the PRODCOM datasets offers a detail level down to different tumble drier technologies. Based on data quality and availability, the GfK data is therefore used for the years where it is available (2006-2016), and the PRODCOM NACE Rev. 1.1 data is used from 1995-2005, and from 1990 to 1994 the sales are assumed to be equal to the 1995 sales.

Future sales are based on the yearly sales growth rates calculated from the GfK data over the last 10 years. According to these data, the average sales growth is 0.7% per year for the entire market in EU28.

2.1.1 Sales split and market shares

The purchased GfK data provided the sales split on different tumble drier types for the years 2013 to 2016, which corresponds to the years the ecodesign and energy labelling Regulations have been applicable. The sales data have been corrected for the countries

[73] 2002 and 2005 data from GfK is reported in the preparatory study
[74]Product code 29.71.13.70 “Drying machines of a dry linen capacity ≤ 10 kg”

not included in the dataset (Czech Republic, Romania, Slovenia, Slovakia, Bulgaria, Latvia, Malta) using a weighted average based on population and GfK coverage per country and are shown in Table 8.

Table 8: Household tumble drier sales in Europe 2013-2016, source: GfK (adjusted to EU28)

Sales, million units		2013	2014	2015	2016
Condenser	Heat pump	1.23	1.78	2.22	2.58
	Heat element	1.93	1.79	1.78	1.75
Air-vented	Heat element	0.78	0.73	0.75	0.72
	Gas-fired	0.001	0.001	0.001	0.001
Total		**3.94**	**4.29**	**4.74**	**5.05**

The data shows that the heat pump technology during the four years has become the prevalent in the EU with the market share increasing from 31% in 2013 to 51% 2016. This has been at the expense of the electric heat element tumble driers, both the condenser and the air-vented type. In 2016 the market share of heat element condenser driers was 34%, down from 49% in 2013, whereas the air-vented market share decreased from 20% to 14% in that same period. The gas tumble drier market share is in the range of 0. 1-0. 2% per year, corresponding to less than a thousand units per year.

The total sales increased on average 1.6% per year from 2007 to 2016, but given the otherwise quite stable sales over the years, it is assumed that this sales growth rate will decrease towards 0% per year in 2030. Assumptions were made for the continued development of the market shares for 2025 and 2030 based on the trends seen in the market until now, with linear interpolation of market shares in the years between. This yielded the shares shown in Table 9. The 2005 market split was calculated from the preparatory study data and is assumed unchanged for all years from 1990-2005.

Table 9: Market shares of the four main tumble drier technologies

Sales, %		2005	2010	2015	2020	2025	2030
Condenser	Heat pump	0%	9%	47%	57%	65%	80%
	Heat element	59%	64%	37%	32%	28%	20%
Air-vented	Heat element	41%	28%	16%	11%	7%	0%
	Gas-fired	0%	0%	0%	0%	0%	0%
Total		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

As the preparatory study stated a very low market share of heat pump driers in 2009, the market share was assumed to be 0% in 2005, however the GfK data showed a share of 31% in 2013, and the linear interpolation for the eight years in between is therefore quite steep.

The market split shown in Table 9 together with the total market size result in the sales figures (shown as million units) in Table 10. As seen from the table, the sales of air-vented driers are expected to decrease and be very close to zero by 2030. This is based on the very rapid decrease of the market share of air-vented driers from 2013 to 2016 as well as the large difficulties associated with installing these driers in homes not already equipped with ventilation holes for the exhaust air compared to condensing driers.

Table 10: Derived tumble drier sales from 1990 to 2030

Sales million units		1990	1995	2000	2005	2010	2015	2020	2025	2030
Condenser	Heat pump	-	-	-	-	0.34	2.22	3.05	3.60	4.46
	Heat element	3.55	3.55	3.44	2.38	2.54	1.78	1.68	1.55	1.11
Air vented	Heat element	0.14	0.14	1.06	1.66	1.11	0.75	0.59	0.39	-
	Gas-fired	0.001	0.001	0.001	0.001	0.001	0.000	0.001	-	-
Total		**3.70**	**3.70**	**4.50**	**4.04**	**3.99**	**4.74**	**5.32**	**5.53**	**5.57**

2.1.2 Sales values

Both the PRODCOM database and the GfK database provides data on value of the EU tumble drier market, however while GfK shows the retail prices, PRODCOM shows the wholesale prices. The comparison can therefore only be made on the trends, and not on the absolute values. As PRODCOM data does not differentiate between drier types, the comparison between the data sets will be made on the entire EU tumble drier market. The market value comparison is shown in Table 11.

Table 11: Tumble drier market values

Market values, million EUR	1995	2000	2005	2006	2010	2015	2016
GfK market value	-	-	-	1,659	1,704	2,260	2,354
PRODCOM market value	518	795	851	995	4,889	4,883	4,897

The market value according to PRODCOM has a significant increase of almost a factor 5 from 2006 to 2010, which is however not true, but is caused by the changing categorisation (from NACE V1.1 to V2.0) and the fact that the market data for washing machines and tumble driers is aggregated in one category from 2008 (see chapter 1.1.4).

Based on the sales and market values in Table 10 and Table 11, the average unit prices of tumble driers can be derived as shown in Table 12. The GfK prices are again retail prices, whereas the prices derived from PRODCOM are wholesale. There is only one year of overlap between the GfK dataset and the PRODCOM NACE 1.1 database, which is year 2006. In this specific year the mark-up factor can be estimated by dividing retail (GfK) price with the wholesale (PRODCOM) price, yielding a mark-up of 2.1.

Table 12: Average unit price of tumble driers in EU

Unit prices, EUR	1995	2000	2005	2006	2010	2015	2016
GfK unit price	-	-	-	375	427	475	464
PRODCOM unit price	205	227	181	179	232	252	258

2.2 Stock

The stock of tumble driers in Europe is determined based on the sale and a normal distribution of the expected lifetime of tumble driers.

2.2.1 Lifetime

In the preparatory study, it was determined that the lifetime of tumble driers was 13 years on average, with a deviation of 1.78[75]. Other sources generally confirm this number; however, 13 years is in the high end of the reported lifetime, which ranged from 8 to 14 years[76]. According to CECED and Umwelt Bundesamt[77], the lifetime is around 12 years and it is therefore suggested to adjust the average lifetime from the preparatory value of 13 years, to 12 years with a standard variation of 2 years. This will be used for all types of tumble driers.

2.2.2 Tumble drier stock

The stock of tumble driers in the EU is calculated based on the sales figures described in chapter 2.1, and the expected lifetimes described previously, shown in Table 13.

[75] Preparatory study of Ecodesign for Laundry Dryers, PriceWaterhouseCoopers, 2009.
[76] http://homeguides.sfgate.com/average-life-frontloading-drier-102084.html and https://www.mrappliance.com/expert-tips/appliance-life-guide/ and https://www.hunker.com/13410811/lifetime-of-driers and https://www.hrblock.com/tax-center/lifestyle/how-long-do-appliances-last/ and http://www.wisebread.com/this-is-how-long-these-6-appliances-should-last
[77] https://www.umweltbundesamt.de/en/publikationen/einfluss-der-nutzungsdauer-von-produkten-auf-ihre-1

Table 13: Average expected lifetime and assumed variations used in the stock model

Tumble drier type		Average lifetime	Standard variation
Condenser	Heat pump	12	2
	Heat element		
Air-vented	Heat element		
	Gas-fired		

A normal distribution of the lifetime was applied based on the lifetime (as the mean) and standard variation from Table 13 (as the variation) and multiplied with the sales volume for each tumble drier type each year, which yielded the total EU stock shown in Table 14. This calculated stock can be used to estimate be penetration rate of household tumble driers by dividing with the total amount of household in EU28 from EUROSTAT[78]

Table 14: Stock of tumble driers in EU from 2000 to 2030, penetration rate from 2010 to 2030.

Stock, million units		2000	2005	2010	2015	2020	2025	2030
Condenser	Heat pump	0.00	0.00	0.44	7.27	21.18	34.89	44.66
	Heat element	24.82	29.38	31.26	29.09	25.17	21.45	18.78
Air-vented	Heat element	17.31	20.71	19.61	15.16	10.67	7.63	4.73
	Gas-fired	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Total		**42.15**	**50.10**	**51.32**	**51.53**	**57.03**	**63.98**	**68.18**
Penetration rate		**NA**	**NA**	**25.0%**	**24.2%**	**25.8%**	**27.7%**	**28.3%**

When looking at the sales and the stock in a compiled graph (Figure 17), it is seen that the sales (and thus stock) increase over time, resulting in a total stock of around 68 million by 2030 compared to 50 million in 2016. With a total number of households in the EU-28 of 214 million in 2016[79], this gives a penetration rate of 24.5%, which is lower than the assumed penetration rate of 36% from the preparatory study[80]. The sales and stock will be used in subsequent tasks to estimate annual energy consumption.

[78] http://ec.europa.eu/eurostat/statistics-explained/index.php/Household_composition_statistics_ Available data from 2009 to 2017. Data from 2018 to 2030 have been projected linearly.
[79] http://ec.europa.eu/eurostat/statistics-explained/index.php/Household_composition_statistics
[80] Prep study page 405

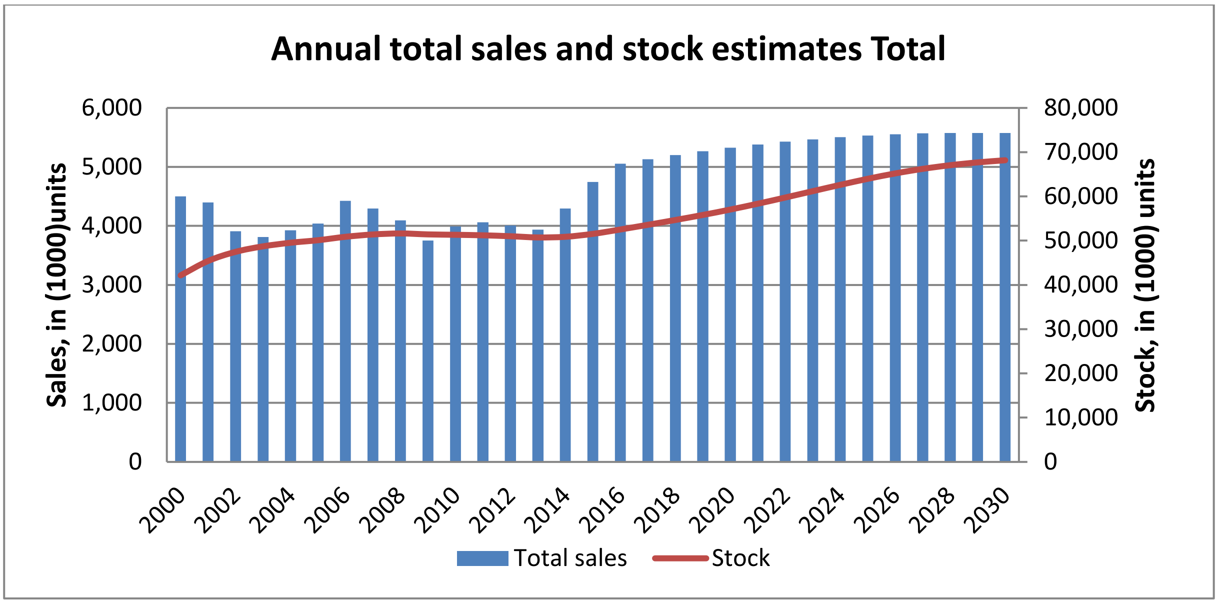


Figure 17: Annual sales and stock of tumble driers (total of all types)

2.3 Market trends

2.3.1 Sales trends

Prior to 2006, where only PRODCOM data is available, the total sales ranged between 3.5 million and 4.4 million. Even though the sales fluctuate from year to year, and overall growth rate of 1.6% p.a. from 2006 to 2016 is seen. This growth rate is expected to go linearly towards 0% until 2030.

The overall increase in sale numbers since 2010 has been dominated by heat pump tumble driers, while all other technologies have decreased in sales numbers. The gas drier sales fluctuate, but since they make up only 0.01% of total sales (2013 to 2016), this has no influence on the total market. Both the air-vented and heat element condenser driers have decreased each one by roughly 1 million units in sales over the last 10 years, the air-vented from 1.7 to 0.7 million units and the heat element condenser from 2.7 to 1.7 million units. In the same period the sale of heat pump condenser driers has increased from less than 100 thousand units to 2.6 million units.

2.3.2 Product trends

This section contains an analysis of the product trends since introduction of the Regulations in 2013. The parameters included in the label are analysed in order to get an overview on the product trends. This is done based on data collected by GfK from 2013 to 2016.

Energy efficiency class

The label distribution of the different tumble drier technologies and their development over 2013 to 2016 can be seen in Figure 18, Figure 19, Figure 20, and Figure 21 for all tumble drier types, heat pump condenser driers, condenser driers, and air-vented driers respectively.

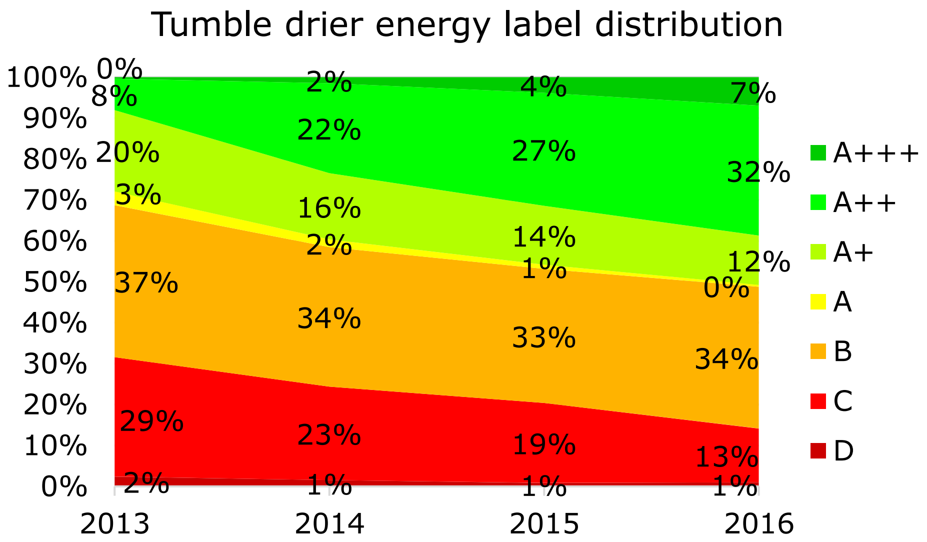


Figure 18: Energy class distribution and development for all tumble driers, 2013-2016

Figure 18 shows the energy class distributions for all types of sold tumble driers from 2013 to 2016. The overall trend is a transition towards more efficient driers as the market shares of D, C, and B, A, and A+ driers are decreasing, while A++ and A+++ dries are increasing.

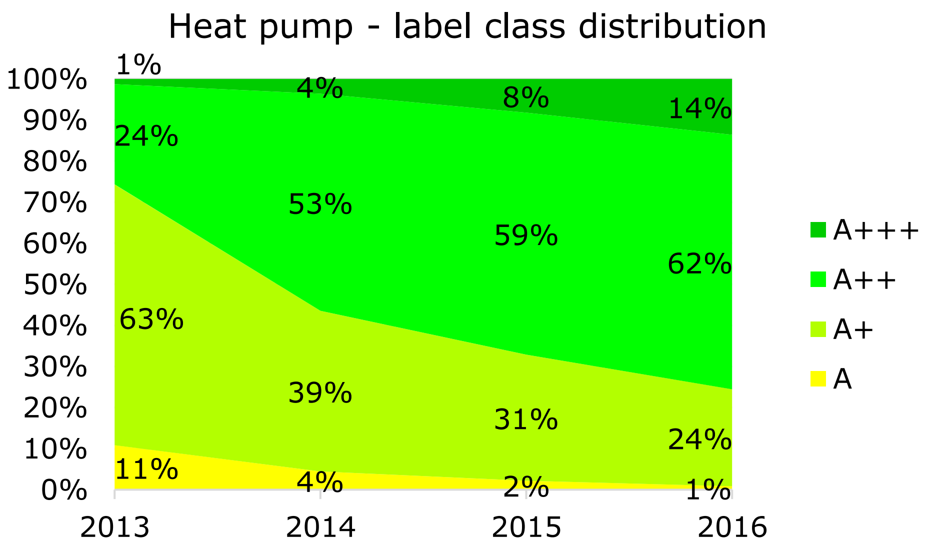


Figure 19: Energy class distribution and development for heat pump tumble driers, 2013-2016

The heat pump condenser driers covered by GfK data are all A energy class and above, with A and A+ labelled driers constituting the largest share on the market in all years. The distribution shows a shift with an increasing trend for A++ and A+++, and a decreasing trend for A and A+. The share of A+++ machines is still quite low (14%) compared to A++ (62%).

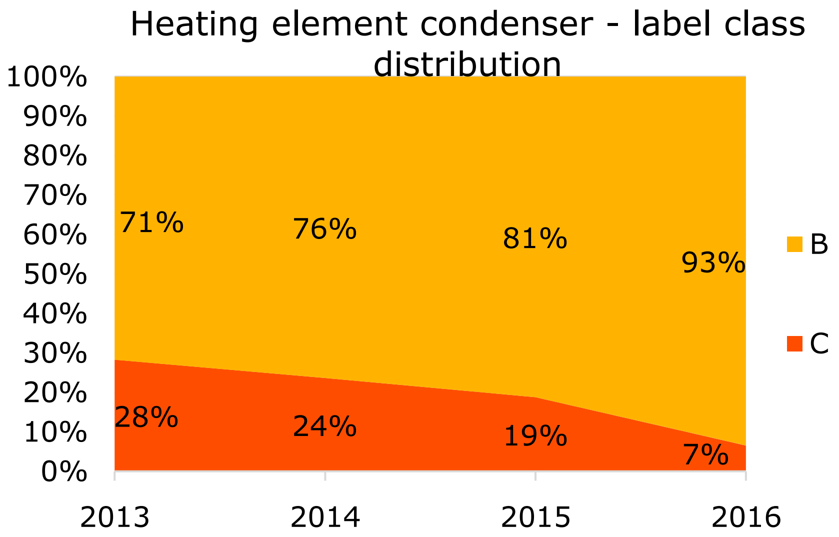


Figure 20: Energy class distribution and development for heating element condenser tumble driers, 2013-2016

The heating element condenser driers covered by GfK data are all in the label class B or C, with B labelled driers constituting the market majority. The market dominance of B labelled driers was reinforced over the four years from 2013 to 2016, with the share increasing from 71% to 93%, and the C labelled driers simultaneously decreasing, primarily due to the C class being prohibited from being placed on the market after November 1st 2015 due to the ecodesign requirements.

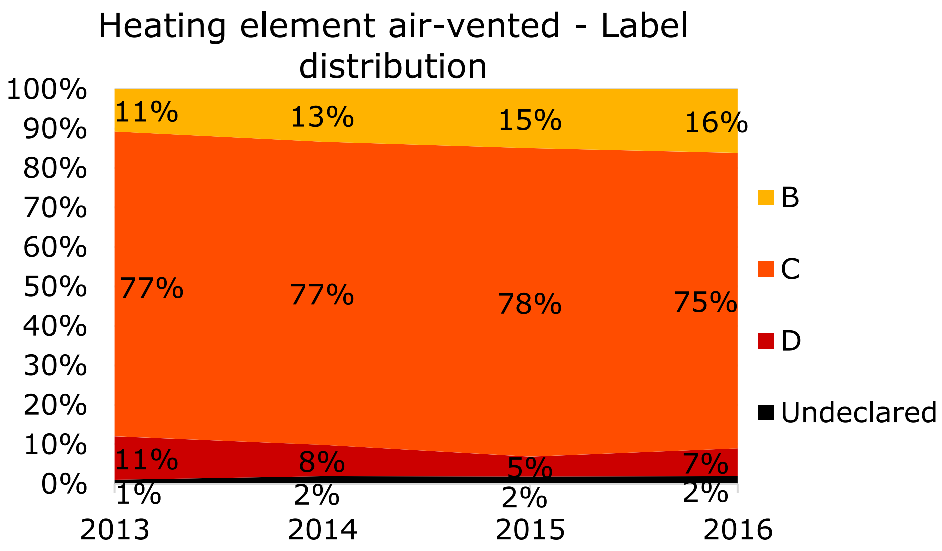


Figure 21: Energy class distribution and development for heating element air-vented tumble driers, 2013-2016

The heat element air-vented driers covered by GfK data are the least efficient in the market with energy classes ranging from B to D (the lowest on the current label). The majority (>75%) of air-vented driers are in label class C in all four years, but the share of B labelled driers has slightly increased from 2013 to 2016 from 11% to 16% at the cost of D labelled driers. The share of air-vented driers on the market in class D decreased in 2014 and 2015 due the first tier of ecodesign requirements, which did not allow driers in energy class D on the market from 1st November 2013. However, the effect is not as apparent as with the condenser driers, and air-vented driers in class D still constitutes a relatively large share of the market in 2016. The energy label distribution shows that heating element air-vented driers have had a minor improvement in energy efficiency compared to condenser driers shown in Figure 19 and Figure 20.

Data were not available for gas-fired tumble driers, but based on information from GfK, it was possible to track from a desktop research three of the models on the EU market which have 63% of the market share. Two of these three models (covering 61% of the market) feature an A+ energy class and the other features a C energy class. Gas-fired air-vented driers on the market are thus able to reach a higher energy class than the heating element air-vented drier.

Annual Energy consumption

Figure 22, Figure 23 and Figure 24 show distribution of the Annual Energy consumption (AE_C) for sold tumble driers during the years 2013-2016 for heat pump, condenser and heat element air-vented tumble driers respectively.

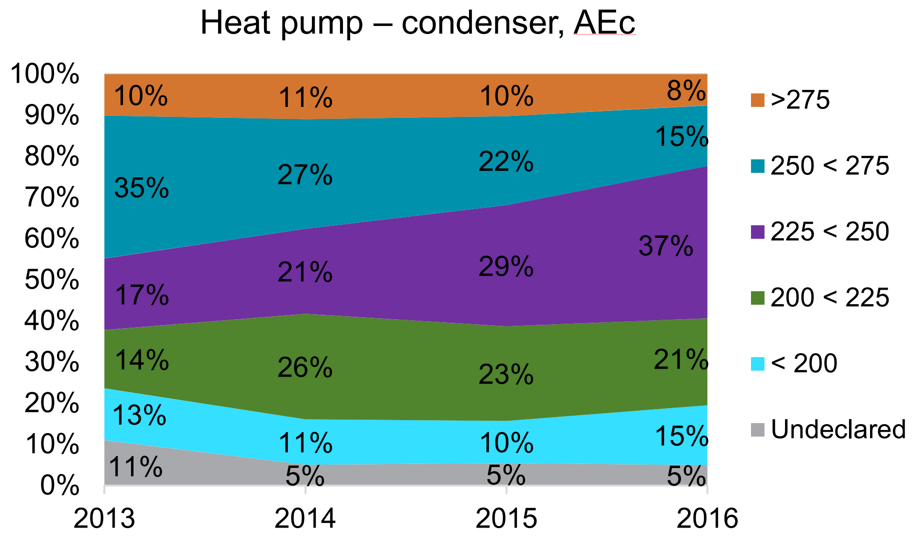


Figure 22: Distribution of annual energy consumption for the heat pump tumble driers from 2013 to 2016

The heat pump tumble drier AEc distribution shows a slow trend with a declining weighted average AEc in the four-year period, where the top highest energy consumption brackets are getting smaller and the one in the middle is getting bigger, resulting in AEc of 246 kWh/year in 2013 and 233 kWh/year in 2016.

The three lowest intervals, '<200' and '220-225', and '225-250' kWh/year, have all made an overall increase in market share from 2013 to 2016. Oppositely, the driers in the >250 kWh/year intervals steadily decreased. The >275 kWh/year interval showed no consistent trend, but the highest consuming machines above 400 kWh/year decreased and those over 500 kWh/year vanished entirely from the market (not shown here due to very low market shares).

Overall the market share of the three lowest AEC intervals (<250 kWh/year) increased from 44% to 73%, and the sales-weighted average AE_C of heat pump tumble driers decreased from approximately 246 kWh/year in 2013 to 233 kWh/year in 2016.

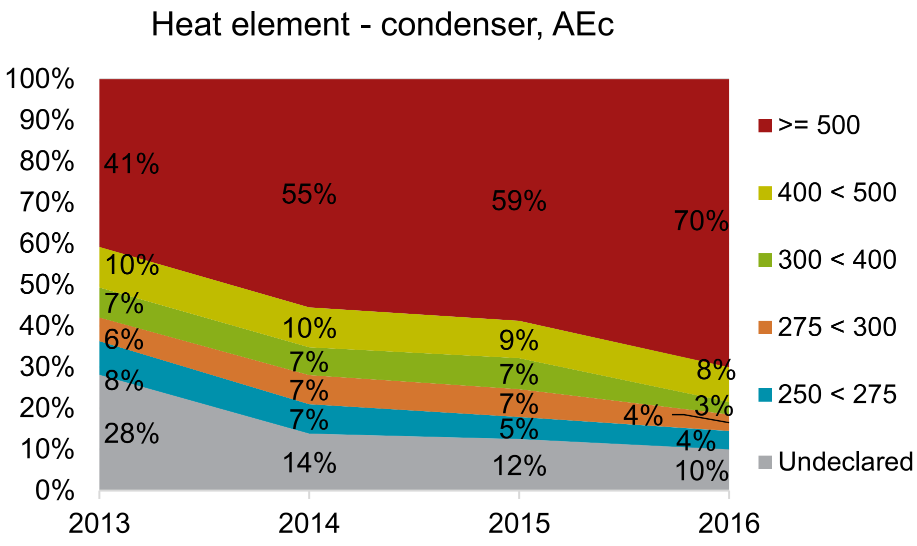


Figure 23: Distribution of annual energy consumption for heat element condenser tumble driers from 2013 to 2016

For tumble driers with heating element and condensing technology, the opposite development than for heat pumps is seen. The share of low AEC tumble driers decreased from 2013 to 2016, whereas the share of 500+ kWh/year increased.

Regarding the sales-weighted energy consumption, the data show a steady increase from 461 kWh/year in 2013 to 506 kWh/year in 2016.

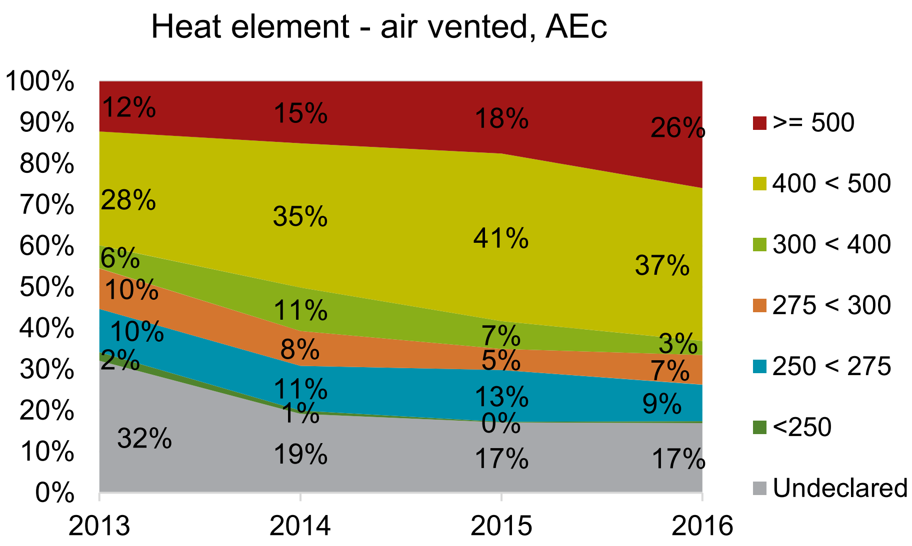


Figure 24: Distribution of annual energy consumption for heat element air-vented tumble driers from 2013 to 2016

Only very low shares of heat element air-vented driers are in the intervals <250 kWh/year. The majority is in fact in the highest consumption intervals >400 kWh/year. The share of heat element air-vented driers with AEc >500 kWh/year increased in market share. The average AEc increased from 402 kWh/year in 2013 to 436 kWh/year in 2016.

The same three gas-fired air-vented tumble driers models previously investigated in terms of the energy efficiency class were tracked in a desktop research, where the model covering 54% of the EU market[81] consumes 256 kWh/year (in gas) by the time of the data gathering (March 2018), the other model covering 7% of the market consumes 261 kWh/year and the last consumes 459 kWh/year. The first two models have a rated capacity of 7 kg, and the last one of 6 kg.

Even though both tumble drier types equipped with heating elements showed an increase in annual energy consumption, it might not be because of a general reduction in energy efficiencies. The annual energy efficiency is calculated based on the rated capacity (see section 3.1 for details on calculating the AEc), which on average is increasing (cf. Figure 33) and is thus influencing the depicted AEc distributions. Figure 19, Figure 20, and Figure 21 show that all drier types have improved in energy efficiency from 2013 to 2016, so the increase in AEc thus originates from the increase in capacity, which is larger than the increase in energy efficiency.

Condensation efficiency

The graphs below show the market distribution of condensation efficiency classes from 2013 to 2016. Both heat pump and heat element condenser driers all have condensation efficiencies in from class C or above, showing all a minimum efficiency of 70% which is the lower limit for class C (and which is Tier 2 ecodesign requirement).

Both technologies have a high market share of products for which the condensation efficiency is not declared according to GfK data, even though this share is decreasing. This amounts to 36%/8% and 67%/45% for years 2013/2016, for heat pump driers and heating element condensing driers respectively. This is especially a problem for heat element condenser driers where the not declared market share is dominating the market. A small portion of this could be due to wrong declaration from the retailers who the data is collected from, however since such large shares is only seen for this parameter, it seems unlikely.

[81] WhiteKnight ECO43

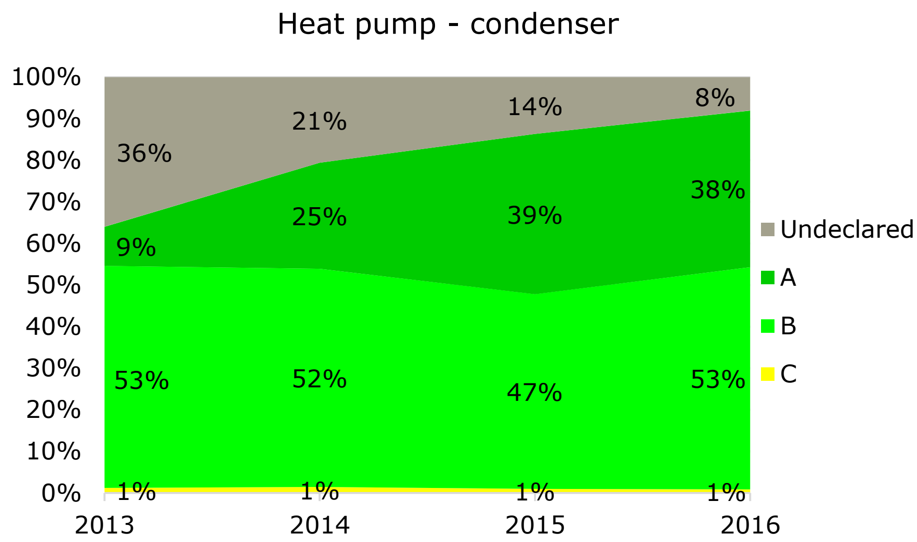


Figure 25: Condensing efficiency label class distribution for heat pump tumble driers, 2013-2016

The heat pump tumble driers are primarily class B and A. The share of A labelled products increased from 9% in 2013 to 38% in 2016, while the B labelled products declined from 53% in 2013 to 47% in 2015 but increased to 53% again in 2016. This is most likely because of the share of products that did not declare the condensation efficiency in the earlier years (decreased from 36% in 2013 to 8% in 2016), which affects the percentages. The heat pump driers with label C condensation efficiency stayed at 1% from 2013 to 2014.

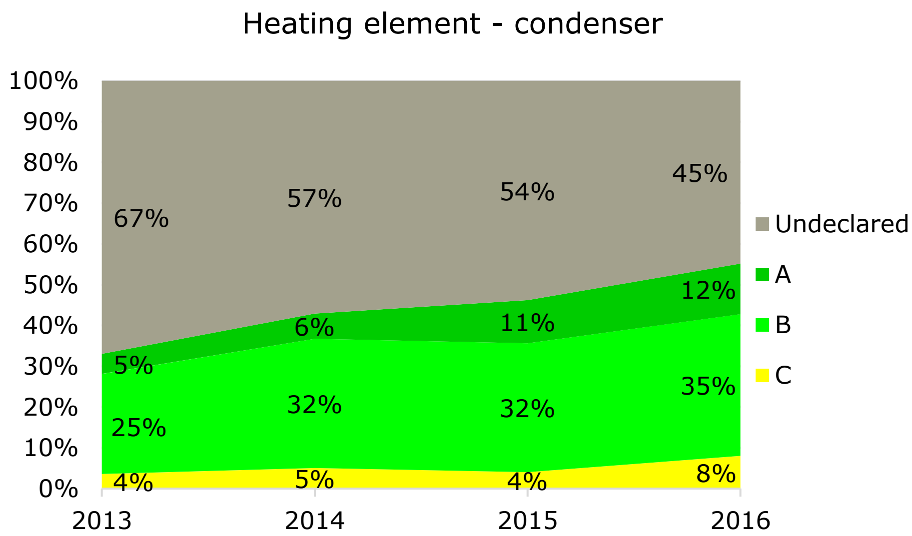


Figure 26: Condensing efficiency label class distribution for heat element condenser tumble driers, 2013-2016

For condenser driers with heat element, those with "not declared" condensation efficiency makes up the majority of the market: 67% in 2013 and 45% in 2016. When looking at the products that are in fact labelled, the largest share of the condenser drier market is class

B. The share of products in class A, B and C are all increasing, but it is not certain whether this is due to a market change or the share of not declared declining.

Low power modes

Two different low power modes exist: off mode, in which the drier is effectively turned off without any kinds of displays being active, and left-on mode, which is activated when the drying cycle is complete. The power consumption is shown in

Figure 27. The majority of available driers have 0W off-mode consumption, while the majority of driers have left-on mode consumption higher than 0.5W

The left-on mode duration is shown in Figure 28. Some tumble driers have no left-on mode at all, and for the majority of tumble driers the duration is below 10 minutes.

Note that

Figure 27 and Figure 28 are based on the APPLiA model database[82], and not on sales data. The figures are thus showing the distributions for the models available for sale on the market, and not real sales weighted values. They are thus not representative for the EU28 market and can only be used as an indicative figure.

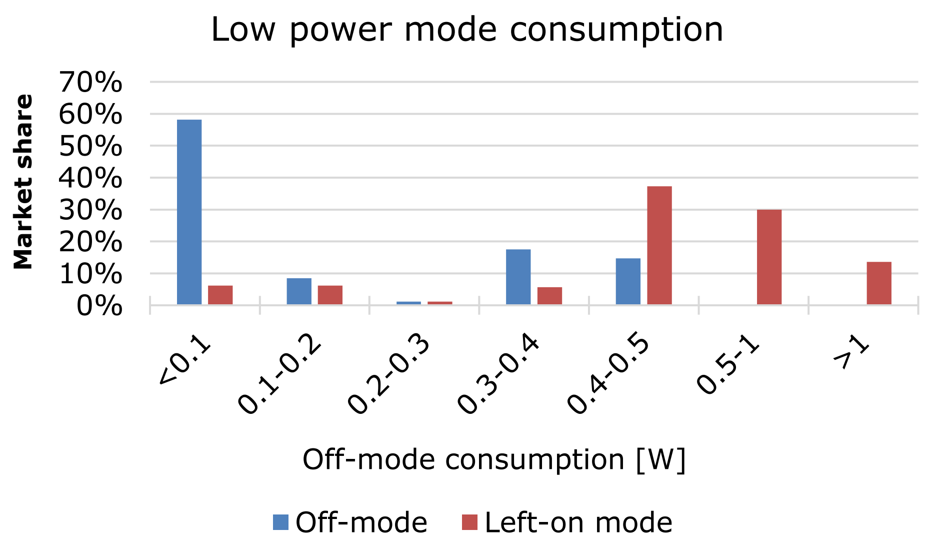


Figure 27: Power consumption in off-mode and left-mode[82]

[82] *Source: APPLIA 2016 model database*

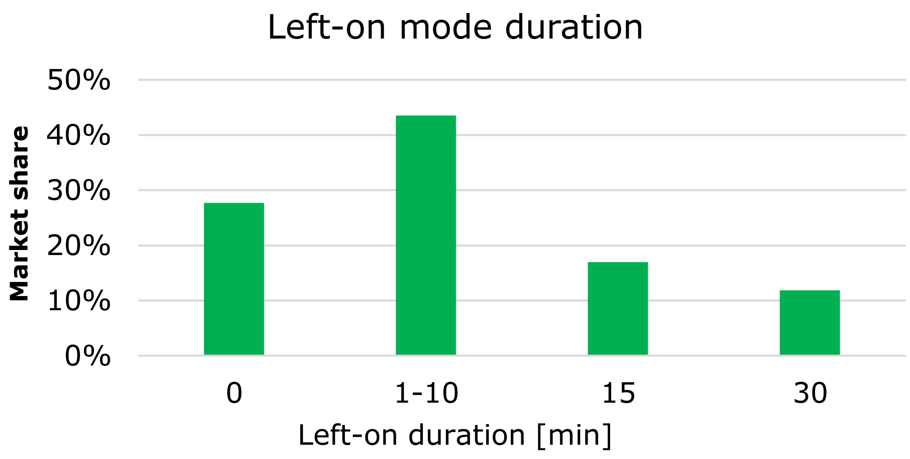


Figure 28: Left-on mode duration[82]

Rated capacity

The rated capacity is stated on the energy label and used in the EEI calculations, but there is no ecodesign requirement for this parameter. The rated capacity is the stated maximum mass in kilograms that can be dried in the tumble drier in the standard cotton programme at full load. The heat pump tumble driers which now constitute the largest share of the market, have a tendency for increasing capacity as seen in Figure 29.

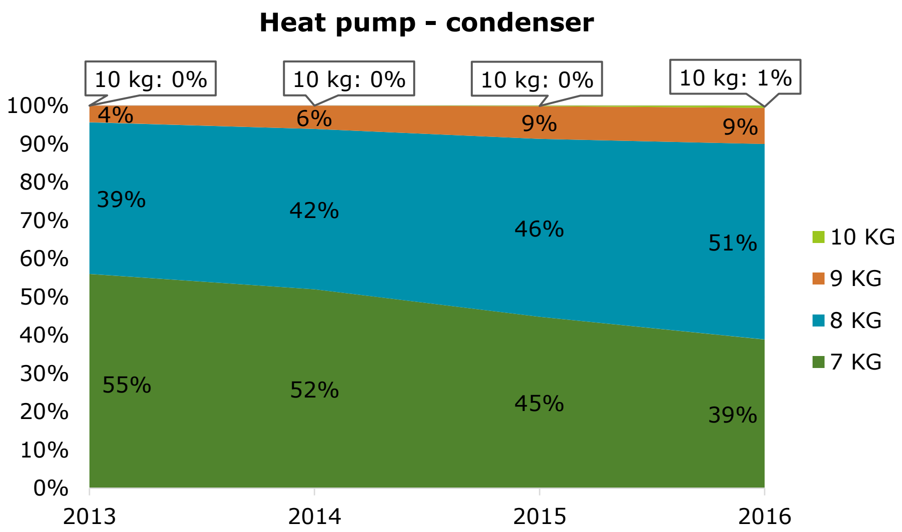


Figure 29: Market distribution of rated capacity for heat pump condenser tumble driers, 2013-2016

The heat pump tumble driers mostly have a rated capacity of 7 or 8 kg, with and increasing trend of 8 and 9 kg machines while 6 and 7 kg machines are decreasing in the market.

A small increase in rated capacity is seen for heat element driers, both condensing and air-vented (see Figure 30 and Figure 31). For air-vented driers there are less 8 kg appliances on the market in 2016, but still the average capacity showed a small increase from 6,4 kg in 2013 to 6,6 kg in 2016.

The heat element condenser driers are, to a large extent, similar to heat pump driers, except that the 7 kg machines are predominant. For heat element air-vented driers, the 6 kg machines also have a large market share, but are declining in favour of 7 kg machines.

The gas drier market is the only one for which the rated capacity shows a declining trend, and even though the 7 kg machines are dominant, the share of <5 kg machines is increasing, while gas driers with all other rated capacities are not present on the market.

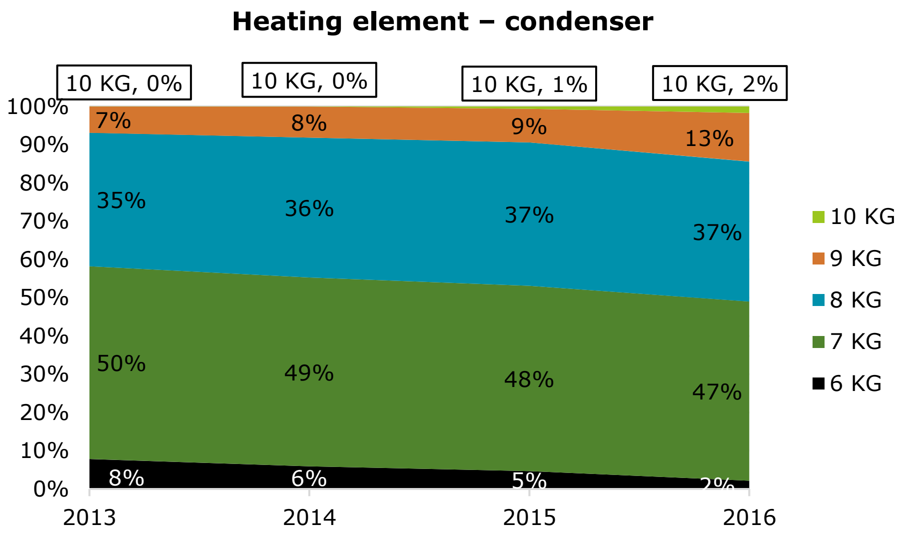
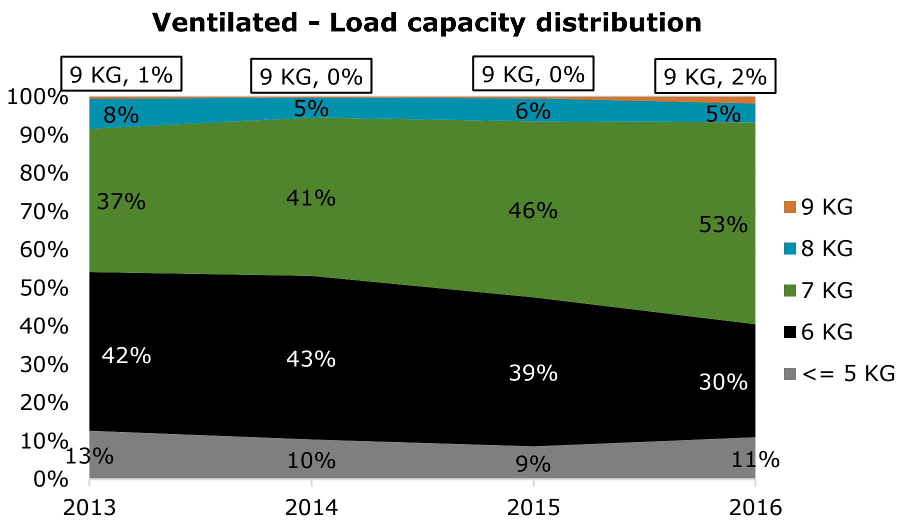


Figure 30: Market distribution of rated capacity for condenser tumble driers, 2013-2016



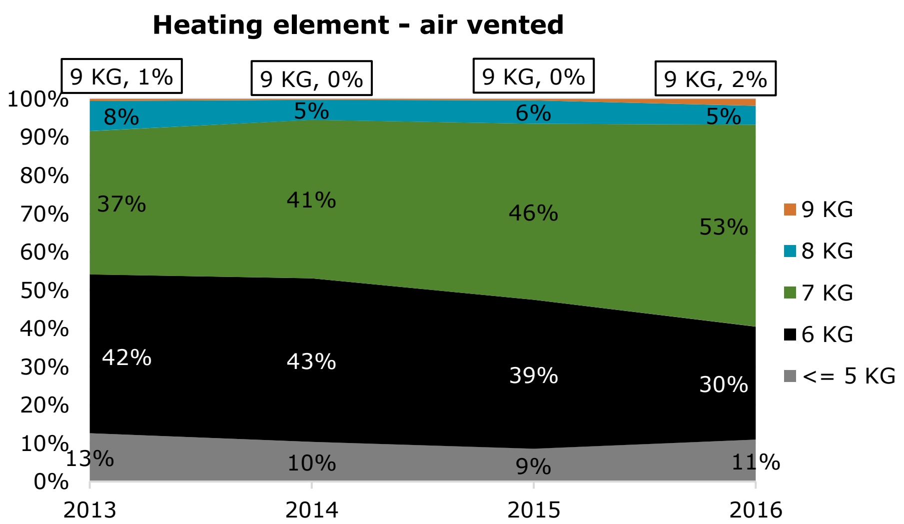


Figure 31: Market distribution of rated capacity for air-vented tumble driers, 2013-2016

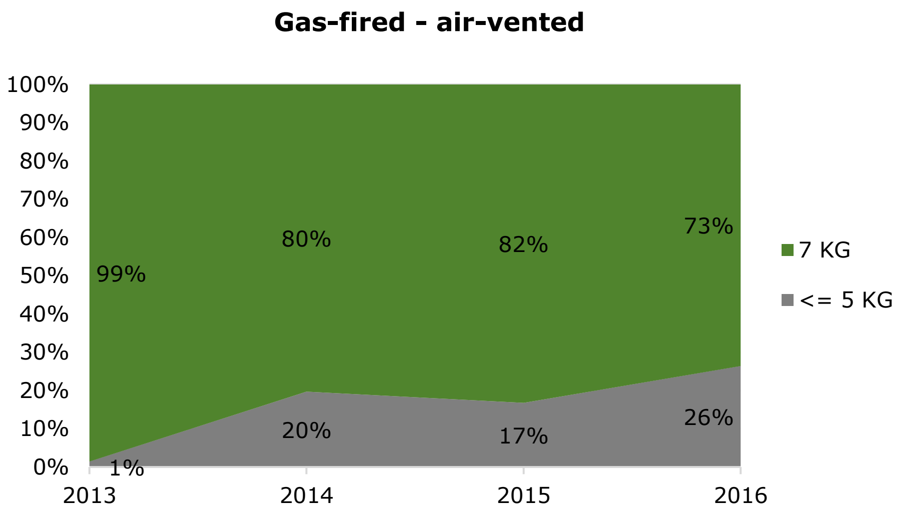


Figure 32: Market distribution of rated capacity for gas tumble driers, 2013-2016

Summarizing the figures above with sales-weighted averages of non-gas tumble drier types and using them to establish a linear projection towards 2030, a general trend can be seen in Figure 33. It shows that these are increasing in size and if this trend continues, the average size of condenser driers and air vented driers will be 8.9 kg and 7.5 kg respectively, based on this correlation. For reference, the average nominal capacities reported in the preparatory study were 4.9 kg in 2002 and 5.4 kg in 2005 respectively.

The increasing average nominal capacity of tumble driers follows the same trend as the washing machines', where models with capacities up towards 13 kg have entered the EU market. The average nominal washing machine capacity was 7.0 kg in 2013 and 7.2 kg in 2014. This is thus lower than the tumble driers.[83]

[83] Ecodesign and Energy Label for Household Washing machines and washer dryers – Preparatory study, final report, JRC, 2017, Table 2.15

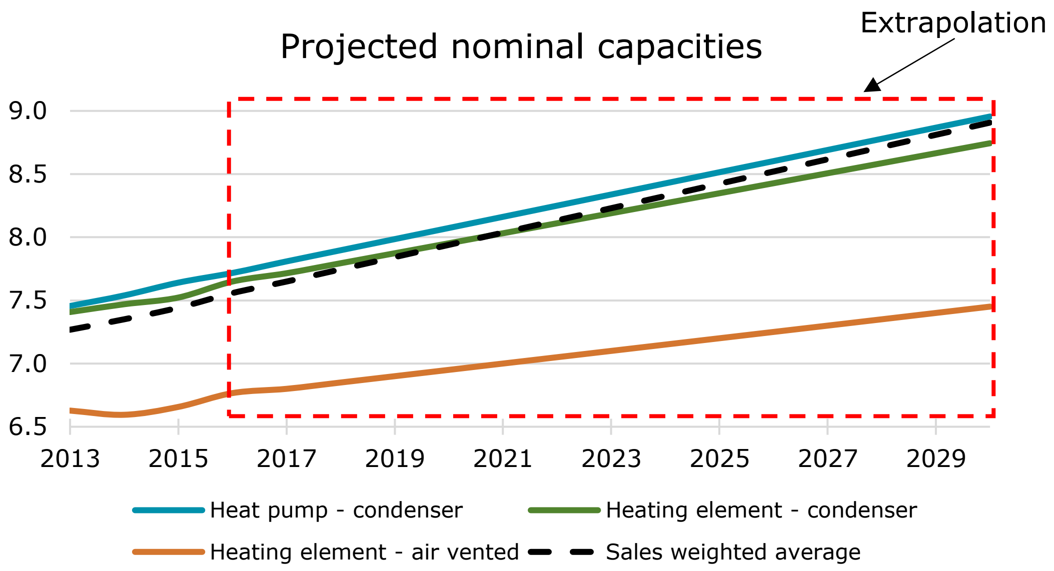


Figure 33: Sales-averaged rated capacity for all non-gas tumble driers (values in the red box are linearly projected)

Cycle time

The cycle time declared on the energy label is the duration of the standard cotton programme at full load, excluding any delay (timer) set by the end user. There is no specific ecodesign requirement for the cycle time.

The market distribution for all technologies is largely unchanged, except for those where the "not declared" share is decreasing, which causes other categories to increase.

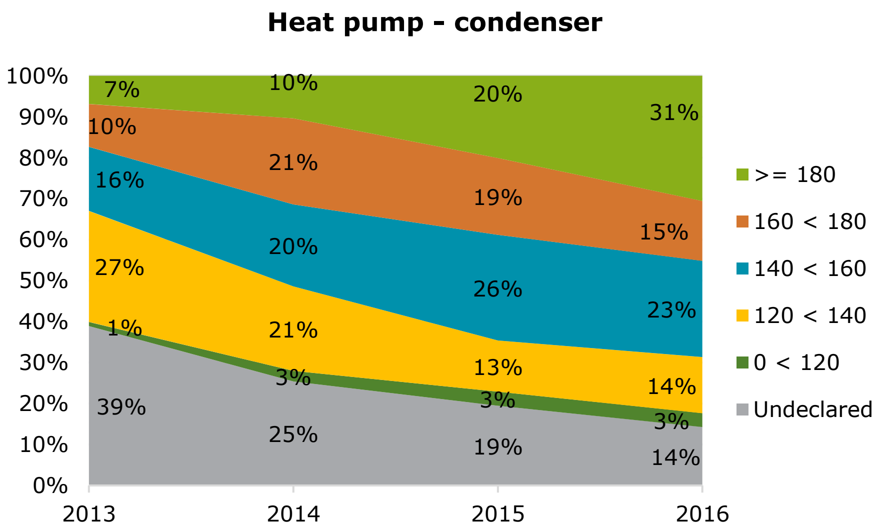


Figure 34: Cycle times in minutes of heat pump driers, 2013-2016

For heat pump driers (Figure 34), the majority of the market in 2016 had cycle times above 180 minutes, while in 2013 the majority (of declared machines) had cycle times between

120 and 140 minutes. However, since the 140-160 minutes market share has increased and the 160-180 has simultaneously decreased, there is no overall trend to the cycle time.

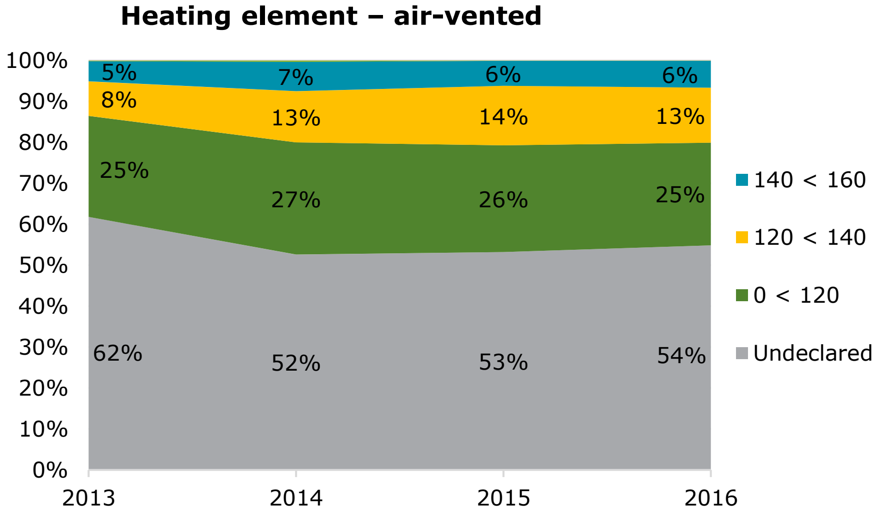


Figure 35: Cycle times of air-vented driers, 2013-2016

For the air-vented driers (Figure 35) there is almost no change in the market from 2013 to 2016, and the "not declared" share continues to be more than 50%.

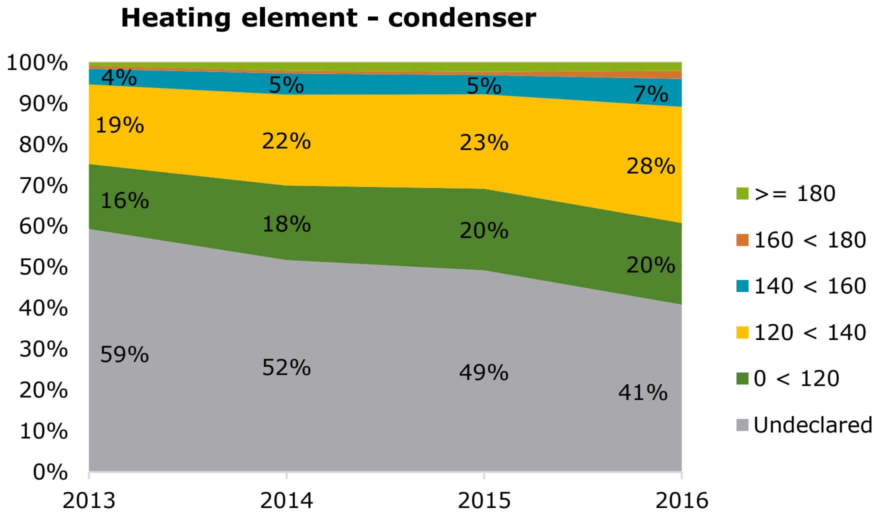


Figure 36: Cycle times of heat element condenser driers, 2013-2016

For the condenser driers (Figure 36), the not-declared share is very high, but declining from 2013 to 2016. It seems that the share of machines in all of the cycle time intervals increase, as "not declared" decreases, hence it is not possible to see a market development from the data.

This is not the case for gas-fired air-vented driers, where the majority of the driers covered by GfK data do not declare cycle time thus no trend is possible to identify (Figure 39).

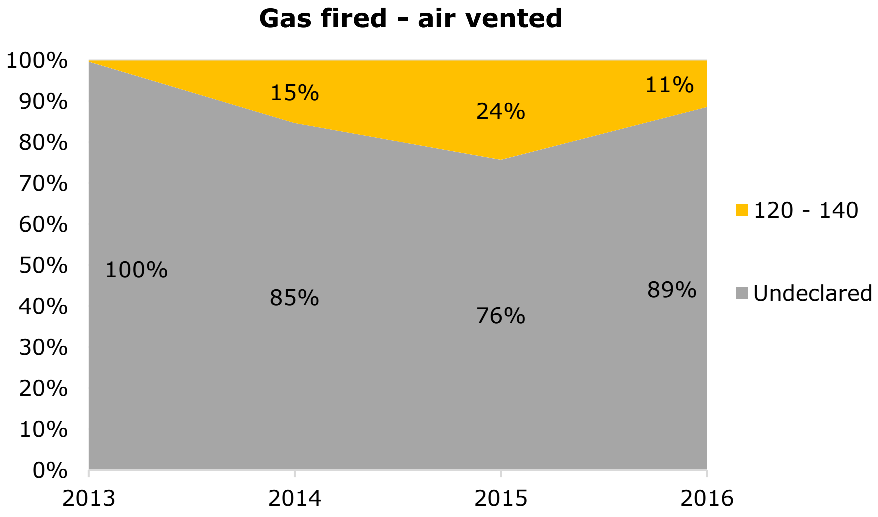


Figure 37: Cycle times of gas driers, 2013-2016

Noise

The Ecodesign Regulation does not set any specific requirements for the sound power level, but it is required to be shown on the label as a value in dB. The sound power level is based on the standard cotton programme at full load. There seems to be no general trend in sound power level for any of the drier technologies.

For heat pump tumble driers (Figure 38), the largest market share has a noise level of 65 dB, even though it is decreasing, while the market share of driers with noise level 66 dB is increasing. The least noisy heat pump driers (<63 and 64 dB) increased from 2013 to 2016, but the market share is still low, and the trend is not unambiguous.

The air-vented driers (Figure 39) mostly have a sound power level >66 dB, or it is nor declared. The market share of machines with noise level 66 dB or below, is roughly unchanged from 2013 to 2016.

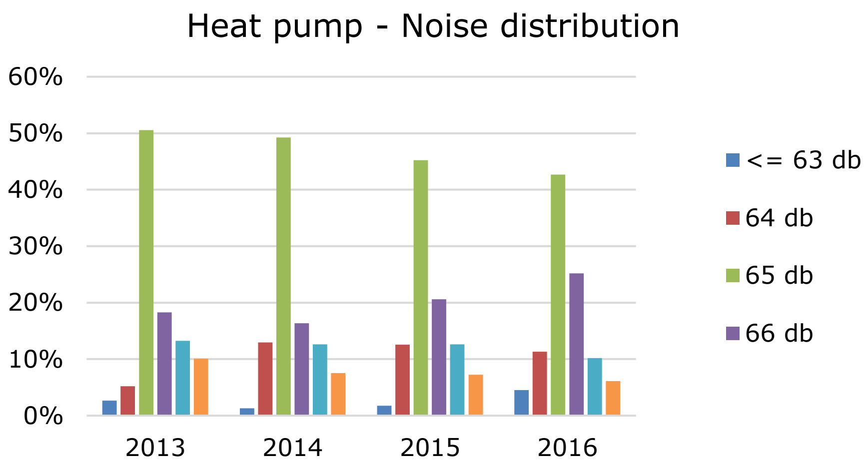


Figure 38: Heat pump driers noise distribution, 2013-2016

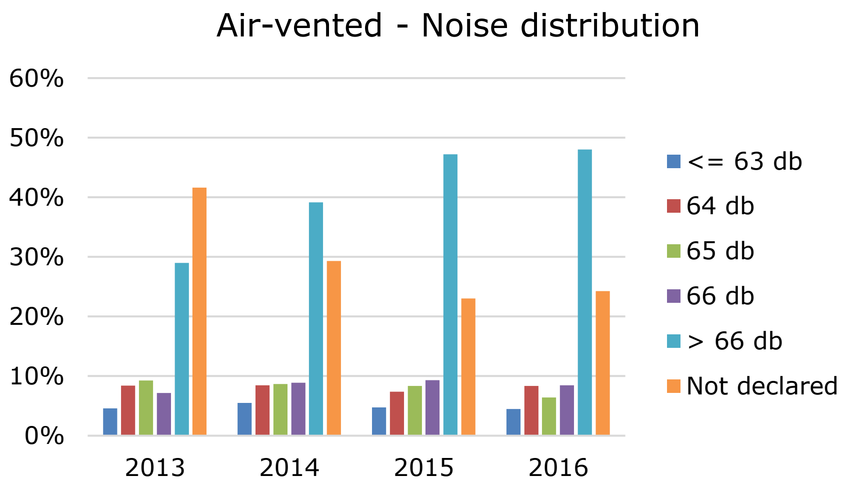


Figure 39: Air-vented driers noise distribution, 2013-2016

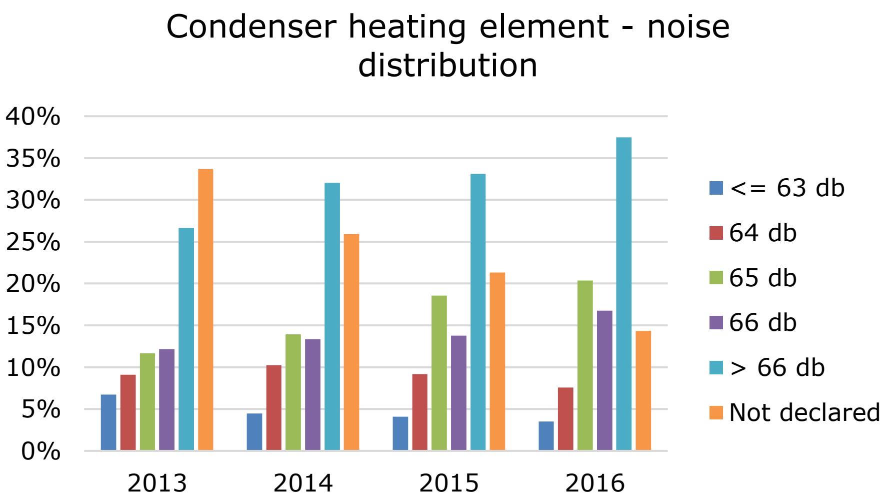


Figure 40: Condenser heating element driers noise distribution, 2013-2016

For the condenser driers (Figure 40) the majority of the market is also driers with >66 dB sound power level, and it has continuously increased, while the not declared share decreased from 2013 to 2016. The share of driers with sound power levels 65 and 66 dB also increased, while the <63 and 64 dB driers decreased.

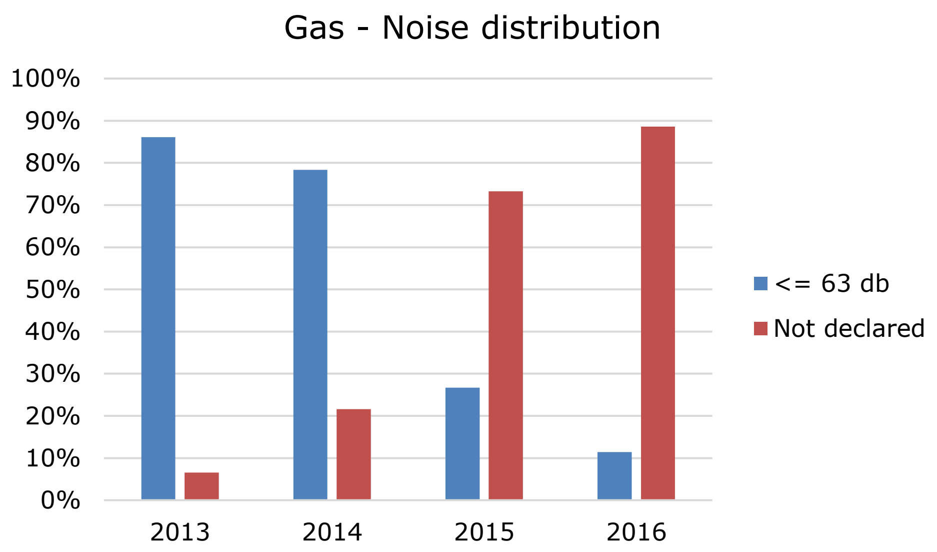


Figure 41: Gas driers noise distribution, 2013-2016

The data for the gas driers (Figure 41) is very limited due to the very low market share of this technology and the only sound power levels with data points is the <63 dB category. The rest was labelled as "not declared" in the data provided by GfK, which increased significantly from 7% to 89% from 2013 to 2016. The share of gas driers for which the sound power level is known is thus only 11% for 2016.

2.3.3 Future impact of ecodesign requirements on air-vented driers

Looking at the predicted sales figures and stock values for air-vented driers in Table 9 and Table 14 respectively, it is clear that existing market forces are regulating the market towards using condenser driers instead of air-vented. This might nullify the effects of new ecodesign Regulations on these types of driers, as they are gradually being removed from the market on a voluntary basis.

Using the GfK data and stock calculations done in sections 2.2.2, and assuming a 10%[84] reduction of annual energy consumption (AEc) can be achieved in all air-vented driers sold after 2020, the total energy consumption reduction of air-vented driers can be seen in Figure 42.

[84] 10% was used as an indicative figure

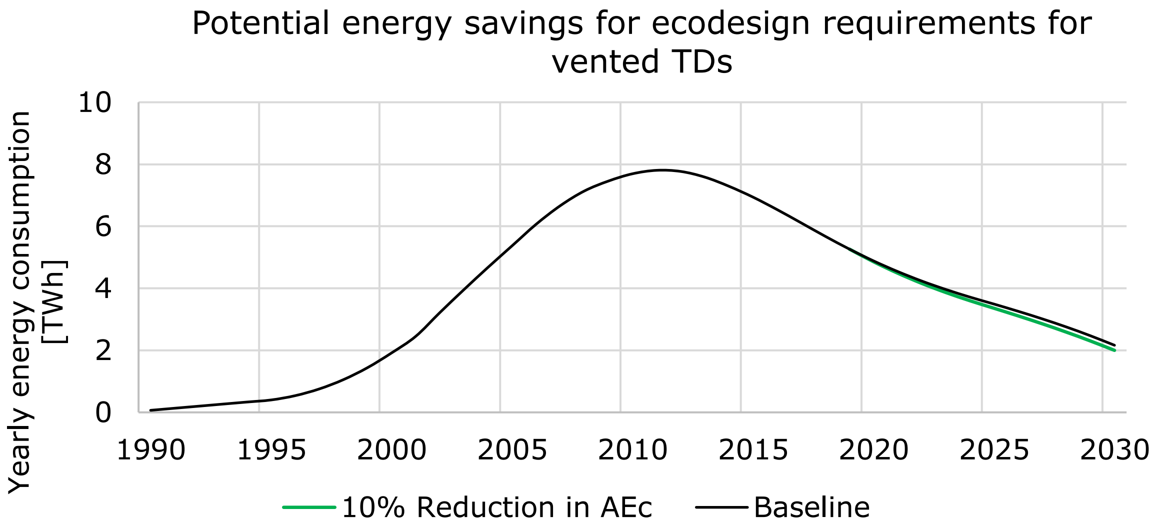


Figure 42: Effects on total energy consumption of air-vented driers, with a 10% reduction of new units sold after 2020. All baseline AEc assumed constant at 460 kWh/year.

The combined effects results in cumulative energy savings of 1.3 TWh of electricity between years 2020 and 2030. In percentage, this corresponds to 3.4% of the total energy consumption for air-vented driers in the same time period.

2.3.4 Market channels and production structure

The market for household tumble driers is characterised by a large number of manufacturers. Major players include, but is not limited to, BSH, Miele, LG Electronics, Samsung, Whirlpool, Arçelik, Electrolux, Candy, Gorenje, Vestel, and Whiteknight. Most manufacturers produce both heating element (air-vented and condensing) and heat pump driers, but only the last manufacturer produces gas fired driers. The market is thus dominated by large players, with very few SME's currently on the market.

2.4 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
- Installation costs
- Repair and maintenance costs
- Electricity and gas prices
- End of life cost

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.

2.4.1 Interest and inflation rates (MEErP method for LCC calculation)

All economic calculations will be made with 2016 as base year, as this is the latest whole year for which data is available. Inflation rates from Eurostat[85] 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.

2.4.2 Consumer purchase price

The consumer purchase 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 the average unit price for each tumble drier type is shown in Table 15.

Table 15: Unit retail prices in EUR for household tumble driers

Unit prices, EUR		2013	2014	2015	2016
Condenser	Heat pump	734	681	648	615
	Heating element	234	232	357	340
Air-vented	Heating element	225	310	244	228
	Gas-fired	225	310	326	343

As seen from the table, the price of heat pump tumble driers has decreased steadily from 2013 to 2016, as the technology matured and took over a larger share of the market. This price decrease happened despite the increase of heat pump driers in category A++ and A+++ (24% and 1% in 2013 compared to 62% and 14% in 2016).

The air-vented heat element technology driers stayed more or less on the same price level despite some fluctuations, and the energy efficiency class distribution also stayed more or less constant over the four reported years with the majority in energy class C (75-78%).

The heat element with condensing technology driers increased in price over the four years, which is consistent with approximately 20% of the market shifting from energy class C to B for in the same period (Class B share increasing from 71% in 2013 to 93% in 2016).

Based on the actual price data shown in Table 15, the purchase prices in the entire period from 2000 to 2030 were extrapolated, using the calculated growth rates.

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[85] http://ec.europa.eu/eurostat/statistics-explained/index.php/File:HICP_all-items,_annual_average_inflation_rates,_2006-2016_(%25)_YB17.png

2.4.3 Installation costs

The installation of electric tumble driers can be done by the end-user or by a professional, while gas appliances need to be installed by a professional. Furthermore, use of gas is only possible where a gas connection is available.

The preparatory study does not include the installation costs[86], and while the impact assessment claims to do so[87], their cost analysis is based on data from the preparatory study, in which the installation is not included. According to both the preparatory study and the impact assessment, the installation cost is large enough to have an effect on the market share of gas tumble driers[88]. In the Impact Assessment it is noted that under "certain conditions and with certain models, the LLCC level is achievable for gas driers", but that this is without taking into account the installation costs, "which can be a substantial addition to the overall costs"[89]. Hence, both studies conclude that the installation cost of gas driers cannot be neglected, but the low market share makes it very difficult to find the actual cost.

Most gas driers are sold in the US, and so US installation costs are easier to find, as seen in Table 16, where most prices had to be converted from US dollars to EUR. The table shows the highest and lowest price found by six different sources. If only one price is stated, it is the average reported. It was not possible to determine why there was such a large difference in installation costs, but it could have something to do with whether or not it is the company selling the machine that also offers installation, or if the installation is done by someone else. The only EU source was Which.co.uk[90], where it was stated that the cheapest quotes were between 67 and 113 EUR and the most expensive between 131 and 170 EUR.

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[86] Prep. Side 306: "Costs do not include installation at the site"

[87] IA side 26-27: The options are assessed using scenarios in which the consumer costs (purchase price, installation and maintenance - electricity is treated separately) are calculated taking into account the development of average efficiency. The data for these costs stems from the preparatory study under task 6.

[88] Prep study side 163 and IA page 12

[89] IA page 20

[90] http://www.which.co.uk/reviews/tumble-driers/article/gas-and-heat-pump-tumble-driers

Table 16: Installation costs for gas driers

USD		EUR[91]	
Low	**High**	**Low**	**High**
96	191[92]	81	162
79	177[93]	67	150
282[94]		239	
81	155[95]	67	131
		113	170[96]
111[97]		94	

An average installation cost for all driers is not realistic, as the cost would depend on the drier type and whether it is done by the manufacturer or not or outsourced or not. However, considering all business models is a big task, so assumptions were made for each base case in Task 5 (see Table 49).

2.4.4 Electricity and gas prices

The annual electricity and gas prices from the PRIME Project[98] will be used for the economic calculations in this study. The electricity prices were reported as EUR/toe (ton of oil equivalent) in fixed 2013-prices. They were therefore converted to EUR/kWh and corrected for inflation to fixed 2016-prices as shown in Table 17.

Table 17: Electricity and gas prices with 2016 as base year will be used

	Price in EUR/kWh (2016-prices) for households	
2005	0.159	0.047
2010	0.175	0.062
2015	0.194	0.072
2020	0.207	0.077
2025	0.213	0.081
2030	0.216	0.085

The prices were given every fifths year and linear interpolation will be used in between.

[91] 1 USD = 0.847364273 Euros
[92] https://www.homewyse.com/services/cost_to_install_gas_drier.html
[93] https://porch.com/project-cost/cost-to-replace-a-gas-drier
[94] https://www.homeownershub.com/maintenance/cost-to-install-a-new-gas-drier-old-one-broke-155357-.htm
[95] https://www.proreferral.com/hg/how-much-does-drier-installation-cost/
[96] http://www.which.co.uk/reviews/tumble-driers/article/gas-and-heat-pump-tumble-driers
[97] https://www.proreferral.com/hg/how-much-does-drier-installation-cost/
[98] https://ec.europa.eu/eurostat/cros/content/prime_en

2.4.5 Repair and maintenance costs

The cost of repair consists of the labour cost and the cost of the spare parts. An example of repairing a tumble drier with a broken heating element is:

- Prices for heating elements for electric driers vary with type of element and model, but they typically range from $35 to $100. Gas ignition coils are similarly priced, and the price shouldn't be above $100 for one.
- Labour cost (if needed) which varies greatly across Europe. See Figure 44.

In cases where driers 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 18[99]. 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[100].

Table 18: Average total labour costs for repair services in EUR per hour

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

Though the labour costs vary greatly across Europe and are presented in **Figure 43**. The labour cost in each country can affect the consumers' willingness to repair.

[99] The net labour cost is not the only cost factor influencing the consumer willingness to repair. It includes also overhead costs, transport costs, etc.

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

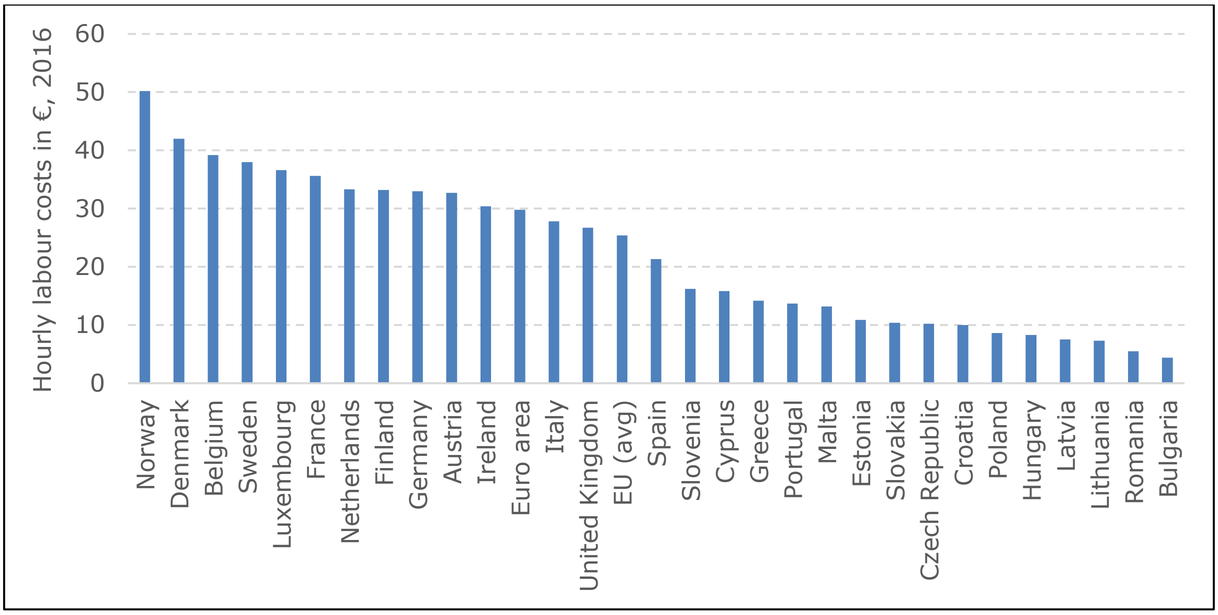

Figure 43: Hourly labour cost in EUR, 2016 for European countries

2.4.6 End-of-life costs

The disposal costs are paid by the end-user buying the product in the form of the Eco tax under the WEEE Directive. For a tumble drier, this corresponds nowadays to a fee of 80 to 120 EUR/tonne. This fee is adjusted on a country basis and by product category depending on recycling costs. The fee is not always included in the final product price, and even if it is, it is not always allowed to be visible at the point of sale.

3. Review of user behaviour

3.1 Consumer behaviour related to use

3.1.1 Parameters influencing the energy consumption of the drier

The performance of the driers is based on two parameters:

- the annual energy consumption (AEc)
- the condensation efficiency (C)

The calculation method of the two parameters are defined in Commission Regulation (EU) No 932/2012 and Commission delegated Regulation (EU) No 392/2012 and reflects the consumer behaviour related to the use of tumble drier. They are presented here because of their utmost importance to the review of the driers' user behaviour.

Annual Energy Consumption (AEC)

The Annual Energy consumption is based on measurements of energy consumption and the cycle time. The measurements are conducted with the standard cotton program reducing the moisture content of the test fabric from 60% to 0%. The measurements are made with both full load and partial load and the Regulation includes an inherent assumption that for every 7 drying cycles, the machine is full loaded 3 times and part loaded 4 times. Thus, the weighted energy consumption and time consumption are calculated as:

$$E_t = \left(3 * E_{dry} + 4 * E_{dry½}\right)/7$$

$$T_t = \left(3 * T_{dry} + 4 * T_{dry½}\right)/7$$

The identifiers "dry" and "dry½" indicate the values measured at full and half load respectively. The weighted energy, E_t, and time, T_t, are then used to calculate the annual energy consumption, AE_C:

$$AE_C = E_t * 160 + \frac{P_o * \frac{525\,600 - (T_t * 160)}{2} + P_l * \frac{525\,600 - (T_t * 160)}{2}}{60 * 1000}$$

The first part of the equation is simply the weighted energy consumption per cycle multiplied with 160 cycles per year. The last part of the equation is the energy consumption in off and left-on mode. With the equation it is assumed that the drier is in off mode half of the time it is not in use, and in left-on mode the other half. Thus, the power consumption (in watts) in off mode, P_o, and left-on mode, P_l, are each multiplied with the number of minutes in one year (525 600) minus the time the machine is in use (i.e. 160 times T_t minutes) and divided by two. Hence the numerator of the fraction constituting the second part of the equation equals the total power consumption in off and left-on mode of the drier in one year, in the unit Watt-minutes. The denominator of the fraction is simply unit conversion to kWh. The AE_C is thus the energy consumption in both active and non-active modes in a whole year.

For tumble driers with power management an alternative formula exists, where the drier automatically goes to off-mode (from left-on) a specific time, T_l, after a program is finished. For these driers the AEc is calculated instead as:

$$AE_C = E_t * 160 + \frac{\{(P_l * T_l * 160) + P_o * [525600 - (T_t * 160) - (T_l * 160)]\}}{60 * 1000}$$

In this equation the time in left-on mode is known, and therefore the energy consumption in left-on is simply the left-on power, P_l, multiplied with the left-on time, T_l, and 160 cycles per year. The drier is then assumed to be in off-mode the remainder of the year, and the off power, P_o, is therefore multiplied with the total minutes in one year (525 600) minus the time in use and in left-on.

For gas-fired tumble driers, the energy consumption is primary energy in the form of gas, compared to electricity which is a secondary type of energy. Therefore, the E_{dry} and $E_{dry½}$ have to be scaled with the primary energy factor f_g=2.5:

$$E_{dry} = \frac{Eg_{dry}}{f_g} + Eg_{dry,a}$$

The energy efficiency scale is based on the EEI value, which is derived from the AE_C and the SAE_C (Standard Annual Energy Consumption) values of the drier, and calculated as a percentage:

$$EEI = \frac{AE_C}{SAE_C} * 100$$

The SAEc is based on the rated capacity, c, of the drier in kg and calculated as:

$$SAE_C = 140 * c^{0.8}$$

Where 140 is a scaling factor correlating energy consumption and capacity, and the exponent "0.8" is to correct the non-linear relationship between total energy consumption and drying load.

For air-vented appliances the SAEC is calculated as:

$$SAE_C = 140 * c^{0,8} - \left(30 * \frac{T_t}{60}\right)$$

Which lowers the SAEc and thus increases the EEI (by lowering the denominator in the EEI formula) in order to account for secondary energy consumptions (e.g. the lost energy in the vented air).

The specific ecodesign requirements are based on the calculated EEI values and introduced in two tiers (see Table 19).

Table 19: Ecodesign requirements for tumble driers

	Tier 1, November 2013	Tier 2, November 2015
EEI vented driers	<85	<85
EEI condenser driers	<85	<76

The EEI level also forms the basis for the energy efficiency scale, as seen in Table 20.

Table 20: Distribution of energy efficiency classes based on EEI values

Energy efficiency class	Energy Efficiency Index, EEI
A+++	EEI < 24
A++	24 ≤ EEI < 32
A+	32 ≤ EEI < 42
A	42 ≤ EEI < 65
B	65 ≤ EEI < 76
C	76 ≤ EEI < 85
D	85 ≤ EEI

In summary, the energy efficiency of tumble driers in ecodesign and energy labelling Regulations is defined by the following parameters:

- Energy consumption pr. cycle at full and half load
- Time duration pr. cycle at full and half load
- Energy consumption in off-mode
- Energy consumption in left-on mode
- Time the drier takes to switch automatically to off-mode after being in left-on mode, once a drying program is finished (when drier counts with a power management function)
- The standard energy consumption of the drier used as reference value, which is calculated from the drier's rating capacity; this includes a penalization factor for air-vented driers

Furthermore, additional assumptions play an important role on the calculation of the energy efficiency:

- For every 7 drying cycles, the machine is full loaded 3 times and half loaded 4 times
- The driers are used 160 cycles per year (i.e. ~3.1 cycles/week)
- When the drier is not in use, it is in off mode half of the time and in left-on mode the other half (when not having a power management function)

Condensation efficiency

The condensation efficiency is only relevant for condensing driers (incl. heat pump driers), and not for air-vented appliances (including gas driers). The average condensation efficiency is calculated based on measurements as a percentage:

$$C = \frac{1}{(n-1)} \sum_{j=2}^{n} \left(\frac{W_{wj}}{W_i - W_f} * 100 \right)$$

The percentage of collected water, W_{wj}, compared to the water removed from the clothes is calculated. Water removal is based on the sample weight before and after the drying process (Wi, and W_f respectively). The measurements after each test run shall be done at least four times (n=4), and summarised for test run j=2, up to n. The average is then calculated by multiplying the sum with the number of test runs summarised (which is n-1).

The weighted condensation efficiency is then calculated in a similar way to weighted energy consumption and cycle time:

$$C_t = \left(3 * C_{dry} + 4 * C_{dry½}\right)/7$$

The specific ecodesign requirements related to condensation is shown in Table 21.

Table 21: Ecodesign requirements for condensation efficiency of condenser driers

	Tier 1, November 2013	Tier 2, November 2015
Condensation efficiency	≥60%	≥70%

In summary, the condensation efficiency of tumble driers in ecodesign and energy labelling Regulations is defined by the following parameters:

- Percentage of water collected pr. cycle at full and half loads
- Sample weight of water in clothes before and after the drying process
- Number of test runs

Furthermore, the assumption concerning the distribution between full and half load play also an important role on the calculation of the energy efficiency:

For every 7 drying cycles, the machine is full loaded 3 times and half loaded 4 times

3.1.2 User Behaviour

Data sources and main parameters

Summarising, the main parameters affected by user behaviour that are important to the energy and condensation efficiency of a tumble drier are:

- The average number of cycles per week
- The loading of the drier per cycle, i.e. how much is the machine filled in average with respect to its rated capacity
- The time the machine is left on left-on mode by the user before it is switched off
- Additionally, the cleaning frequency of lint filter and heat exchanger is important to ensure consistent performance of the machine, as failing to regularly do so will increase the energy consumption per cycle[101] [102]

Two online surveys are available that cover a wide range of aspects concerning the user behaviour of tumble driers in the EU market by consumers: the 2009 preparatory study and the study conducted for APPLiA by InSite Consulting[103]. Other studies on washing behaviour are also available. Due to the interlink between washing and drying loads, these studies can be used to assess the general laundry behaviour and/or to validate the drying behaviour studies.

Results from the drying studies are summarised in Table 22. Results from the washing studies are summarised in Table 23.

Note that the APPLiA study only covered people who owned a tumble drier. Similarly, the preparatory study consumer survey covered a sample of people with 86% owning a tumble drier. This is consequently far from the penetration rate of 23% found in task 2. Values in Table 22 and Table 23 represent mostly people owning a tumble drier and not the whole of EU28. This can also explain the large difference in drying amounts between the APPLiA and the Alborzi study.

There are generally two different ways the studies are conducted, by online surveys or by measuring the actual load used in each cycle ("Metering studies"). The online surveys from

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[101] According to input from stakeholders
[102] "EXPENSIVE MEASURES FOR THE ENVIRONMENT", Berge et al., RÅD & RÖN No. 7, 2012
[103] APPLiA and InSites Consulting. (2018). Tumble dryer usage and attitudes: A survey in 12 European countries (not publicly available). Draft version.

the preparatory study, APPLiA, and Alborzi have by far the largest statistical population and geographical scope, but also introduce subjectivity as these are not 'metering studies' and thus answers are being subject to personal bias and subjectivity.

Table 22: Key findings for drying behaviour studies

Data source	***Preparatory study***[104]	**APPLiA consumer questionnaire**[92]
Author	*PWC*	InSites Consulting
Data source, age	Online survey, 648 valid surveys, 2008.	Online survey, 2426 valid surveys, 2018.
Countries	UK, FR, PL	NL, UK, FR, GE, ES, IT, PL, CZ, HU, FI, SE, TR
Scope	Drying behaviour	Drying and washing behaviour
Average load/cycle	4.5kg / 3.4kg[105]	4.4[106]kg
Average nominal capacity	5.7 kg	7.1 kg
Frequency of use [Cycles/Person/Week]	0.7 (Summer) 1.1 (Winter)	0.6 (Summer) 0.8 (Winter)
Frequency of use [Cycles/Household/Week]	2.3 (Summer) 3.6 (Winter)	1.7 (Summer) 2.4 (Winter)
% of washing load that is dried in tumble drier during winter	50%	72%
% of washing load that is dried in tumble drier during summer	24%	51%

[104] Preparatory studies for Ecodesign requirements of Energy-using-Products (EuP) – Lot 16, Ecodesign of Laundry Dryers, PriceWaterhouseCoopers, 2009.
[105] The conducted online survey during the preparatory study resulted in 4.5kg. However, the preparatory study team chose 3.4kg after stakeholder consultation, to keep consistency with washing machine studies.
[106] Based on average loading %, and average machine capacity.

Table 23. Available studies on washing behaviours

Data source	**Study 1** [107]	**Study 2**[108]	**Study 3**[109]	**Study 4**[110]
Author	Berkholz et al.	Krushwitz et al.	Alborzi et al.	P&G
Data source, age	30-day metering study, 100 households, 2007	28-day metering study, 236 households, 2009.	Online survey, 4843 valid surveys, 2015.	Metering study, 276 households, 2015
Countries	DE	DE	CZ, DE, FI, FR, HU, IT, PL, RO, SE, ES, UK	FR
Scope	Washing machines	Washing behaviour	Washing machines, drying behaviour	Washing machines
Average washing load/cycle	3.4kg	3.3kg	5.7kg[111]	3.24kg
Average capacity (Washing machine)	5kg	5kg	6.5kg	6.24kg
Frequency of use [Cycles/Person/Week]	1.7	1.7	1.5	-
% washing load that is dried in tumble drier during winter	-	-	19%	-
% washing load that is dried in tumble drier during summer	-	-	11%	-

Cycles per week

The number of drying cycles per week is affected by the washing cycles per week, as all the dried laundry is wetted through the washer.

The amount of **cycles per week** has decreased from the preparatory study (2008) to the APPLiA survey (2018). This is consistent with the increase in rated capacity but might also be due to the very different scopes of the surveys.

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[107] Berkholz P., et al: Verbraucherverhalten und verhaltensabhängige Einsparpotenziale beim Betrieb von Waschmaschine, Shaker-Verlag, 2007

[108] Kruschwitz, A.; Karle, A.; Schmitz, A. & Stamminger, R. (2014). Consumer laundry practices in Germany. International Journal of Consumer Studies, 38(3), pp. 265–277.

[109] A Alborzi, F.; Schmitz, A. & Stamminger, R. (2017). Washing behaviour of European consumers 2017, *Shaker Verlag*

[110] Proctor & Gamle: Load Weight Study - France 2015, Workshop on how to improve testing methods for washing machines and washer-dryers, Annex 6, 2016.

[111] Calculated as a weighted average, based on consumer loading behaviour on physical loading capacity, fig. 87.

The APPLiA survey shows that especially the northern countries (I.e. Sweden, Finland) use their tumble driers significantly more during the winter. This might also express the large difference in the percentage of laundry being dried at summer/winter times between the two studies. As the preparatory survey did not include any of these, the comparison might not be justified. The APPLiA study is used as reference, at 1.7 & 2.4 cycles per week per household during the summer and winter respectively, equal to an average of 2.05 cycles per week or 107 cycles per year.

The Alborzi study also investigated the percentage of drying done in tumble driers. These figures significantly differ from the other studies. No explanation on why is however available.

Loading of the drier

As the market trend is favouring driers with larger capacities (see Figure 33) two things can happen to consumer loading behaviour:

a. The loading behaviour can remain constant, meaning that the amount of laundry loaded per cycle is unchanged compared to 2008[112], or
b. the loaded laundry can increase, which could mean fewer but longer cycles.

The loading of the drier is important as it affects the *specific* energy consumption of the drier in terms of the energy used per kg of dried laundry. According to input from industry, a fixed energy is required to heat up the drier itself, regardless of the amount of loaded laundry. This increases the specific energy consumption at partial loads[113]. Furthermore, as the drum volume is less full at lower loads, the drying air comes into less laundry-surface area, which reduces the effectiveness of the drying and hence increases the energy consumption.

Some manufacturers use the same drum volume independently of the nominal capacity. The change in capacity is thus based on motor sizes and heating capabilities instead. Other manufacturer differentiate between drum volumes between models at different rated capacities. For manufacturer using the same drum volume for driers at capacities of i.e. 7kg and 9kg, the increase in specific energy consumption at partial loads will be smaller, compared to manufacturer using different drum volumes.

The effect is visualised in Figure 44 where specific energy consumption at full and half load operations are shown for 177 drier models on the market. Differences up to 14% in energy

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[112] Year of survey used in the preparatory study.
[113] "Partial" here meaning a drier not loaded at 100% nominal capacity.

consumption are observed. Note that the increase in energy consumption at 9 kg might be due to insufficient data points, as few heating element driers are with 9kg+ capacities.

Table 24 lists each drier type and their increase in specific energy consumption. The difference in specific energy consumption between full- and half load operations decreases with a higher rated capacity. This might be because physical dimensions (and in some cases, the drum volume) of the driers do not increase, even though the nominal capacity does. The energy required to heat up the drier itself remains to some extend constant, which is hence marginalized at higher rated capacities.

For heat pump driers, a special case exists. For some top performing driers with heat pump technology (A^{+++}), a variable speed drive can be used with the compressor motor. This enables the heat pump circuit to reduce the compressor speed at partial loads, and thus decrease the pressure differences (and thus temperatures) in the cycle which results in a more thermodynamically efficient process. This increases the part load performance compared to other driers.

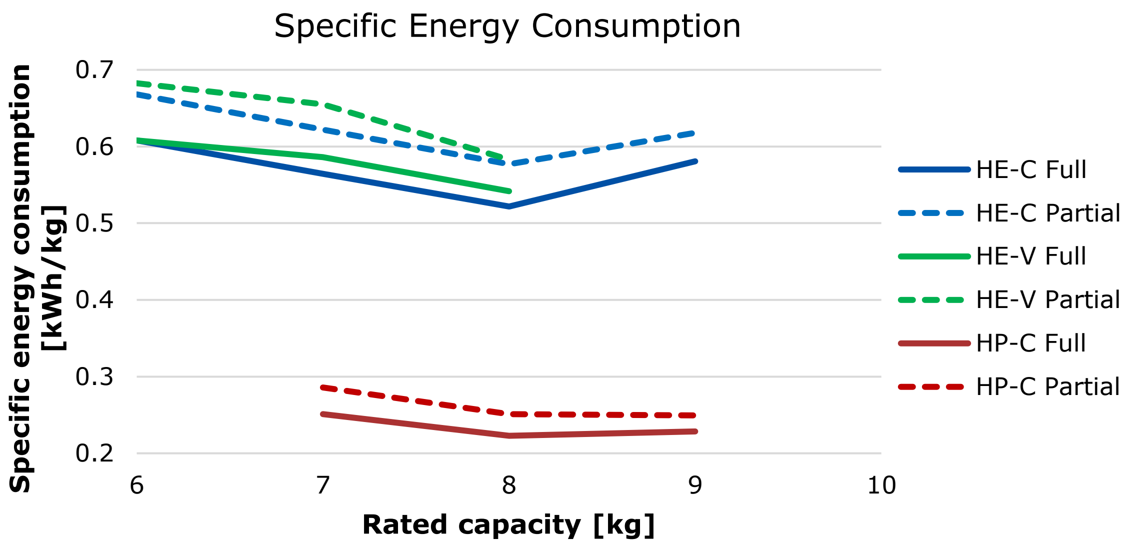

Figure 44: Specific energy consumption of three types of driers, at full and half (partial) load: Condensing with heating element (HE-C), Air-vented with heating element (HE-V) and condensing with heat pump (HP-C)[114]

[114] Source: APPLIA Model database 2016, n=177.

Table 24: Increase in specific energy consumption between full and half load operations[114]

Capacity [kg] / Type	HP-C	HE-C	HE-V
6	-	10%	12%
7	14%	10%	12%
8	13%	11%	8%
9	9%	6%	-
10	-	-	-

The washing machine preparatory study from 2017 shows that washing machines are increasing in average nominal capacity but not in average load. This study shows an increase in specific energy consumption for washing machines at up to 50% at part load operations[115].

In terms of investigating the average load in the online surveys, different approaches where used. The 2009 tumble drier preparatory study asked the consumers what their average load per cycle was, with ranges (e.g. 4-5kg) as options. Asking the consumers to specify the amount of kilos of laundry they wash per cycle can be especially difficult, as no reference point exists and thus consumers will likely not know the amount of load per cycle.

Alborzi addresses this by asking the consumers how they usually load their machine, in terms of the maximum physical capacity ("How do you usually load your machine?") of the machine (i.e. nominal load). This might also suffer from the same bias as the preparatory study, as consumers might have different ideas of what a "full" machine looks like.

The APPLiA study tries to remedy this by supplying pictures of a machine being loaded 25%-100%.

Three of the washing studies[116] were made by measuring the processed laundry, hence removing the consumer bias uncertainties. The average washing load measured from these (3.4kg, 3.3kg, and 3.24kg) differs greatly from the Alborzi online survey study at 5.7kg. Even though the studies are only related to German and France households, Alborzi F. et al[117] shows that at least from a consumer's point of view, German and French washing behaviour is close to the EU-28 average, meaning these studies could be used as a reference for determining the laundry behaviour of the EU-28 average.

Furthermore, comparing the loads from the 2015 P&G study on washing machines and 2018 APPLiA consumer survey on tumble drying load at 3.2kg and 4.4kg respectively, it is

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[115] Ecodesign and Energy Label for Household Washing machines and washer dryers – preparatory study, JRC, 2017, p.326
[116] Berkholz et al., Krushwitz et al., P&G.
[117] Alborzi, F.; Schmitz, A. & Stamminger, R. (2017). Washing behaviour of European consumers, fig. 87, 2017, *Shaker Verlag*

clear that the major difference between the different studies origins in the way they are fundamentally conducted. Even though the metering studies might prove to be more precise per data point, they are aimed at washing behaviour and with a significantly smaller statistical population and country coverage. The real drying average load is hence assumed to be somewhere between 3.2kg – 4.4kg, based on the P&G and APPLiA study respectively, as they consist of the newest available data.

The preparatory study estimated that about 160 kg of laundry per person are dried by every tumble drier in the EU every year, based on an average use of 0.9 cycles/week/person and an average load of 3.4 kg/cycle. Assuming the 160 kg dried laundry per person per machine per year is still valid and using the new cycles/week from the APPLiA study (see Table 22), this results in an average load of 4.37kg[118]. 4.4kg is hence used as a baseline load for the rest of the study. From this study an average loading percentage of 62% was established as well, based on an average drier size for the people surveyed at 7.1 kg.

Cleaning frequency of filters

The APPLiA study investigated the cleaning frequency of the lint filter and condenser unit, shown in Figure 45. It shows that 45% of users clean the lint filter before every cycle as suggested by the manufacturers, and that 29% of consumers with heat element condensing driers clean the condenser after every drying cycle. Overall, this means that on average it can be estimated that the EU consumers clean their lint filters every 1.7 cycles and their condenser filters every 2.3 cycles[119]. Based on stakeholders' input, these estimated frequencies are too high. APPLiA suggested that the values for "Cleaning of other filters" was used instead. This had a lower cleaning frequency of 4.1 cycles between each cleaning.

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118 $\frac{\left(\frac{0.7+1.1}{2}\right)\times 3.4\times 365/7}{\left(\frac{0.6+0.8}{2}\right)\times 365/7} = 4.37\text{kg}$

119 Calculated using a weighted average of the time between each filter cleaning from Figure 45 and the associated percentages, and the previously found cycles per week. For instance, 18% of answered households clean the filter every month. Using an average cycle of 2.05 cycles/week, this means that the filter is cleaned 0.11 times per cycle equal to 8.9 cycles between each clean $\left(\frac{1\,\frac{clean}{month}}{2.05\,\frac{cycles}{week}\times 4.3\,\frac{week}{month}} = 0.11\,\frac{clean}{cycle} = 8.9\,\frac{cycle}{clean}\right)$.

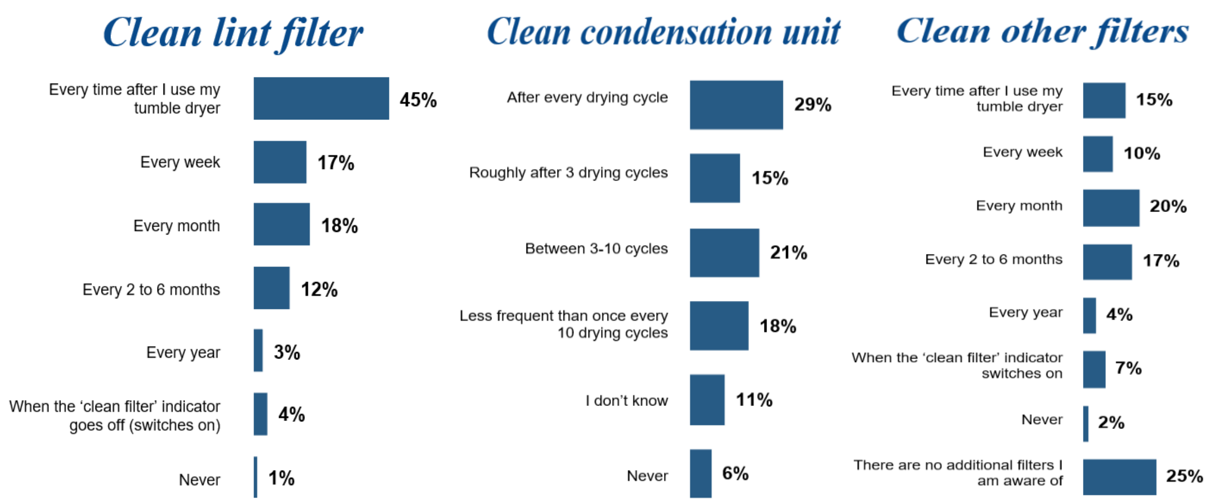

Figure 45: Cleaning behaviour of lint filter, condenser units, and "other filters"[103]

The effects of failing to regularly clean the filters and condenser are hard to determine. The "dirty" lint filter will undoubtable result in a loss of flow and can thus extend cycle times and possible increase energy consumption. For the condenser driers with heating elements, the same effect is expected to be applicable to the condenser. The effect however is most significant in heat pump condensing driers, where the efficiency of the integrated heat pump circuit is very dependable on the effectiveness of the heat exchangers , which is reduced when the flow is limited by lint and residues on the heat exchanger (see 4.1 for a more detailed description). A "dirty" condenser can hence lead to a higher energy consumption for the drying cycle.

This effect is hard to estimate. Few studies are available on this topic and the lint build-up in the condensers happens over time, making testing difficult and expensive because standardised tests are made for products just placed on the market. Three different sources[120,121,122] show a decrease in performance due to lint-build up in the condensers.

The first source[120] reports a significant increase in energy consumption (up to +95%) after 8 cycles. Stakeholders, however, reported that this test was done with extra fluffy loads not suitable to be used as a general benchmark.

The second source[121] reported inconclusive results. Two out of ten driers were very influenced by the consecutive cycles in terms of energy consumption. One model reported

[120] "EXPENSIVE MEASURES FOR THE ENVIRONMENT", Berge et al., RÅD & RÖN No. 7, 2012
[121] Euroconsumers study on the performance of heat pump driers at 8 consecutive cycles without cleaning the condenser, 70% loading. 2017
[122] Stakeholders input from in-house test on the performance of heat pump driers after being used for 3-7years in households, and the effects of cleaning the condensers. 2016.

energy consumptions more than 250% higher for the 8th cycle compared to the 1st cycle, but the majority of the tested driers reported no significant change in energy consumption.

The third source[122] looked at the performance of the tumble driers after 3-7 years of every-day use in households. It tested the difference in performance before and after a cleaning of the condenser filter. The study showed an increase in energy consumption for five out of six models ranging between 17% - 60% due to dirty condenser filters. Unfortunately, no information on usage patterns and cleaning frequencies of the tumble driers were available. The study reported also two inoperable models with self-cleaning heat exchangers that had extensive lint build up at the front of the condensers.

Overall, the effect of neglecting to clean the condensers is difficult to quantify since none of the available studies have conclusive data possible to correlate the age, type, and cleaning frequency of the drier with an increase in energy consumption. The effect will thus not be quantified in the further calculations. However, the effect on the energy consumption can be very significant, according to some of the shown results of these three sources. Especially for users not cleaning the condensers at all, which might result in the drier becoming inoperable, and which might be up to 27% of all users[103].

Conclusion

Comparing the average nominal (rated) capacity and the average load, the real energy consumption is heavily dependent on part load efficiencies of the driers. They are currently being tested for energy consumption at full and at half capacity (cf. Commission Regulation No 932/2012 Annex II), which gives an average loading testing factor of 71%[123] (see section 3.1.1 "Annual Energy Consumption" for reference).

If the average load at 3.2kg of laundry is used, then driers with a capacity of 7kg or more (Which is >98% of all sold condensing driers and >60% of air-vented driers in 2016, see Task 2) is on average running below even the partial loading capacity (i.e., half load) used in Regulation 392/2012. The driers are hence labelled at running conditions which they seldom, if ever, operate in. The introduction of driers with a capacity of 10kg seems especially disproportionate.

Using the P&G survey data, Figure 48 shows the washing machine loading behaviour of consumers, in respect to the nominal capacity of their washing machine. Assuming that all the dried laundry comes from washing machines, this can be linked to the tumble drier loading factor.

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[123] (3*1+4*0,5)/7*100%

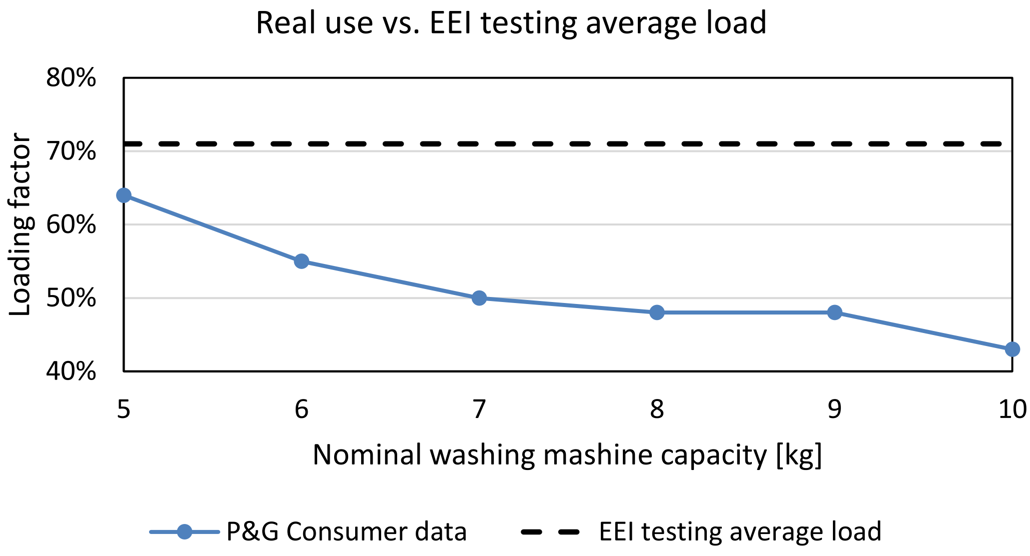

Figure 46: Nominal washing machine rated capacity compared to real use. Loading factor defined as $\frac{\text{Real amount of laundry pr. cycle}}{\text{Recommend maximum load}} \times 100\%$**. *Data source: P&G*[110]**

Using the washing machine rated capacity as reference, Figure 46 shows that even the smallest machines with a capacity of 5-6kg, are on average running below the average load of the energy consumption testing procedure. This difference is only increasing with machines with higher rated capacities. As the figure shows the amount of washed laundry per cycle is not directly proportional to the capacity of the machine.

Users are heavily influenced by the energy efficiency when buying new tumble driers[124], but as the efficiency of the driers are generally higher at larger capacities (especially heat pump driers due to compressor efficiencies in general), users could be biased towards buying driers with higher capacities which are labelled as more energy efficient, although they in real life conditions – due to part load operations – may not be.

The current testing procedures at full and half load conditions can hence be used as a comparative tool between products but is unlikely to represent the real annual energy consumption for the average user, and less so in the future with foreseen increasingly large capacity driers on the market. Changing the testing procedure to reflect the real use, could potentially reverse the trend of manufacturers producing unnecessary large units, and emphasize the importance of having driers which can differentiate between being fully loaded and being almost empty.

The annual energy consumption is currently based on 160 cycles/year. As stated in section 3.2, this might not be representative, as the amount of drying done in tumble driers has

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[124] PWC: Ecodesign of Laundry Dryers, Preparatory studies for Ecodesign requirements of Energy-using-Products (EuP) – Lot 16, Final Report, March 2009, fig. 68.

lowered. Using the average number of drying cycles/week/household of 1.7 / 2.4 for summer and winter times respectively, this gives an average of 107 cycles/year.

3.1.3 Impacts of tumble driers on secondary energy systems

During the use phase, tumble drier types affect the room which the drier is located in, but the effect happens to different extents depending on the tumble drier type. As the drying process is done at elevated temperatures, heat transfer through convection to the room is to be assumed for all types, depending on the amount of insulation present in the drier. For non-air-vented driers, leakage of humid air is also to be expected at varying degrees. The net energy contribution to the secondary system (inhouse climate) depends on whether the drier is located in a heated room or not. 59% of existing tumble driers were in 2018 located in heated rooms[103].

Besides raw heat, moisture is leaked to the room due to non-perfect condensation processes. The air-vented driers do not have this problem, as all moisture is vented to the outside environment. The leaking moisture can in severe cases lead to structural damage and/or mould[125], especially if the drier is situated in small non-heated rooms where the moisture can condensate to droplets on cold walls. If placed in a heated room, the requirements for increased ventilation would naturally add to the energy consumption of the local space heating systems. Driers with heating elements have generally lower condensation efficiency compared to driers with heat pumps: 91% of heat pump driers sold in 2016 had condensation efficiency labels B or better, while only 47.2% of driers with heating elements achieved this[126].

Air-vented driers

Air-vented tumble driers exhaust the hot humid air to the ambient. If the drier is located in a heated room, the drier uses the temperate indoor air as air supply, which after being heated in the machine, is vented to the ambient. This means that cold ambient air (especially in northern Europe) needs to replace the vented air. This air needs to be heated through the space heating system, giving rise to an additional energy consumption related to the use of the tumble drier, if the drier is located in a heated room. The process is visualised in Figure 47. Furthermore, installing an air vented drier means drilling a hole through the building envelope which results in a passive leakage of energy throughout the year. Additionally, if a mechanical ventilation system is installed in the building, this hole can bypass a potential heat exchanger increasing the household heat consumption. These effects will however not be further investigated.

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[125] https://www.ncbi.nlm.nih.gov/books/NBK143947/
[126] Source: GfK data from 2016

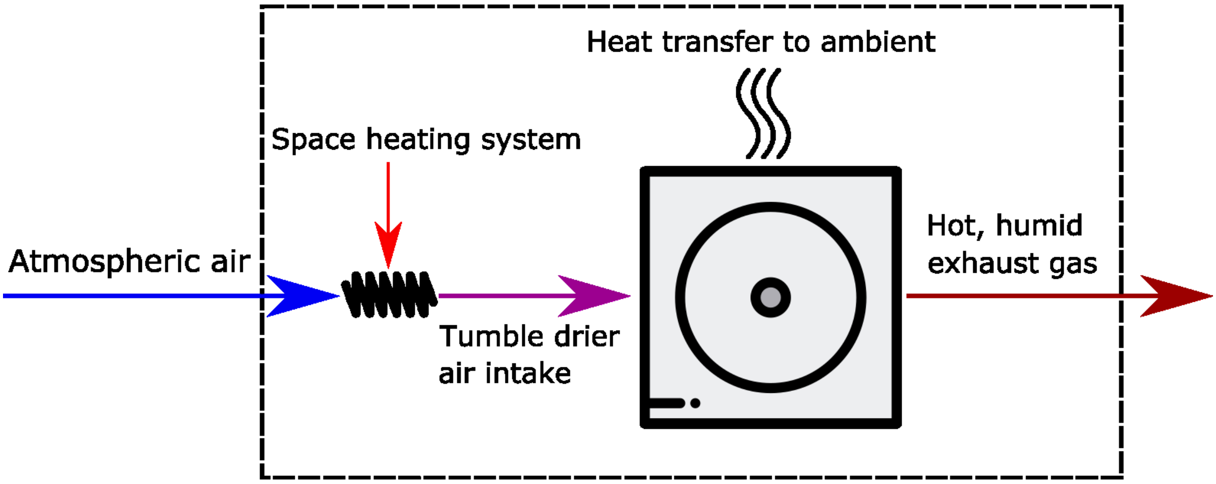

Figure 47: Secondary system impact for air-vented tumble driers

Assuming an average air flow of 120 [m^3/h][127], and a cycle time of 123 minutes[128] the additional energy consumption based on ambient/atmospheric temperatures can be calculated as:

$$Q = c_p * \dot{m} * (T_{room} - T_{atmospheric})$$

With c_p being the specific heat capacity of air, and $\dot{m}$ being the air mass flow. The additional energy consumption (in heat) can be seen on Figure 48 in both instantaneous consumption in kW (Left Y-axis), and total consumption for an 123 min cycle in kWh (Right Y-axis)

[127] Preparatory study, p.194
[128] Based on the average value of a weighted cycle time (for full and half loads) for air-vented driers, from GfK, 2016 data

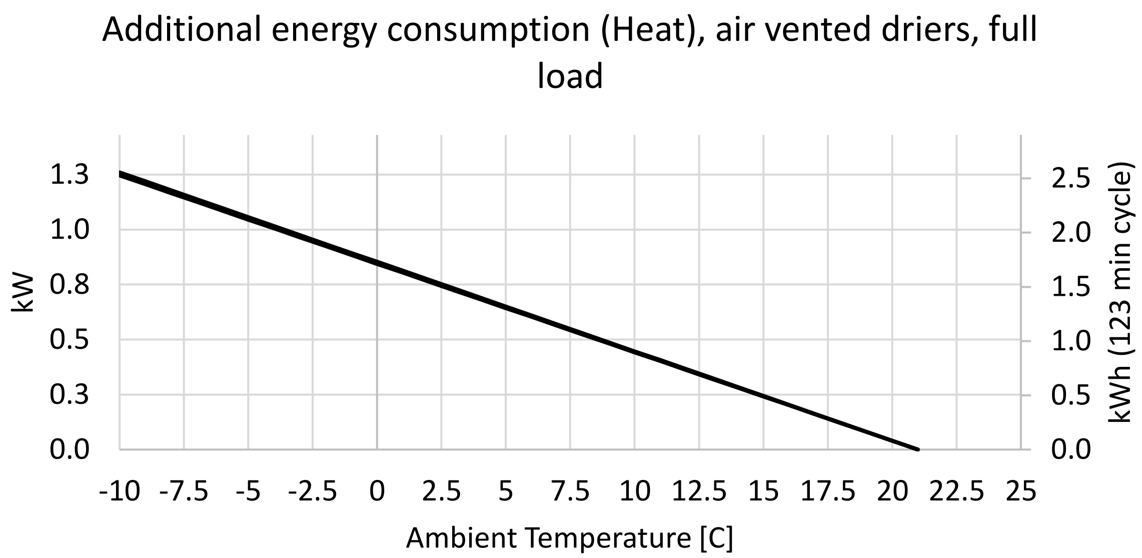

Figure 48: Additional energy consumption for air-vented driers

Comparing with the SAEc adjustment factor for vented driers (see section 3.1.1), the actual additional energy consumption is heavily influenced by the ambient temperature. Figure 49 shows the percentage increase in total energy consumption for a drier with an energy consumption of 3.4 kWh/cycle[129], assuming the drier is located in a heated room at 21°C. The dotted line is the current penalization/adjust factor for the EEI calculation. It can be seen that especially for colder regions the adjustment factor is insufficient, as the additional energy consumption is generally higher than what the Regulation adjusts for. Furthermore, people tend to generally use their tumble drier more during winter times (see section 3.1.2), which can increase this discrepancy.

The average European surface temperature was estimated at 10.9C in 2010[130]. This means that an adjustment factor of 17% is more appropriate.

The added energy consumption is in the form of heating and not electricity. If for instance a heat pump with a COP[131] of 3 is supplying the inhouse heating, the values should be divided by 3 for the demand of electricity.

[129] Based on the average value of a weighted energy consumption per cycle (for full and half loads) for air-vented driers, from APPLIA Model database 2016

[130] "Monitoring European average temperature based on the E-OBS gridded data set", G. van der Schrier, E. J. M van den Besselaar, A. M. G. Klein Tank, and G. Verver, JOURNAL OF GEOPHYSICAL RESEARCH: ATMOSPHERES, VOL. 118, 5120–5135, doi:10.1002/jgrd.50444, 2013.

[131] "Coefficient of Performance", denoting the efficiency of the heat pump. A COP of 3 means that for 1kWh of electricity, 3kWh of heating is delivered.

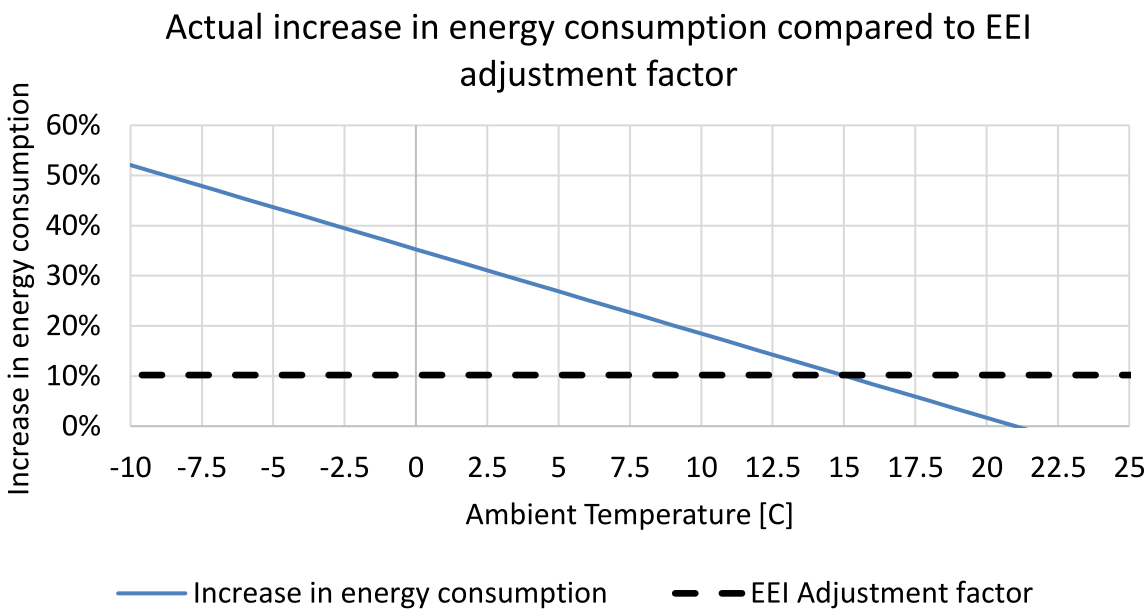

Figure 49: Increase in energy consumption compared to air-vented tumble drier with an electric load of 3.4 kWh/cycle[132]

Condensing driers with heating element

Condensing driers condenses the evaporated moisture (instead of venting it) by using the inhouse/ambient air to condense the water in the hot and humid process air through a heat exchanger. The process is visualised in Figure 50. As the exhaust air in this case is not vented outside, the latent heat from the condensation process is effectively delivered to the inhouse climate, decreasing the energy consumption in the space heating system. The ambient temperature affects the energy consumption of the drier, with a high ambient temperature increasing the energy consumption of the drier due to the dew point being directly related to the temperature. This means that condensing driers should not be placed in small rooms where drier operations could increase local ambient temperature levels.

[132] The 10% EEI adjustment factor can be calculated by assuming a cycle time of 123min (GfK data 2016) and using the average rated capacity of 6.75kg for air vented driers in 2016 (see Figure 31). SAEc for non vented = 140*6.75^0.8 = 645. SAEc for vented = 140*6.75^0.8 – (30*123/60) = 584. % increase = 10%.

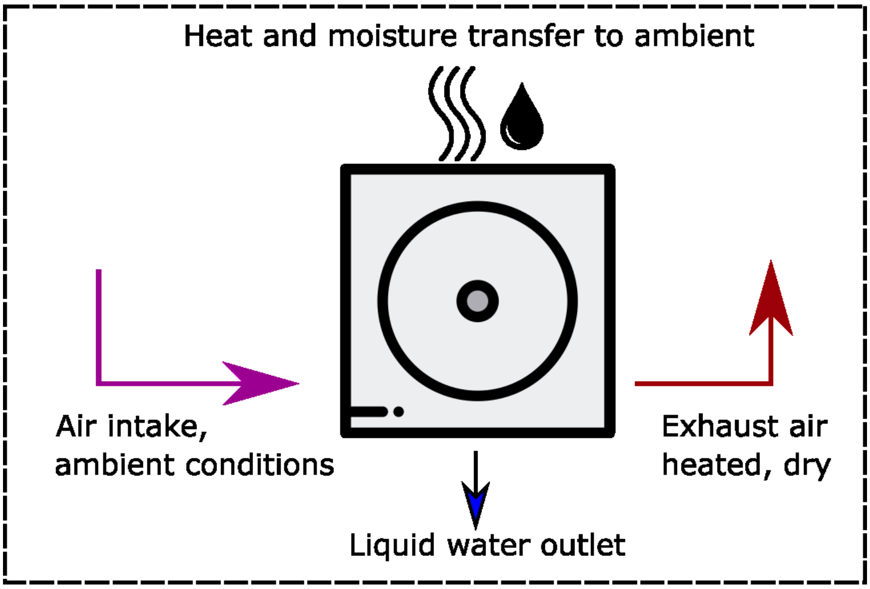

Figure 50: Secondary system impact for condensing driers

Condensing drier with heat pump technology

Driers using heat pump technology use a refrigerant to transfer heat between the drum and the condenser, instead of air. This means that the only impact on secondary systems is heat transfer through convection, and moisture leakage. This allows for a greater flexibility in placing the drier, compared to the other types which have a greater impact on the inhouse climate. The process is visualised in Figure 50.

The heat pump circuit does however have a limited temperature working range, as the compressor requires constant cooling. This is done via a secondary air fan, using ambient air. If the ambient temperature is too high, this can cause the compressor to reach critical temperature, forcing it to stop. This can lead to increased cycle times, and increased energy consumption. Heat pump driers should hence also not be places in small rooms without adequate ventilation.

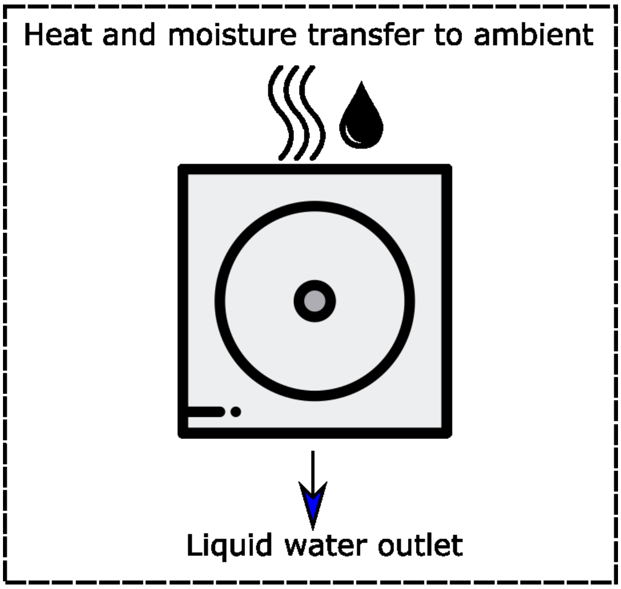

Figure 51: Secondary system impact for driers with heat pump technology

3.2 Consumer behaviour related to product durability and end of life

Aspects concerning the end of life of products that are influenced by consumer behaviour are assessed and presented in this section. In particular those that affect the durability, reparability, disassembly and recyclability of tumble driers.

According to the Ecodesign Working Plan 2016-2019[133], special focus to be investigated regarding these aspects are:

- Durability: Minimum lifetime of products or critical components with a view to assess possibilities for extending product lifetime
- Reparability: Availability of spare parts and repair manuals with a view to assess possibilities for design for repair
- Disassembly: Removal of certain components with a view to assess possibilities for increase their reuse and/or recycling at end of life (i.e. by easy removal)
- Recyclability: Identifying materials that hinder recycling with a view to assess possibilities to avoid them in the product design

Only the aspects related to consumer behaviour are presented in task 3, particularly regarding durability and reparability. Otherwise they are presented in task 4, as they are related to product design and technologies.

[133] https://ec.europa.eu/energy/sites/ener/files/documents/com_2016_773.en_.pdf

3.2.1 Durability and lifetime

Longer lasting products could have the potential to reduce overall life cycle impacts imposed by appliances. With a longer lifetime the impacts of consumption of raw materials is reduced since the impacts of mining, production, transportation etc. are spread over a longer period of time and displaces the need for new equipment[134]. The product lifetime can be interpreted in numerous ways. Different definitions exist (See Table 25) from other ecodesign studies[135].

Table 25: Different definitions of lifetime

The design lifetime	The behavioural (or social) lifetime	Definition used in this study
Intended lifetime regarding functioning time, the number of functioning cycles, etc., foreseen by the manufacturer when he designs the product, provided that it is used and maintained by the user as intended by the manufacturer. The design lifetime must not be confused with the guarantee period of products, which is a service offered by the manufacturer and fulfils other constraints, namely commercial.	Is defined as the number of years until the device is replaced for other reasons than technical failure or economic unattractiveness. This generally regards social and consumption trends, a product including new feature has been released and is preferred.	The term "lifetime" used in the current study must be understood as the period (i.e. the number of years) during which the appliance is used and consumes electricity ("actual time to disposal"). Therefore, it is a value included between the social lifetime and the design lifetime.

An accurate lifetime can be difficult to determine as many factors can affect the lifetime such as location, hours of operating and maintenance practice. These factors relate to the durability of the appliances, but other factors such as customer requirements and the

134 Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV
135 https://www.eceee.org/ecodesign/products/airco-ventilation/

desire for new appliances can also affect the lifetime. This tendency is often seen with computers and mobile phones. These products are often replaced or exchanged due to a desire of a newer or better model and not because the product is faulty. The reason for purchasing a new tumble drier was investigated in a recent German study[136] and presented in Table 26.

Table 26: The reason for purchasing a new tumble drier

Year of survey	The old device broke down	The old device was faulty /unreliable	The old device still worked, but I/we wanted a better device
2004	71 %	17 %	12 %
2008	75 %	9 %	16 %
2012	68 %	13 %	19 %

Based on the German study the share of people exchanging a functional machine with a new model is increasing from 12 % in 2004 to 19 % in 2012. This tendency may be due to increased efficiency of tumble driers or new functions or the purchase of combined washer/driers. For all large household appliances, it should also be noted that the proportion of appliances that were replaced in less than 5 years due to a defect increased from 3.5% to 8.3% between 2004 and 2012.

In the preparatory study the average lifetime used (number of years which the tumble drier is used) was estimated as 10 to 19 years based on stakeholder input and a literature review. These numbers seem to be still valid though it is expected that only very few tumble driers have a lifetime of 19 years while most would have a lifetime up to 14 years maximum[137]. According to the German study the average lifetime of household equipment is falling. The study investigated the lifetime of large household appliances and found that the lifetime has declined from 14.1 years to 13.0 years between 2004 and 2012. This highest reduction in life time was observed for freezers and tumble driers, where the lifetime decreased from 18.2 to 15.5 years and 13.6 to 11.9, respectively. So, the average lifetime of tumble driers used in the current study is reduced to 12 years (definition used in this study, see Table 25). Regarding heat pump condenser driers, the lifetime seemed to be reduced with the first models available on the market but today the manufacturers have no indication that suggest the heat pump condenser driers have a shorter lifetime

[136] Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz“. Available at: http://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_11_2016_einfluss_der_nutzungsdauer_von_produkten_obsoleszenz.pdf

[137] Assumption confirmed by industry

than other types of tumble driers. According to manufacturers, tumble driers are tested with a durability test which ensures a lifetime that fits with the brand of the tumble drier.

The current age of tumble driers on the market is investigated by APPLiA and the results of the survey are presented in Figure 52.

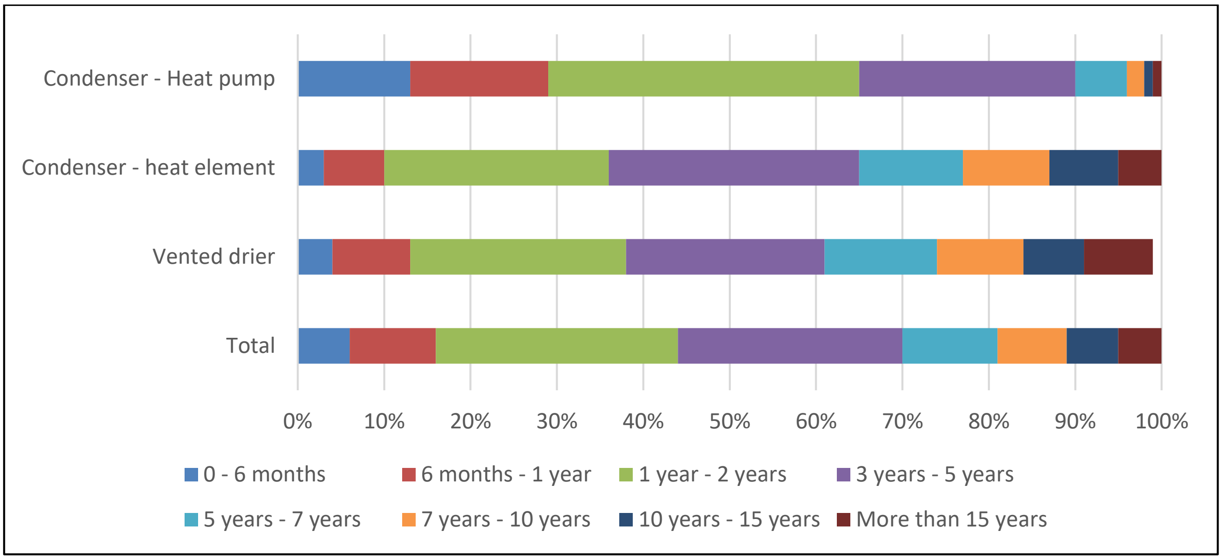

Figure 52: Age of tumble drier[138]

This survey only shows the current age of tumble dries on the market today and does not inform about the actual lifetime. However, the survey reveals that more than half of the tumble driers are less than five years old. The high share of new products may be a natural consequence of increasing sales, which means more new products are sold each year. Also, older tumbler driers exist on the market (above 15 years). Hence, the survey from APPLiA cannot conclude the average lifetime of tumble driers, but the numbers indicate that an assumed average life of 12 years is not unrealistic.

3.2.2 Repairability and maintenance

A way to improve the lifetime of household appliances is to design products with more possibilities of repair so it is more affordable for the consumers to repair than purchase new appliances. Currently repair and maintenance are expected to be done by professionals and in some cases by the end-user. If the repair is done by professionals the cost of repair is constituted of the labour costs and the cost of the spare parts, which means that the affordability of repair is very much dependent on the labour costs

Based on labour cost (presented in Figure 43) the amount of repair by professionals is expected to be low in northern countries and higher in southern and south-eastern countries. Another important factor is also the age of the equipment. Near their end-of-life

[138] APPLiA and InSites Consulting. (2018). Tumble dryer usage and attitudes: A survey in 12 European countries (not publicly available). Draft version.

(above 9-10 years) tumble driers are probably too expensive to repair compared to the price of a new model because new models are assumed to be more efficient or at least it is possible to get a new tumble drier with the same specifications at a lower price. Furthermore, a new model is also expected to be more efficient so that the total cost of ownership is lower for the new model compared to repairing the old one and extending the lifetime. This balance is dependent on the energy consumption, the price of a new model and the cost of repair. The consumer behaviour and likeliness for repair was investigated in the preparatory study and found that approximately 35% of the consumers were ready to repair their tumble driers if needed, and that an additional 40% would *probably* repair it if it broke down.

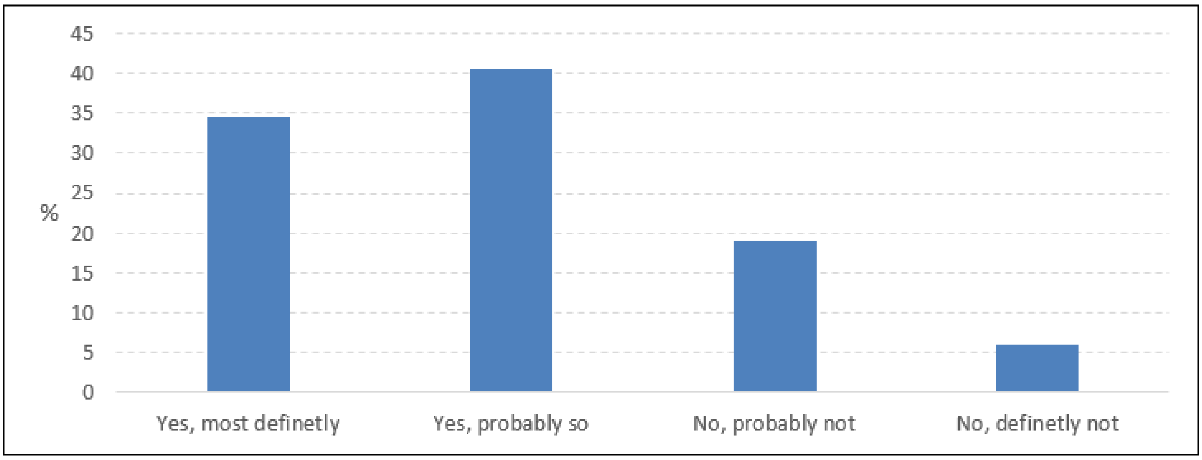

Figure 53: Survey results from the preparatory study on the consumers' willingness to repair their tumble drier.

These numbers are still thought to be representative to the current situation despite the increased tendency to replace functioning machines as many tutorials towards repairing and troubleshooting are available online[139]. Though, some manufacturers have expressed concern regarding any regulatory measures that promote self-repair due to safety reasons. Instead, they believe it is more important to ease the maintenance of tumble driers. APPLiA have investigated the share of consumers that have experienced technical issues. The result from their survey are presented in Figure 54.

[139] E.g. https://www.partselect.com/Repair/Dryer/ , http://www.ukwhitegoods.co.uk/help/fix-it-yourself/tumble-dryer-self-help and https://www.ifixit.com/Device/Dryer

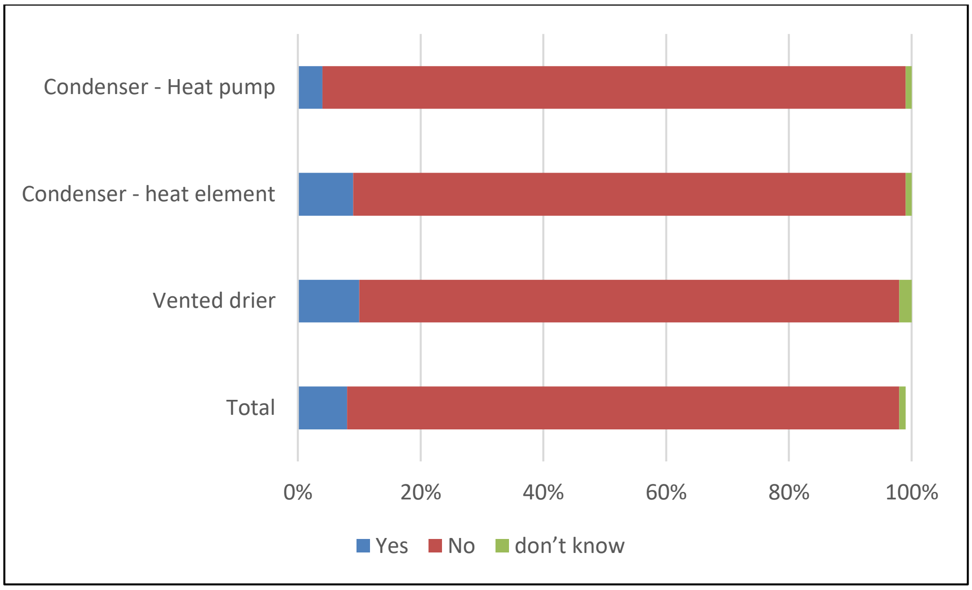

Figure 54: Experienced technical issues[140]

Based on the results from the survey performed by APPLiA it seems like most tumble driers are durable since less than 10% of the consumers have experienced technical issues. Air-vented - heat element driers are most likely to experience technical issues (10% of the consumers) while condenser – heat pump driers seem durable (only 4% of the consumers have experienced technical issues). This tendency could very be well due to the age of appliances where heat pump condenser driers are mostly new appliances on the market (see Figure 52).

The maintenance of tumble driers is assumed to be performed by the end-user on a regular basis. This maintenance practice can include the following elements (see Table 27). How often the filters and condensation unit are cleaned in real life are investigated by APPLiA and presented in Table 28.

Table 27: Maintenance practice for different tumble driers

Maintenance practice	Condenser – heat element	Condenser – heat pump	Air-vented – heat element	Air-vented - gas fired	Remarks
Option 1- Clean the lint filter	X	X	X	X	
Option 2 – Empty the condensate box	X	X			Condenser drier can also be connected to the drain, then it is not needed to empty
Option 3 – Consumer to clean the heat exchanger	X	X (some of them)			

[140] APPLiA and InSites Consulting. (2018). Tumble dryer usage and attitudes: A survey in 12 European countries (not publicly available). Draft version.

Maintenance practice	Condenser – heat element	Condenser – heat pump	Air-vented – heat element	Air-vented - gas fired	Remarks
Option 4 – Cleaning the additional lint filter		X			
Option 5 – Cleaning the filter of the condensate box	X	X			
Option 6 – Cleaning the exhaust duct			X	X	
Option 7 - Cleaning the door gasket	X	X	X	X	
Option 8 – Clean the sensor	X	X	X	X	Not needed for non-automatic driers

Table 28: Real life maintenance practice[141]

Clean lint filter	
Every time after I use my tumble drier	45%
Every week	17%
Every month	18%
Every 2 to 6 months	12%
Every year	3%
When the 'clean filter' indicator goes off (switches on)	4%
Never	1%

Clean other filters	
Every time after I use my tumble drier	15%
Every week	10%
Every month	20%
Every 2 to 6 months	17%
Every year	4%
When the 'clean filter' indicator switches on	7%
Never	2%
There are no additional filters I am aware of	25%

Clean condensation unit	
After every drying cycle	29%
Roughly after 3 drying cycles	15%
Between 3-10 cycles	21%
Less frequent than once every 10 drying cycles	18%
I don't know	11%
Never	6%

The majority of the consumers seems to regularly maintain their tumble driers, though a few state that they never clean filters and the condensation unit, in spite they should be cleaned. These driers are subject to premature failure, increased energy consumption and increase duration of the drying process.

If the lifetime of tumble driers is decreasing, it is important to consider the possible trade-offs between resource efficiency and energy efficiency. A study from 2011 on washing

[141] APPLiA and InSites Consulting. (2018). Tumble dryer usage and attitudes: A survey in 12 European countries (not publicly available). Draft version.

machines[142] indicated that it was beneficial to replace at the time of the study a C-labelled washing machine with an A+ or A++ immediately after purchasing the product with regard to most environmental impact categories (including energy consumption and CO_2-emissions), despite the impacts of producing a new machine[143]. Tumble driers have many similarities with washing machines and it is also assumed that it is beneficial to replace poorly labelled tumble driers with new and efficient models. With time it is assumed that tumble driers will reach a level of energy efficiency that limits further improvements which means that an improved (longer) lifetime could be beneficial.

A study on the impacts of increased reparability[144] concluded that simple measures could have neutral to positive impact on the environment, but with some clear gains of resources. The study assessed the environmental impacts on four different measures related to reparability. These four measures are briefly described below:

- Option 1 – Measures to ensure provision of information to consumers on possibilities to repair the product
- Option 2 – Measures to ensure provision of technical information to facilitate repair to professionals
- Option 3 – Measures for the provision of technical information to consumers to facilitate simple self-repairs
- Option 4 - Measures to enable an easier dismantling of products

These options are connected with a range of assumptions but common for all is their ability in some degree to support the ideas of the circular economy and stimulate more repair of products and prolong the lifetime. The impacts on the energy consumption, emission of CO_2-eq and consumption of resources (used for the production of appliances and spare parts) of the four measures are presented in Table 29. Note that the baseline is described as:

"The baseline corresponds to the business as usual scenario where a new product is bought when the previous fails unless it is repaired according to the current repair rates. Products are replaced by new more efficient ones at the end-of-life. A certain share of the products at the end-of-life is repaired and changes ownership. Disposed products are treated as waste with some materials being recycled and other materials landfilled or incinerated."

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[142] Environmental Life Cycle Assessment (LCA) Study of Replacement and Refurbishment options for household washing machines (2011). Final report. WRAP. Available at: http://www.wrap.org.uk/sites/files/wrap/Technical%20report%20Washing%20machine%20LCA_2011.pdf

[143] http://www.wrap.org.uk/sites/files/wrap/Technical%20report%20Washing%20machine%20LCA_2011.pdf

[144] Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV.

Please note that the results mostly can be used as indicative to show whether each measure has a negative, neutral or positive impact on the environment.

Table 29: Impact of different measures to increase the reparability

Washing machines						
	Baseline		Option 1	Option 2	Option 3	Option 4
Energy	7,173.9 mil. GJ	Min	-0.1%	-0.1%	0%	-0.1%
		Max	-0.3%	-0.3%	0%	-0.5%
Emission of CO_2-eq	1319.4 mil. tonnes	Min	0%	0%	0%	0%
		Max	0%	-0.1%	0%	-0.1%
Resource consumption	26.4 mil. tonnes	Min	-0.1%	-0.1%	0%	-0.2%
		Max	-0.4%	-0.3%	0%	-0.7%

The findings in the study indicate that option 1, option 2 and option 4 all have a positive effect on the environment with reductions in energy consumption and resource consumption. Option 2 and option 4 may also have a positive effect on the emission of CO_2-eq. Option 3 which is the measure for the provision of technical information to consumers to facilitate simple self-repairs has neutral impact, as the consumers are considered to perform only simpler repairs.

Availability of spare parts

Spare parts are crucial to ensure a long lifetime of products and are needed to prevent premature failure.

It is assumed that most manufacturers provide spare parts but the availability in time can differ from the different manufacturers. In some cases[145], spare parts are available on the internet and in others, third party companies offer spare parts and sometimes also a repair service.

From a quick survey on the internet it seems like spare parts are available from a large range of different manufacturers but the availability in time is difficult to quantify. A stakeholder has indicated that they supply spare parts for at least 10 years which seems to be adequate compared with the assumed lifetime. However, the spare parts availability may not always be sufficient. A recent survey[146] found that 17% of the consumers that tried to purchase spare parts could not find them. From those who found the necessary parts, 18 % of them found them too expensive.

[145] E.g. https://www.miele.co.uk/domestic/spare-parts-and-accessories-383.htm
[146] https://www.ellenmacarthurfoundation.org/assets/downloads/ce100/Empowering-Repair-Final-Public.pdf

The study on the impacts of increased reparability[147] also investigated the impact of measures to ensure supply of spare parts for at least a certain amount of years and the combination of different options, which are:

- Option 5 – 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
- Option 6 – Combination of option 5 and option 2 presented in the above section about repair and maintenance (measures to ensure provision of technical information to facilitate repair to professionals)
- Option 7 – Combination of scenarios 5 & 4 presented in the above section about repair and maintenance (measures to enable an easier dismantling of products)

The results of these assessments is shown on Table 30. Please note that the results mostly can be used as indicative to show whether each measure have a negative, neutral or positive impact on the environment.

Table 30: Impact of different measures to increase the reparability – availability of spare parts

Washing machines					
	Baseline		**Option 5**	**Option O6**	**Option O7**
Energy	7,173.9 mil. GJ	Min	-0.2%	-0.2%	-0.2%
		Max	-0.7%	-0.8%	-1%
Emission of CO_2-eq	1319.4 mil. tonnes	Min	0%	0%	0%
		Max	-0.1%	-0.2%	-0.2%
Resource consumption	26.4 mil. tonnes	Min	-0.2%	-0.3%	-0.3%
		Max	-0.9%	-1%	-1.2%

In Figure 55 all options are compared with each other and it seems like that the most beneficial single option is the measure to ensure spare parts for a certain amount and years (Option 5). However, both of the combined options (option 6 and option 7) may have even greater impact (positive impact) on the environment. It should be noted that both of these combined options also include option 5.

[147] Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV.

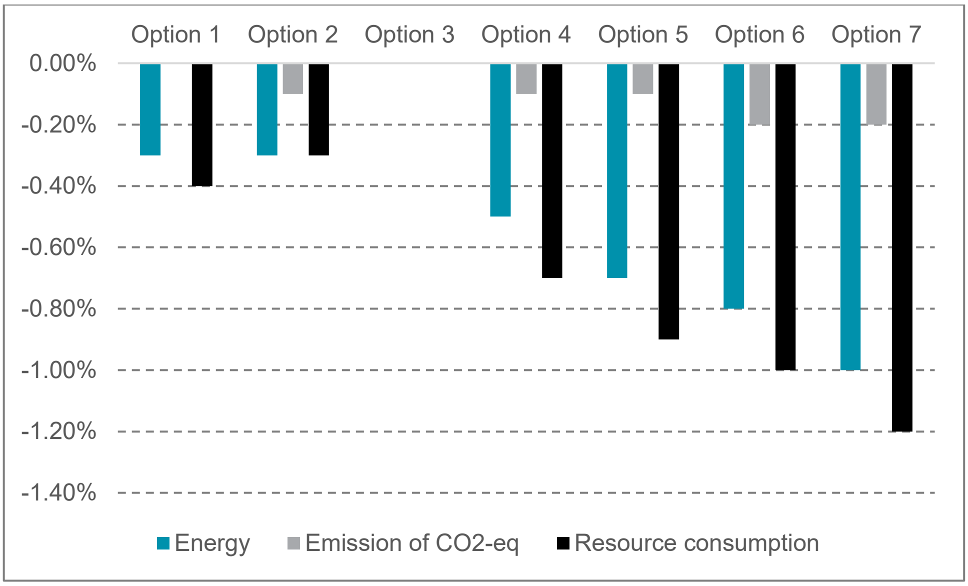

Figure 55: Impact of all options towards increased reparability

Different approaches can be implemented towards improved reparability, reusability, recyclability, dismantlability and a prolonged lifetime as discussed above. The lifetime is not solely dependent on break downs or malfunctioning components as more consumers are replacing functioning appliances due to a desire for an improved model with e.g. improved efficiency.

Critical parts

Critical spare parts are the parts that are important for the function of the tumble driers. Based on a survey and inputs from manufacturers[148] the critical spare parts are presented in Table 31.

Table 31: Critical components and assessment of the ease of replacement

Component	Is the component easy to replace?
Pumps	Depending on brand and location of the pump
Fans	Depending on brand as some states it is difficult to replace while other states it is easy for a professional
Motor(s)	Depending on brand as some states it is difficult to replace while other states it is easy for a professional
Electronics	Depending on brand as some states it is difficult to replace while other states it is easy for a professional
Compressor	Difficult to replace or no access
Heat exchanger	No access

[148] Stakeholder consultation

According to input from stakeholders[149], the most replaced parts in tumble driers that are repaired are pumps, belts (moving the drum) and resistance (heating element). The frequency of these replaced parts and their price range are presented in Table 32.

Table 32: Frequency and price range of replaced parts[149]

Component	Frequency of replacement	Price range
Resistance	42.19%	40-80 EUR
Pump	18.75%	25-50 EUR
Strap/belt	14.06%	10-15 EUR
Turbine	13.28%	15-40 EUR
Drum	9.38%	100-180 EUR
Tension idler	2.34%	10-30 EUR

According to preliminary results from an ongoing study on the development of a scoring system for repair and upgrade[150], 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

Pumps appear as important in both Table 31 and Table 32, and are critical parts because they are likely to fail and the price would not be a barrier for replacement. Heating elements are also important because of their frequency of failure, in spite they are not listed as critical components. Fans and motors are essential for the functioning of the driers, same as compressors and heat exchangers although there is limited information on the ease of disassembly for the latter.

In summary, it can be concluded the critical parts of tumble driers are:

- Pumps
- Motors
- Fans

[149] Stakeholder consultation, inputs based on NGO network working on repair in France. The presented values are for the most sold model (tumble drier)

[150] Analysis and development of a scoring system for repair and upgrade of products – draft version 1. Published 20th June 2018 by Joint Research Centre, Directorate B, Growth and Innovation (Sevilla). Unit 5, Circular Economy and Industrial Leadership.

- Heating elements

Potential resource efficiency requirements could focus on the availability of these critical parts.

3.2.3 Best practice in sustainable use

Sustainable product use can minimize the energy consumption of tumble driers and a few best practices are listed in this section.

As discussed previously, it is important to purchase a properly sized tumble drier and not buying it oversized. This may result in operation at part load, which increases the specific energy consumption (see section 3.1.1). According to presented data in this section, consumers load the machines similarly regardless of the capacity. Consumers may buy large appliances for the convenience if they want to dry large blankets resulting in operation with a low load most of the year. It is also important to spin the clothes properly in the washing machine as it is less energy intensive to spin the clothes in the washing machine than to dry it in the tumble drier.

Other important aspects may be:

- Proper maintenance of the appliance and specially to clean the lint filter between uses. This will allow the correct air flow through the appliance.
- Use a lower dryness level than, e.g. cupboard dry, if the clothes have anyway to be ironed afterwards.
- Use the moisture sensor if it is available to avoid over drying.

3.2.4 Collection rates at households/other users

Following the framework of the WEEE Directive, tumble dries must be collected at end-of-life and sent to suited facilities for reprocessing. Illegal trade and sales of scrap challenge the collection rate for some product categories. The statistics from Eurostat present products placed on the market and waste collected for large household equipment[151]. No statistics are available specifically for tumble dries collected so the actual collection rate is difficult to quantify.

From 2019 onwards, the minimum collection rate to be achieved annually shall be 65% of the average weight of Electrical and Electronic Equipment (EEE) placed on the market in the three preceding years in each Member State, or alternatively 85% of Waste Electrical and Electronic Equipment (WEEE) generated on the territory of that Member State[152]. Table 33 shows the collection rate for large household appliances calculated based on the WEEE

[151] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_waselee&lang=en
[152] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=EN

collected in 2014 and the average weight of EEE placed on the market in the three preceding years.

Table 33: Calculated collection rate of large household equipment in Europe, 2014

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

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

3.2.5 Conclusion on consumer behaviour related to product durability and end-of-life

In general, the average lifetime of household equipment is falling, and the initial service life has declined from 14.1 years to 13.0 years between 2004 and 2012 of large household appliances. This highest reduction in life time was observed for freezers and tumble driers which decreased from 18.2 to 15.5 years and 13.6 to 11.9, respectively. So the average lifetime of tumble driers in the current study is reduced to 12 years. Regarding heat pump condenser driers, the lifetime seemed to be reduced for the first models available on the market but today the manufacturers have no indication to suggest that heat pump condenser driers have a shorter life time than other types of tumble driers. Based on a consumer study performed by APPLiA the durability of heat pump condenser driers is not expected to present particular issues and the consumers rarely experience any technical failures.

A way to improve the lifetime of household appliances is to design products with more possibilities of repair so it is more affordable for the consumers to repair than exchange appliances. Currently the repair and maintenance practices are expected to be done by professionals and in some cases by the end user. Based on the Deloitte study 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

The option with measures to facilitate simple self-repairs was considered to have a neutral effect because of the limitation in repair procedures that can be performed by the consumers.

3.3 Local infrastructure

3.3.1 Electricity

The power sector is in a transition state moving from fossil fuels to renewable energy. The origin of the electricity is a very important factor to consider both regarding the environmental impact by using a tumble drier and how it may affect the consumer behaviour (smart grid functionalities). Within the EU there are a number of renewable energy targets for 2020 set out in the EU's Renewable Energy Directive[153]. The overall target within the EU is 20% of final energy consumption from renewable sources. The final energy consumption is the total energy consumed by end-users, such as households, industry and agriculture. It is the energy which reaches the final consumer's door and excludes that which is used by the energy sector itself[154]. To achieve this goal of 20 % from renewable sources the different EU countries have committed to set their own individual goal ranging from 10 % in Malta to 49% in Sweden. In 2015 the share of renewable energy was almost 17% (gross final energy consumption)[155].

The electricity consumption is a major part of the final energy consumption and the electricity mix is highly relevant for quantifying the environmental impacts of tumble driers at EU-level. The electricity mix in 2015 is presented in Figure 56.

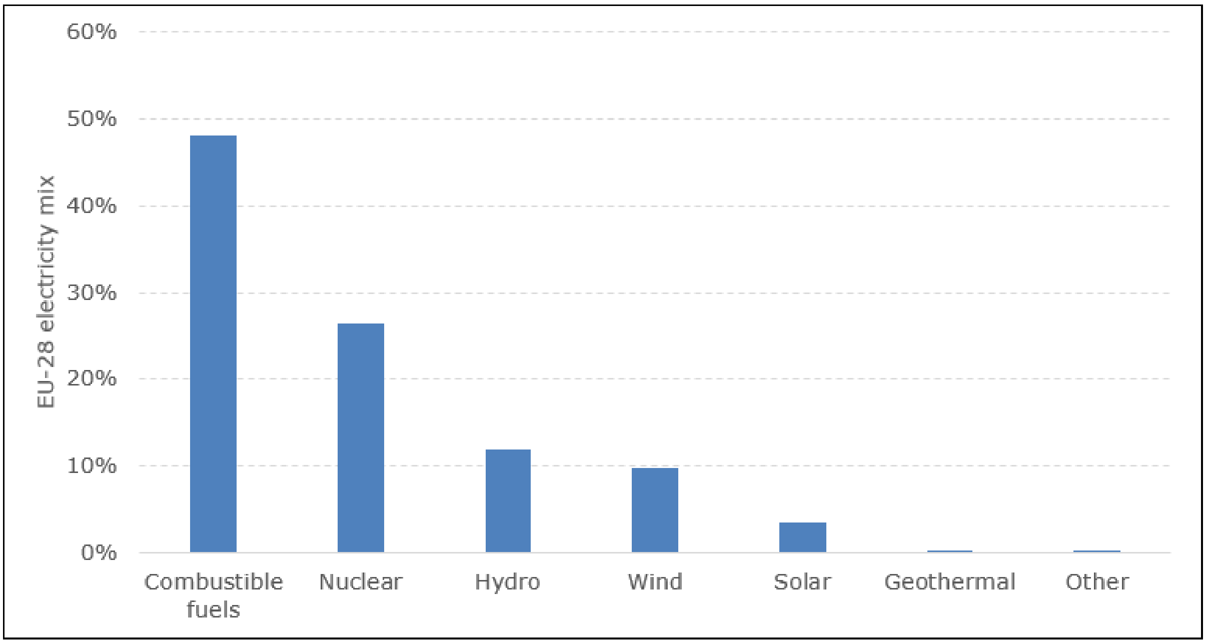

Figure 56: Net electricity generation, EU-28, 2015 (% of total, based on GWh)[156]

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

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 two-directional transfer of energy

[153] https://ec.europa.eu/energy/en/topics/renewable-energy
[154] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Final_energy_consumption
[155] http://ec.europa.eu/eurostat/documents/2995521/7905983/8-14032017-BP-EN.pdf/af8b4671-fb2a-477b-b7cf-d9a28cb8beea
[156] http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Net_electricity_generation,_EU-28,_2015_(%25_of_total,_based_on_GWh)_YB17.png

(e.g. electric cars that can supply electricity to the grid when it is not in use). Due to technological development, the reliability of the electricity supply in many EU countries is ensured via the expansion of the electricity grid to distribute renewable energy. The quality of the electricity grid in Europe is considered to be high and among the best in the world. Every year the World Economic Forum releases a Global Energy Architecture Performance Index report. The report is ranking the different countries on their ability to deliver secure, affordable, sustainable energy. In recent years European countries have dominated the top spots (see Table 34)[157].

Table 34: Top spots of the global Energy Architecture Performance Index report

Country	2017 score	Economic growth and development	Environmental sustainability	Energy access and security
Switzerland	0.8	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

The consumer behaviour might affect the electricity system in some countries since the use of tumble driers are assumed to be more common in the winter period where the monthly energy consumption is higher for most countries. In Table 35 are the monthly electricity consumption presented for most of the EU countries[158]. Note that the peak consumption is marked with red and the lowest consumption marked with blue.

[157] https://www.weforum.org/reports/global-energy-architecture-performance-index-report-2017
[158] Data provided by ENTSO-E

Table 35: Monthly electricity consumption

MONTHLY CONSUMPTION (IN GWh)													
Country	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Total**
Austria	6498	5984	6203	5542	5468	5376	5588	5436	5271	5900	6005	6234	69505
Belgium	8057	7312	7653	6940	6795	6657	6548	6609	6731	7221	7202	7284	85009
Bulgaria	3455	3068	3111	2639	2404	2363	2611	2537	2416	2703	2766	3171	33244
Cyprus	368	364	338	283	314	343	452	495	441	351	298	358	4405
Czech Republic	6019	5584	5774	5200	4972	4818	4859	4641	4865	5509	5553	5624	63418
Germany	48952	45608	46179	40889	39607	39875	41470	39824	40911	45723	46280	45289	520607
Denmark	3188	2909	2916	2306	2648	2907	2556	2692	2697	1943	2555	3113	32430
Estonia	816	719	743	679	634	573	574	593	624	719	714	751	8139
Spain	23883	22048	22279	19837	21016	21614	24972	22341	20897	20964	20985	22069	262905
Finland	8437	7336	7645	6756	6268	5838	5941	6008	6118	7138	7279	7730	82494
France	52475	48579	45707	36847	33873	33225	34887	31582	33483	39167	40985	44593	475403
United Kingdom	32243	29083	31380	26097	26044	24327	24569	24361	25082	28320	30380	30768	332654
Greece	4829	4299	4504	3772	3823	3965	4855	4687	4086	3835	3895	4610	51160
Croatia	1538	1429	1461	1314	1292	1288	1573	1494	1336	1351	1369	1539	16984
Hungary	3629	3316	3507	3218	3209	3249	3484	3342	3313	3507	3490	3491	40755
Ireland	2498	2279	2397	2154	2192	2055	2100	2087	2120	2276	2353	2445	26956
Italy	26786	24948	26793	24169	25027	26328	31970	24458	26449	25907	25675	25818	314328
Lithuania	1005	891	920	873	862	825	846	863	866	955	958	995	10859
Luxembourg	574	538	579	516	497	503	542	512	492	554	547	514	6368
Latvia	692	616	635	589	571	522	549	568	562	625	626	654	7209
Netherlands	10343	9183	9588	8741	8881	8823	9191	9049	9149	9685	9763	10119	112515
Poland	13546	12327	13116	12060	12011	11716	12333	12295	12099	13257	13066	13254	151080
Portugal	4713	4232	4167	3727	3939	3964	4280	3907	3883	3987	3977	4189	48965
Romania	5023	4598	4791	4435	4258	4202	4636	4398	4266	4665	4634	4877	54783
Sweden	14100	12610	12851	10967	10494	9602	8907	9561	9888	11578	12242	13130	135930
Slovenia	1233	1130	1178	1067	1092	1088	1149	1073	1099	1175	1164	1199	13647
Slovakia	2470	2277	2393	2194	2157	2115	2191	2136	2128	2360	2350	2405	27176

Only a few southern countries have their peak consumption in July and August and the majority of the countries have their peak consumption in January. The lowest monthly electricity consumption levels are, for most countries within EU, in June. The hourly load values for a random Wednesday in March 2015 for selected countries are presented in Figure 57.

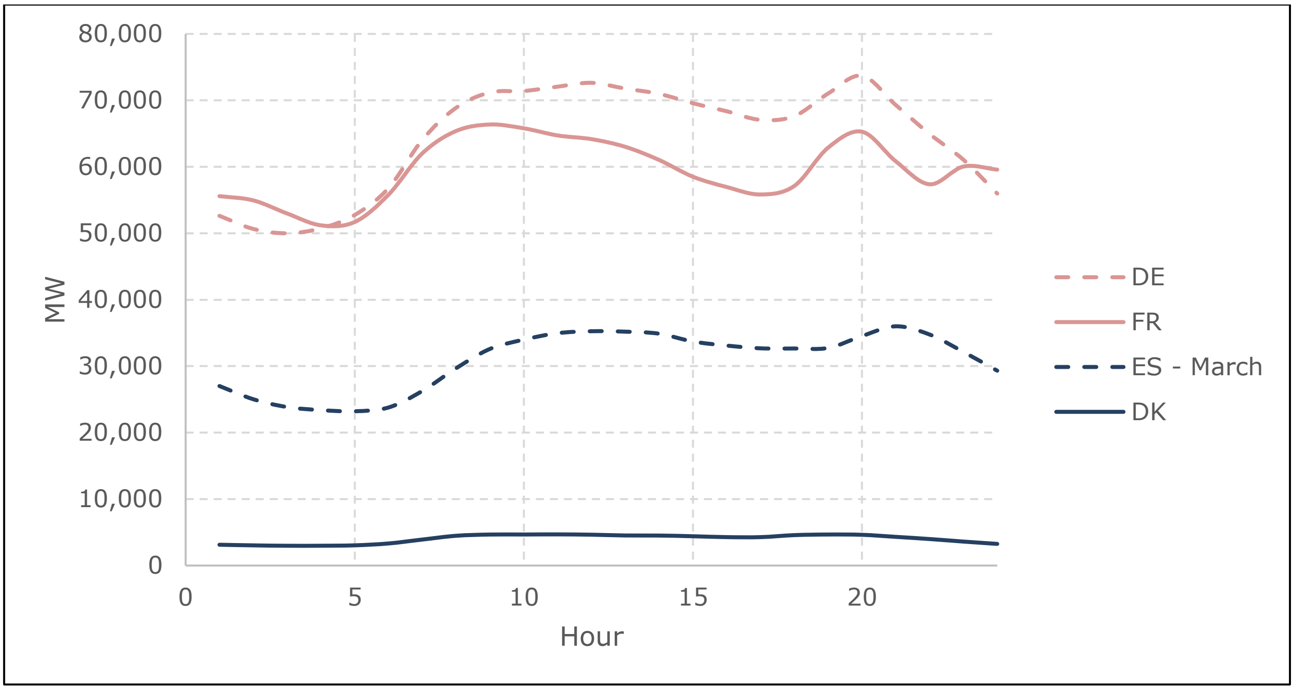

Figure 57: Hourly load values a random day in March

All presented countries have similar hourly load values with two peaks, one in the morning and one in the evening. It is barely visible for Denmark, but this is due to scale of the graph. However, there are small shifts in the peaks. In Denmark, the peaks occur a little earlier than in Spain. 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 is at 5 AM. For most countries, this hourly load curve fits this description of the majority of the days. For months and days with a higher or lower consumption tendency the profile is very similar with more pronounced shifts up or down.

Renewable energy production can vary greatly from hour to hour and day to day. In the future, products that can respond to an external stimulus (e.g. smart appliances), can provide balance and flexibility to the energy system. Though, tumble dries are dependent on washing machines and they need to be operated within a certain time period after the end of the washing cycle to avoid bad odour from the clothes. It is possible to postpone the start of tumble driers a little, but the flexibility of combined washers and driers are assumed to be higher.

3.3.2 Gas

The reliability of the energy system as a whole is high. The values presented consider the entire energy system including the gas system. Nevertheless, the gas supply may be less reliable than the electricity supply due to the high imports of gas from non-EU28 countries. Norway and Russia are major suppliers of gas, and Russia's supply often goes through transit countries such as Ukraine and Belarus. The gas supply in Europe is roughly described in Figure 58[159] and presents possible shortage in the supply chain.

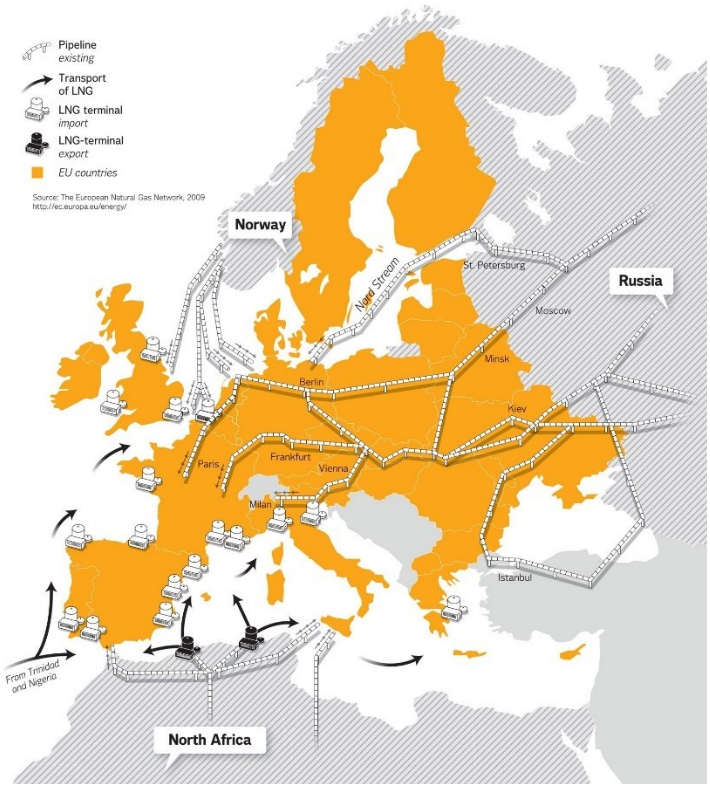

Figure 58: Rough drawing of the transport of gas in Europe

Roughly a quarter of all the energy used in the EU is natural gas, and many EU countries import nearly all their gas and some of these countries are heavily reliant on a single source or a single transport route for the majority of their gas. These countries are more vulnerable to disruptions in their gas supply. Disruptions can be caused by infrastructure failure or political disputes.

To prevent supply disruptions and quickly respond to them if they happen, EU created common standards and indicators to measure serious threats and define how much gas EU countries need to be able to supply to households and other vulnerable consumers. In 2017, a new Regulation regarding the security of the gas supply[160] was introduced. The new Regulation has a number of requirements which e.g. requires the European Network for Transmission System Operators for Gas (ENTSOG) to perform EU-wide gas supply and infrastructure disruption simulation in order to provide a high level overview of the major supply risks for the EU and introduces a solidarity principle (EU countries must help each other to always guarantee gas supply to the most vulnerable consumers even in severe

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[159] https://corporate.vattenfall.com/about-energy/energy-distribution/gas-distribution/
[160] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1938&from=EN

gas crisis situations). Such precautions increase the reliability of the gas supply and therefore is the supply of gas assumed to be reliable.

3.4 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 in Table 36 are given in the Regulations.

Table 36: Verification tolerances set out in the Regulations

Test parameter	Unit	Tolerance
Weighted annual energy consumption (AE_c)	kWh/year	6%
Weighted energy consumption (E_t)	kWh	6%
Weighted condensation efficiency (C_t)	%	6%
Weighted programme time (T_t)	Minutes	6%
Power consumption in off mode and left-on mode (P_o and P_l)	W	6% for consumption more than 1.00W. 0.1W for consumption below 1.00W
Duration of the left-on mode (T_l)	Minutes	6%

The verification tolerances are closely related to the tests and their uncertainties. It is proposed to keep the current tolerances for verification purposes, until the results of the Round Robin Test performed by APPLiA are disclosed[161]. This is also aligned with what recommended by JRC in their preparatory study for washing machines and washer driers (2017) for their energy consumption (E_t) value.

[161] According to latest input from industry, the results of the RRT are expected to be shared with the Commission in May 2019.

4. Technologies

Technical improvements at product level have emerged on the market for tumble driers since the preparatory study, but mostly for heat pump condenser tumble driers. As seen in task 2, the four main types of tumble driers, air-vented with heating element, air-vented with gas combustion, condensing with heating element and condensing with heat pump still exist. However, very few models of gas-fired tumble driers have been available for sale on the EU market and no major developments in this type of drier has been made in the past 10 years[162]. Gas fired tumble driers represented 0.01% of the total sales from 2013-2016[163].

Concerning technologies, some technologies and/or addons mentioned as available during the preparatory study have been discontinued[164] (see below):

- **Air-vented** driers:
  - Exhaust air recovery.
  - Air-vented drier with heat pump technology.
- **Condensing** driers:
  - External heat source driers.

The Best Available Technology (BAT) from the preparatory study was condensing heat pump driers. Nowadays, these are still presenting the highest energy efficiency. The increase of efficiency of the BAT has been obtained by improving the integrated heat pump and adding more efficient components, instead of introducing a new type of heating technology. Heat pump driers have progressed from having a market penetration rate below 5% during the preparatory study (in 2009), to being the most commonly sold type of tumble drier accounting for 52% of sold units in 2016[163]. The heat pump drier can hence be considered as the most common tumble drier technology on the current market.

As the working principle of the current available technologies have had no major alterations since the preparatory study, the focus in this task is to look at the different components in the tumble drier, to identify the major developments that have been made.

The tumble drier unit consists of multiple components which can be of different types and qualities. Some are found in all tumble driers types and from these, the following components and their configurations have a major influence on the energy consumption:

- The motor type and setup

[162] According to input from industry
[163] Source: GfK data
[164] According to desktop research

- The presence of variable speed drives for fans and drum motors
- The controller, including humidity sensor components
- The drum design and sealing method
- The cleanliness of lint filters and heat exchangers

Additionally, for condensing driers:

- Air to air heat exchanger type, material, and size

And furthermore, for heat pump condensing driers

- Compressor size, type and motor

Based on input from industry[165], Table 37 shows a list of the major components and technologies having an impact on the energy efficiency of the drier. Each component/technology and relevant improvement options are described in more details in section 4.1.

Table 37: List of components for the average tumble drier.
HP-C = Condensing heat pump drier, HE-C = Condensing heating element drier, HE-V = air-vented heating element drier, GA-V = air-vented gas fired drier.

Tumble drier technology/Component	Average drier on the market	*Relevant for*			
		HP-C	**HE-C**	**HE-V**	**GA-V**
MOTORs					
Motor type setup (one or multiple)	One	x	x	x	x
Motor type (drum)	AC-Induction	x	x	x	x
Motor type (compressor)	AC-Induction	x			
↳ If permanent magnet, has REM[166]	No	x	x	x	x
VSD on motor drum drive	No	x	x	x	x
VSD on motor fans	No	x	x	x	x
VSD on compressor motor	No	x			
CONTROLLER					
Type of automatic controller	Automatic moisture sensor controller (direct way)	x	x	x	x
HEAT EXCHANGER (Air to air)					
Heat exchanger material	Aluminium		x		
Heat exchanger type	Plate-fin[167]		x		
Self-cleaning heat exchangers	No		x		

[165] Questionnaire sent to APPLiA members on technologies during months February-March 2018
[166] Rare earth materials
[167] https://en.wikipedia.org/wiki/Plate_fin_heat_exchanger

Tumble drier technology/Component	Average drier on the market	*Relevant for*			
		HP-C	**HE-C**	**HE-V**	**GA-V**
HEAT EXCHANGER (Refrigerant - air)					
Heat exchanger material	Aluminium fins + copper tubes	x			
Heat exchanger type	Fin-and-tube[168]	x			
Self-cleaning heat exchangers	No	x			
COMPRESSOR					
Compressor size	400-600 W	x			
DRUM					
Drum material	Steel	x	x	x	x
Direct Drive	No	x	x	x	x
Drum leakage	High/Medium	x	x		
FILTERS[169]					
Anti-clogging design	No	x	x	x	x

4.1 Products with standard improvement design options

The following subsections give general descriptions of key components and how improvements for each component can lead to energy efficiency improvements.

4.1.1 Motors for all drier types

The motors used for driving the drum and fans are of different types, from single-phase capacitor run induction motors to synchronous motors, such as brushless DC motors (BLDC). Furthermore, variable speed drives can be used for motors running the drum drive, the fans and/or the compressor (the latter only for heat pump driers).

Synchronous motors, such as BLDC motors, are generally more efficient than traditional asynchronous AC induction motors (both single and three phased)[170]. This is partly because induction motors use current to create electromagnets, where synchronous motors utilize permanent magnets. Synchronous motors are however typically more expensive, and they require a controller (frequency inverter) to be present in the unit.

With the introduction of BLDC motors, the overall motor configuration has changed as well. Whereas in the preparatory study almost every drier used one single motor to drive the drum and the fan for process air and to drive the fan for the condensing air (in condensing driers only) or compressor cooling air (heat pump driers only), some top-class driers nowadays use a smaller BLDC for each of these systems. This can improve the overall efficiency, as it enables the machine to switch individual systems on/off as they are needed.

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[168] https://www.enggcyclopedia.com/2012/03/finned-tube-heat-exchangers/
[169] Both the primary lint filter, and for the condenser lint filter for HP-C driers without self-cleaning heat exchangers.
[170] http://www.orientalmotor.com/brushless-dc-motors-gear-motors/technology/AC-brushless-brushed-motors.html

4.1.2 Variable Speed Drives for all drier types

The introduction of variable speed drives introduces a range of benefits. They can be placed on each of the before mentioned systems, as well as on the compressor for heat pump driers.

Using a variable speed drive on the heat pump compressor can give major improvements to the efficiency[171], especially with regard to part load operation or when reduced drying temperatures are wanted (for long cycles or delicate fabrics).

A heat pump efficiency is fundamentally linked to the temperature levels in the evaporator and condenser. A large temperature difference results in low efficiency and vice versa. These temperatures, represented as the evaporation and condensation temperature, are the results of multiple parameters, such as pressure ratios, heat exchanger effectivities, and refrigerant flow rate. Larger heat exchangers can sustain a lower temperature difference between the refrigerant and the process air, which improves performance by reducing the difference between the evaporation and condensation temperatures.

When lowering the flow rate by reducing the speed of the compressor, the heat flux from the condenser to the process air is lowered. As the size of the heat exchangers however remain constant, the temperature difference can be lowered and thus – as mentioned before – increase the performance. Another major benefit is the reduction of the energy consumption associated with start-up of the heat pump unit, which can be substantial at part load operations, as the heat pump unit can run continuously instead of start-stop operation.

4.1.3 Controller for all drier types

99% of all commercially available driers are equipped with a controller that automatically turns off the drier when a specific moisture content is reached in the laundry[172]. This is done either by directly measuring the moisture level through a conductivity sensor in contact with the laundry, or indirectly by measuring the humidity level in the process air. Accurately monitoring the moisture content is key to an efficient drying process, as an inaccurate measurement can lead to either under- or over drying the laundry, either resulting in poor drying performance, or an increased energy consumption.

4.1.4 Heat exchangers for condensing driers

Two different types of heat exchangers exist. For heating element condensing driers, a condenser exists which condenses the water vapor in the process air, by parsing it through

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171 http://www.rehva.eu/publications-and-resources/rehva-journal/2012/052012/capacity-control-of-heat-pumps-full-version.html
172 APPLIA Model database 2016

a heat exchanger cooled by the outside air via a fan. This is hence an air-to-air heat exchanger.

For heat pump condensing driers, an additional heat exchanger exists between the process air and the refrigerant, which is used to deliver the heat from the heat pump cycle to the process-air. It acts as a condensing unit for the refrigerant and is thus a liquid/air-to-air heat exchanger.

Furthermore, the process-air condensing heat exchanger uses the heat pump cycle instead of outside air to condense the water. It acts as an evaporator unit for the heat pump cycle and is thus also a liquid/air-to-air heat exchanger.

The efficiency of the heat exchangers plays an important role with regard to the energy consumption of the driers – especially the heat pump unit, as more efficient heat exchangers can reduce the pressure levels in the heat pump cycle. For the heating element condensing driers, a more efficient heat exchanger increases the condensation rate.

Common for both types, is that the thermal conductivity in the material used is directly linked to the efficiency. Copper is a commonly used material for heat exchangers but is also expensive. Other options are aluminium, nickel alloys, or even stainless steel – all of which are cheaper, but also have a lower thermal conductivity and thus comparably lower effectiveness.

4.1.5 Compressor for heat pump condensing driers

In heat pump driers, the size of the compressor (i.e. pressure ratio and volume flow) is directly linked to the maximum achievable temperature of the process air. Larger compressors can hence reduce drying times but are also more expensive. Larger compressors are thus seen in some top models, which add shorter cycle times as a feature.

As the compressor is the component using the largest amount of energy, it is vital that the compressor itself is efficient. The whole heat pump circuit (compressor, heat exchangers, refrigerant) can however only run efficient if all components are optimised with respects to each other and the goal of which the optimisation process is revolved around, whether it is to run efficient, fast, or a combination hereof. For instance, if replacing a compressor in a circuit with a larger more efficient, the heat pump cycle might experience bottle-necking in the heat exchangers, resulting in frequent start/stop of the compressor. This could lead to the whole system being less efficient, even though the new potential compressor has a higher efficiency than the original.

4.1.6 Refrigerants for heat pump condensing driers

Different types of refrigerants currently exist in tumble driers on the market. These range from F-gasses (Like R134a) to organics (Like R290/Propane). The type of refrigerant is chosen based on the sought temperature levels and specific compressor and its corresponding pressure ratios. Organic refrigerants are preferred from a global warming potential perspective, and more recent desktop research shows they do not have an effect on the energy efficiency of the whole heat pump circuit. A report from the Energy Efficiency Task Force of the Montreal Protocol[173] states that using organic refrigerants instead of F-gasses can change energy consumptions by +/- 5% - 10%. The potential added energy consumption and thus CO_2-eq. emissions are however ~35% lower[174], when taking the GWP of the F-gasses used into consideration. This is assuming that no recycling of the refrigerants takes place.

Stakeholders however have reported that driers with R290 is not negatively affected regarding energy efficiency compared to driers with R134a. Models with R290 is currently on the market and able to achieve an A+++ energy label[175]. The thermodynamic properties of R290 supports this, requiring a lower pressure difference in order to sustain the same heat flux compared to R134a[176].

4.1.7 Drum, bearings, and sealing for all drier types

The drum itself can be of different kinds of material (e.g. stainless steel, steel, zinc). This have however no impact on energy efficiency, and only on the look and feel of the model.

The sealings are crucial to the condensation efficiency of the drier, but also to the energy consumption of the drum motor. A better seal causes more friction when turning the drum, and thus requires more torque from the drum motor. The energy and condensation efficiency of the drier are thus to some extent inversely proportional. If the drier however is places in a heated room, a low condensation efficiency requires additional ventilation and thus reduces the overall system energy efficiency.

4.1.8 Filters for all drier types

The lint filters act as a protective screen against lint-build up in the machine. Clogged filters reduce the process air flow, which reduces the drying efficiency. This effect is present as

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[173] http://conf.montreal-protocol.org/meeting/oewg/oewg-40/presession/Background-Documents/TEAP_DecisionXXIX-10_Task_Force_EE_May2018.pdf
[174] Assuming a 12-year lifetime, 240 AEc, and 380g of R134a refrigerant.
[175] According to stakeholders, and according to a desktop study.
[176] For instance, the difference in condensation and evaporation temperatures are higher for R290 than it is for R134a for equal pressure differences. *Source:* CoolProp

soon as the cycle starts, and thus marginally increases energy consumption during the cycle[177]. Designing filters less prone to clogging, or simply with better flow characteristics, reduces this effect and is thus advantageous to the energy efficiency.

4.1.9 Additional features

Network connectivity: Some high-end tumble driers from major manufacturers are beginning to be equipped with modules for internet connectivity over LAN or Wi-Fi. This enables control of the unit with a dedicated smartphone application, for remote start operations and for notifications when the cycle is completed.

Self-cleaning heat exchangers for condensing driers: Top model heat pump driers can be equipped with self-cleaning condenser heat exchangers[178], by flushing the heat exchanger during the drying cycle. This removes the need for regularly maintaining the heat exchanger. This is an extra feature, which might reduce efficiency losses through wear and lint build up, which otherwise could lead to significantly higher energy consumption and cycle times[177].

Some manufacturers claim that the self-cleaning heat exchanger technology reduces the lifetime of the drier, as the water-and-lint slurry eventually accumulates (if not cleaned every 20 cycles as recommended by some manufacturers), in the unit and leads to clogging in inaccessible parts of the machine which can then only be remedied by a repair.

4.2 Best Available Technology BAT

The list of improvement-capable components can be summarized similarly to the average tumble drier in Table 37. Table 38 shows the BAT for each component. Note that the heat pump driers *always* outperform the other types and should hence still be classified as the BAT tumble drier.

During the preparatory study, air vented driers with heat pumps as heat source were presented as a BAT technology and a design option. No air vented models with heat pumps are currently available on the market. According to stakeholders, no models of this type are currently in the pipeline.

Combining an air vented drier with a heat pump circuit would increase the unit cost substantially and would induce problems with condensation in the evaporator. In short, an air vented heat pump drier would properly cost the same as current heat pump driers, but with a higher energy consumption and with the added draw backs associated with air

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[177] "EXPENSIVE MEASURES FOR THE ENVIRONMENT", Berge et al., RÅD & RÖN No. 7, 2012
[178] Condenser here being the *water* condenser, and the heat-pump cycle evaporator

vented driers described in 3.1.3. This option is hence not pursued any further, as no market seems to exist for these types of driers.

Table 38: List of components for the BAT-tumble drier.
HP-C = Condensing heat pump drier, HE-C = Condensing heating element drier, HE-V = air-vented heating element drier, GA-V = air-vented gas fired drier.

Tumble drier technology/Component	BAT-Tumble drier	*Relevant for*			
		HP-C	HE-C	HE-V	GA-V
MOTOR					
Motor type setup (One or multiple)	One / Multiple	x	x	x	x
Motor type (Drum)	BLDC[179]	x	x	x	x
Motor type (Compressor)	BLDC[179]	x			
↳ If permanent magnet, has REM	No	x	x	x	x
VSD on motor drum drive	Yes	x	x	x	x
VSD on compressor motor	Yes	x			
CONTROLLER					
Type of automatic controller	Automatic moisture sensor controller (direct way)	x	x	x	x
HEAT EXCHANGER (Air to air)					
Heat exchanger material	Aluminium		x		
Heat exchanger type	Plate-fin		x		
Self-cleaning heat exchangers	No		x		
HEAT EXCHANGER (Refrigerant - air)					
Heat exchanger material	Aluminium fins + cobber tubes	x			
Heat exchanger type	Fin-and-tube	x			
Self-cleaning heat exchangers	No / Yes	x			
COMPRESSOR					
Compressor size	400-600 W	x			
DRUM					
Drum material	Stainless Steel	x	x	x	x
Direct Drive	No	x	x	x	x
Drum leakage	Low (<10%)	x	x		
FILTERS[169]					
Anti-clogging design	Yes	x	x	x	x

4.3 Best Not Yet Available Technology BNAT

None of the BNAT technologies described in the preparatory study have emerged on the market. These include:

- Modulating gas driers

[179] A synchronous permanent magnet motor, i.e. brushless permanent magnet motor (BLDC). Can also be referred to as ECM/PMSM

- Vacuum driers
- Mechanical steam compression driers
- Microwave driers

They are hence still considered as BNAT technologies in this study. Additionally, a new technology is being tested at the University of Florida, which uses piezoelectric oscillators to mechanically dry the clothes by "vibrating" it at ultrasonic frequencies instead of using heat[180]. This means that the water is physically removed instead of being evaporated, which removes the need to overcome the latent heat of the water in the evaporation phase. This could reduce drying times, as well as reduce the energy consumption by (reported) up to 70%. No news about production timelines is available as of February 2018.

Furthermore, self-cleaning lint filters are under development. This could reduce the need for cleaning the lint filter, and thus lead to energy efficiency improvements for end-users not regularly cleaning the filter, as only 45% of users do this before every cycle (see Figure 45).

4.4 Production and distribution

The production and distribution provide a quick overview of the material composition and distribution of tumble driers. The inputs will be used to model the environmental footprint in later task. The material composition also gives valuable inputs to the discussion on resource efficiency.

4.4.1 Bill-of-Materials (BOM)

This section presents the BOM of tumble driers. The presented values will be used as inputs in the EcoReport Tool for Task 5.

Bill-of-Materials (BOM) of tumble driers

The material composition and weight of tumble driers are based on stakeholder input and are somehow similar to the values presented in the preparatory study, but with the addition of heat pump tumble driers. The material composition is of great importance to the recyclability since some materials are easier to recycle than others which will have an effect in later tasks. No data is available for gas tumble driers, so they are assumed to have a material composition similar to a regular air-vented type.

The assumed material composition of tumble driers is presented in Table 39.

[180] https://energy.gov/sites/prod/files/2016/04/f30/31297_Momen_040516-1205.pdf

Table 39: Assumed average material composition of tumble driers in the preparatory study

Material Type	Materials (examples)	Air-vented – Heat element (in g)	Condenser – Heat element (in g)	Condenser – heat pump (in g)
Bulk Plastics	PP, PP GF, ABS, PA GF[181]	9300	12800	13900
TecPlastics	Elastomer	900	679	1200
Ferrous	Sheet metal steel	18700	23473	18500
Non-ferrous	Aluminium, copper	150	1364	3500
Coating		0	0	0
Electronics	Various	5600	6040	13350
Misc.		2800	2800	6800
Total		**37450**	**47156**	**57550**

It appears that air-vented tumble driers are approximately 10 kg lighter than condenser heat element driers and 20 kg lighter than heat pump condenser driers. Heat pump condenser driers have the highest use of materials and also the highest consumption of electronics. The amount of ferrous are almost identical for these types of tumble driers, but the amount of bulk plastic is considerable higher for the condenser types.

4.4.2 Primary scrap production during manufacturing

The primary scrap production is estimated to be negligible. It is assumed that cuttings and residues are directly reused into new materials. So, the actual losses of materials are low.

4.4.3 Packaging materials

Cardboard, plastic and expanded polystyrene are used to protect the products during transport. More packing materials are sorted by the end-user and recycled. Cardboard are easily recyclable for the next purpose while the plastic likely is burned or recycled otherwise. 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.

4.4.4 Volume and weight of the packaged product

The volume of the packaged product is assumed to be same as the standard dimensions[182] of tumble driers including five additional centimetres due to packaging such as polystyrene. This means that the volume of the packaged product (full size tumble drier) is:

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[181] Nomenclature used in the EcoReport tool. PP=Polypropylene, PP GF=Polypropylene Glass Reinforced, PA=Polyamide, PA GF=Polyamide Glass Reinforced.

[182] Standard dimensions provided by stakeholders

$$Volume_{full\ size} 85\ cm\ \times 65\ cm \times 65cm = 0.36\ m^3$$

4.4.5 Means of transport

The means of transport are often negligible in life cycle assessments since the impact often is small compared to the environmental impact of the rest of the product. Most tumble driers are assumed to be shipped by freight ship or by truck. Both means of transport have in general a low impact in the final assessment.

4.5 End-of-Life

Resource efficiency is a growing concern within Europe. More raw materials are categorised as critical and the dependency of these materials are increasing. In addition, it seems that more resource requirements are included in ecodesign Regulations. To improve the resource and material efficiency the following elements are key parameters;

- Recyclability: Identifying materials that hinder recycling with a view to assess possibilities to avoid them in the product design. The recyclability of tumble driers is directly addressed in section 4.5.1.
- Reparability: Identification of spare parts (those which fail too early in driers lifetime).
- Disassembly: Removal of certain components with a view to assess possibilities for increase their reuse and/or recycling at end of life (i.e. by easy removal).

4.5.1 Recyclability of tumble driers

After collection, tumble driers are treated at suited facilities. Tumble driers with heat pump technology are handled together with other appliances containing refrigerants such as refrigerators. These appliances are treated at specialised facilities which can handle the refrigerants. The waste process flow[183] for refrigerants appliances (RA) are visualised in Figure 59.

[183] http://www.sciencedirect.com/science/article/pii/S0921344915300021

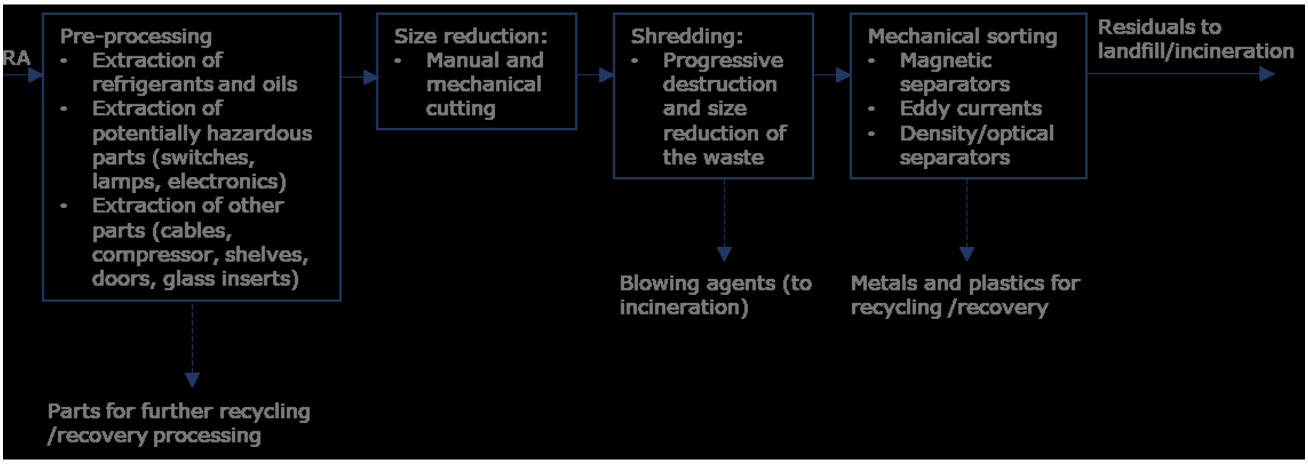

Figure 59: The waste process flow for commercial refrigerants appliances

The pre-processing[184] is the first step in the recycling process of tumble driers containing refrigerants. 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 and allow compliance with current legislation on hazardous substances and waste and prevent damage to the facility in the following steps. It is also during the pre-processing the refrigerants and oils are removed by piercing the tubes followed by suction to safely remove these substances. The heat exchangers of tumble driers with heat pumps are likely to be removed since they may contain a lot of copper. According to the WEEE Directive components such as electronic components (e.g. printed circuit board, capacitors, switches, thermostat, liquid crystal displays) and lighting systems (gas discharge lamps) are additionally dismantled when present. Equipment with large dimensions might be cut to smaller pieces before shredding.

Next step[185] is shredding, which reduces the tumble driers in smaller pieces. These facilities also handle insulation foams which may contain different hydrocarbons (if present) so these are removed in an initial shredding in closed atmosphere. These foams are usually burned.

After the equipment has been shredded into smaller pieces (approximately 1 cm to 10 cm) different technologies handle the sorting. These technologies are often:

- Magnetic separation removing ferrous metals
- Eddy current separators removing non-ferrous metals such as copper, aluminium, and zinc
- Density separators for different types of plastic.

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[184] http://www.sciencedirect.com/science/article/pii/S0921344915300021
[185] http://www.sciencedirect.com/science/article/pii/S0921344915300021

Air-vented and condenser heat element tumble driers (without heat pump) are assumed to be recycled at regular shredders which are very similar to the above description except the handling of refrigerants. This means that the tumble driers are:

- Pre-processed – extraction of cables and some electronics
- Size reduced – manual and mechanical cutting
- Shredded – Progressive destruction and size reduction
- Mechanical sorted - magnetic separation, eddy current, density separators and optical separators

The effectiveness of the recycling process for all types of tumble driers (the share of recovered, recycled, and reused materials) is based on the EcoReport tool[186] but updated regarding plastics[187]. The recycling rates used in the current study are presented in Table 40.

Table 40: End of life rates to different reuse, recycling, recovery and disposal routes from EcoReport Tool adopted in the current study

	Bulk Plastics TecPlastics*	Ferro Non-ferro Coating	Electronics	Misc.	refrigerant
EoL mass fraction to re-use, in %	1%	1%	1%	1%	1%
EoL mass fraction to (materials) recycling, in %	29%	94%	50%	64%	30%
EoL mass fraction to (heat) recovery, in %	40%	0%	0%	1%	0%
EoL mass fraction to non-recov. incineration, in %	0%	0%	30%	5%	5%
EoL mass fraction to landfill/missing/fugitive, in %	30%	5%	19%	29%	64%
TOTAL	100%	100%	100%	100%	100%

**Adjusted values (regarding plastics) compared to the EcoReport tool*

With these numbers the total recovery rate (including recycling of materials and heat recovery from incineration) is above 50%. The numbers also express high recycling rates for metals and lower rates for plastic. Traditionally it is also easier for recycling facilities to recover the value of metals than plastic. Plastics are often mixed with other types of plastics which challenge the quality of the recycled plastic. Often recycled plastics are downgraded if not properly separated.

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186 http://ec.europa.eu/growth/industry/sustainability/ecodesign_da

187 Plastic Europe, Available at: http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf

4.5.2 Design options regarding resource efficiency

Different approaches can be implemented towards improved resource efficiency at End-of-Life. Several options are available for design improvements and covers both more holistic guidelines and product specific suggestion.

Common "design for X" practices which cover all types of EEE products could be[188]:

- Minimise the number and type of fasteners, so fewer tools are needed during disassembly and repair.
- The fasteners should be easily accessible and removable.
- Easy to locate disassembly points.
- If snap fits are used, they should be obviously located and possible to open with standard tools to avoid damaging the product during repair.
- It is beneficial if fasteners and materials are either identical or are compatible with each other in the recycling process.
- The use of adhesive should be minimised.
- Minimise the length of cables to reduce the risk of copper contamination, or connection points could be designed so they can break off.
- Simple product design is preferable.

These suggestions are not specifically targeting tumble driers, they are suggestions for all EEE products, which need to be evaluated on a case by case basis. Overall, if the above measures would be implemented for tumble driers, they would become easier to disassemble and thus more people might consider repairing the product.

Design for recycling mainly focuses on the recycling compatibility of different materials avoiding losses at End-of-Life. This can be done by respecting a few common guidelines such as minimising the use of non-reversible adhesives. Even the suggestions seem simple, design for recycling is quite complicated due to the mix of products at End-of-Life. Different products are discarded together which increases the complexity and risk of contamination. Even within the same product group contaminant can appear. To prevent contamination at End-of-Life and to improve the quality of the recycled material it is important to consider the material mix and how the different materials are liberated at End-of-Life. In design for recycling, it is important to consider[189]:

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[188] Chiodo, J., 2005. Design for Disassembly Guidelines. Available at: http://www.activedisassembly.com/strategy/design-for-disassembly/.

[189] Reuter, M.A. & Schaik, A.V.A.N., 2013. 10 Design for Recycling Rules, Product Centric Recycling & Urban / Landfill Mining. , pp.1–15.

- To reduce the use of materials, and especially the use of materials that will cause loss or contamination in the recycling process. It should be considered how the materials would behave in the sorting and processing at End-of-Life.
- To identify materials in assemblies combined in an inappropriate causing loss of resources during recycling, e.g. the connection between a metal screws and plastic, where one of them may be lost due to incomplete liberation. Also, some mixes of metal are problematic, and some types of metal require further processing than what the typical smelters technologies offer (see Figure 105). Figure 105 shows a metal wheel which explains which metal resources can be recovered by different smelters and other processing technologies. Table 87 shows the compatibility of different types of plastics when being recycled.
- Proper labelling both on plastic, but also general futures such as marking of tapping points of generators.
- Minimise the use non-reversible adhesives and avoid the use of bolt/rivets to obtain maximum liberation at End-Of-Life.

Other relevant measures for improved resource efficiency are discussed in section 3.2 where availability of spare parts, repair instructions and prolonged lifetime is discussed.

Guidelines based on valuable or critical resources

The awareness of resources and resource criticality 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 and platinum group metals)

The following main parameters are used to determine the criticality of materials[190]:

- Economic importance - the importance of a material for the EU economy in terms of end-use applications and the value added of corresponding EU manufacturing sector.
- Supply risk - reflects the risk of a disruption in the EU supply of the material. It is based on the concentration of primary supply from raw materials producing countries, considering their governance performance and trade aspects.

The updated list of critical raw materials is presented in Table 41.

[190] https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_da

Table 41: 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

Tumble driers may contain several raw materials categorised as critical. Raw materials like vanadium and phosphorous are in some designations of steel used as alloying elements. Other critical raw materials may be included in the magnets (motor) of tumble driers, as some magnets contain rare earths. Besides critical raw materials are many raw materials targeted in the End-of-Life treatment as there are highly valuable e.g. gold and copper (lower value but higher quantities). The critical and valuable raw materials are considered to be part of the following components and materials:

- Printed circuit boards which may contain several critical materials such as gold, silver, palladium, antimony, bismuth, tantalum etc.[191]
- Compressor and heat exchangers which may contain copper (but according to manufacturers it is possible also to produce heat exchangers with aluminium fins and tubes)
- Wires which may contain copper
- Motors which may contain copper and rare earth elements (magnets)
- Alloying elements which may contains a range of different critical raw materials

The composition of printed circuit boards is difficult to quantify but it is estimated as low grade for tumble driers in general. The product development of some tumble driers indicates higher grades of circuit boards in the future due to the implementation of more functions (network functions).

Printed circuit board are already targeted components according to the WEEE Directive and compressors, heat exchanger and wires are already target due to their high amount of copper. Copper is also very important to remove before shredding to minimise the risk of copper contamination in the iron fraction since it directly can influence the mechanical properties of the recycled iron/steel[192]. Avoiding contaminants is one of the key points of design for recycling guidelines. If the heat exchanger consists of aluminium fins and cupper

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[191] http://www.wrap.org.uk/sites/files/wrap/Techniques%20for%20recovering%20printed%20circuit%20boards%2C%20final.pdf
[192] http://www.rmz-mg.com/letniki/rmz50/rmz50_0627-0641.pdf

tubes the aluminium is likely to be lost in the recycling process, so it could be beneficial if the heat exchangers are made of the same material.

Furthermore, manufacturers have indicated that the drum often is made of stainless steel (which may contain rare earths elements as alloying elements) only for the feel and look of the drier. In principle it could be beneficial to use regular steel as long as the lifetime not are affected.

Regulatory measures

Material efficiency requirements can be very difficult to model, as the material efficiency is dependent on the waste handling system which again are dependent on the commodity prices. The current preferred waste processing is shredding but within the next 20 years it may change significantly, and it is therefore difficult in later task to quantify any measure towards improved material efficiency. Also, when products are shredded with other types of products the impact of any requirements toward a specific product may be reduced. Material requirements may therefore have greater effect if they are aligned across all product groups. A summary of the different requirements related to material efficiency in other regulations (adopted and not yet adopted) are presented in Table 42.

Table 42: Alignment with proposals from other Regulations

	Information requirements for refrigeration gases	Requirements for dismantling for the purpose of avoiding pollution, and for material recovery and recycling	Spare part availability	Spare part maximum delivery time	Access to Repair and Maintenance Information	Lifetime and durability requirements
Dishwashers (Suggestion)	x	x	x	x	x	
Washing machines (Suggestion)	x	x	x	x	x	
Water Heaters					x	
Domestic and commercial ovens, hobs and grills					x	
Residential Ventilation					x	
Circulators and pumps					x	
Ventilation Fans					x	
Electric motors					x	
Vacuum cleaners		x			x	x
Local room heating products					x	
Domestic and commercial ovens, hobs and grills					x	
TVs					x	
Personal computers and portable computers		x				

Dishwashers and washing machines may in the future have the most ambitious requirements regarding resource efficiency[193]according to proposed amendments to the current Ecodesign Regulations for these products[194].These Regulations are not yet adopted but it seems to be the general trend. Previously there have been different requirements regarding information relevant for the disassembly but one of the greatest barriers towards increased repair and refurbishment is the lack of available spare parts[195]. By alignment with other Regulation it will be insured that all product groups constitute to transition from a linear economy to a more circular economy.

Recommendations regarding resource efficiency

The low collection rate of tumble driers can challenge the improvement potential of any suggestions regarding resource efficiency since many products do not reach the desired recycling facility. The collection rate is expected to increase and fulfil the WEEE Directive

[193] Note that vacuum cleaners also have ambitious requirements with durability and lifetime, which are not reflected in Table 42.

[194] Proposals was discussed at meetings in Consultation Forum on 18 and 19 December 2017. The working document where these suggestions are presented are available on: https://www.eceee.org/ecodesign/

[195] Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV.

in 2019. The current low collection rates cannot be directly addressed in the Ecodesign Regulation for tumble driers since this is not related to the design of the product.
Based on the list of critical raw materials and the WEEE Directive the following components and materials are of special interest:

- Printed circuit boards which may contain several critical materials such as gold, silver, palladium, antimony, bismuth, tantalum etc.[196]
- Compressor and heat exchangers which may contain copper (but according to manufacturer it is possible also to produce heat exchangers with aluminium fins and tubes).
- Wires which may contain copper.
- Motors which may contain copper and rare earth elements (magnets).

By alignment with other Regulations (especially with the suggested dishwasher and washing machine Regulation), printed circuit boards are easily removed when they are larger than 10 cm^2 which also seems very beneficial from a critical resource perspective and supporting the WEEE Directive (see Annex II). Some requirements may be difficult to address from a market surveillance perspective because the requirements are difficult to control such as requirements of ease of dismantling. However, the current work on a scoring system on reparability may ease any resources needed for the verification of resource efficiency requirements. Requirements on e.g. ease of disassembly and repair are proposed in amendments to the washing machine ecodesign.

[196] http://www.wrap.org.uk/sites/files/wrap/Techniques%20for%20recovering%20printed%20circuit%20boards%2C%20final.pdf

5. Environment and Economics

The aims of this task are:

- Define the base cases taking into account the scope proposed in task 1, the market analysis in task 2, the user behaviour analysis in task 3 and the technologies identified in task 4. The base cases will be used in the next tasks of the report to identify design improvement options, draw policy options and evaluate their effects per base case.
- Assess the life cycle environmental impacts and the life cycle costs (LCC) of these base cases

5.1 Product specific inputs

According to MEErP methodology[197], the base cases (BC) should reflect representative products on the market in terms of energy efficiency, resource efficiency, emissions and functional performance. Different products with similar functionalities, Bill of Materials (BoM), technologies and efficiency can be compiled into a single BC. Therefore, although it may not refer to a specific product on the EU market, it does represent the range of typical products. The base cases are used for modelling the environmental and economic impacts of the products and is representing the reference line (baseline) in the scenario analysis in task 7.

5.1.1 Base cases for household tumble driers

Section 2.1.1 shows that even though heat pump driers account for almost half of the EU tumble drier market, heating element driers still persist and may continue to be sold. Sales figures however indicate a steady reduction of heating element air-vented sales, and these types are assumed to be discontinued around 2030. This is not the case for gas-fired air-vented driers, as they continue to be sold and the current available data does not present evidence for a discontinuance of these models before 2030[198]. After 2030, the estimated sales are too low to accurately estimate in stock models[199] which might or might not result in these models being removed from the market.

The base cases have been split into the four main tumble driers heat source technology types in the market, in order to differentiate life cycle costs and environmental impacts and investigate improved design options at this segregated level. This will give more details on the costs and environmental hotspots as well as improvement potentials.

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[197] Section 4.1 – Technical product description. Page 76.
[198] Gas-fired manufacturers did not provide input on the future sales trends of this product type
[199] For the stock model developed and used in this study, gas-fired driers represented 0.002% of the total sales in 2030 and are therefore almost completely neglible for any results whatsoever.

The four selected base cases are:

- Base case 1: Condenser tumble driers (heating element)
- Base case 2: Condenser tumble driers (heat pump)
- Base case 3: Heating element air-vented
- Base case 4: Gas-fired air-vented

Table 43 shows the main differences in performance parameters between the base cases. The average values are based on data collected in previous tasks and from preparatory study.

Table 43: Key performance parameters for the four selected base cases (2018 values)

Parameter		Base case 1: Condenser, Heating element	Base case 2: Condenser, Heat pump	Base case 3: Air vented, Heating element	Base case 4: Air-vented, Gas fired	Sources and notes
Performance	Average nominal rated capacity [kg]	7.7	7.8	6.8	6.8	Figure 33 (GfK)[200]
	Average energy consumption per cycle (E_{dry}), 100% loaded [kWh]	4.4	1.9	4.0	1.9	Specific energy consumption from Figure 44 (APPLiA) at full load, multiplied with the nominal capacity. Gas data based on WhiteKnight ECO43.
	Average energy consumption per cycle ($E_{dry½}$), 50% loaded [kWh]	2.4	1.0	2.2	1	Specific energy consumption from Figure 44 (APPLiA) at partial load, multiplied with 50% of the nominal capacity. Gas data based on WhiteKnight ECO43.
	Average energy class	B	A^{++}	C	A^{+}	Figure 19 , Figure 20, Figure 21 (GfK). Based on data from 2016. Gas data based on a desktop study and data from GfK.
	Average condensation efficiency class	B	B	-	-	Figure 25, Figure 25 (GfK). Based on data from 2016.
	Average lifetime [years]	12	12	12	12	Section 2.2.1

[200] Gas fired are assumed to follow the size of air vented heating element driers due to lack of data.

Parameter		Base case 1: Condenser, Heating element	Base case 2: Condenser, Heat pump	Base case 3: Air vented, Heating element	Base case 4: Air-vented, Gas fired	Sources and notes
	Average cycle time, full load (T_{Dry}) [minutes]	129	163	123	94	Figure 34, Figure 35, Figure 35 (GfK). Based on data from 2016. Gas data based on WhiteKnight ECO43.
	Average noise level [dBa]	>66	65	>66	62	Figure 38, Figure 39 (GfK). Based on data from 2016. Gas data based on WhiteKnight ECO43.

Table 44 shows parameters related to use, which are divided into "standard values" and "real values". The standard values represent standard conditions defined in the current legislation, and the real values represent real user behaviour based on data collected in Task 3.

Table 44: Standard and real key user behaviour parameters for the four base cases (2018 values)

Parameter		Base case 1: Condenser, Heating element		Base case 2: Condenser, Heat pump		Base case 3: Air vented, Heating element		Base case 4: Air-vented, Gas fired		Sources and notes
		Standard value	Real value	Standard value	Real value	Standard value	Real value	Standard value	Real value	
User behaviour	Number of cycles per year	160	107	160	107	160	107	160	107	160 from current regulation, 107 from Table 22 (APPLiA) based on 2.05 cycles/week on average. Real value from section 3.1.2 (APPLiA).
User behaviour	Average load per cycle [kg]	5.5	4.4	5.7	4.4	5.0	4.4	5.0	4.4	Standard value corresponds to 71% of the rated capacity at the current regulation[201]. Real value from section 3.1.2 (APPLiA).
User behaviour	Average energy consumption per cycle, average load [kWh]	2.9	2.4	1.4	1.1	2.7	2.3	1.5	1.3	AEc from Figure 22, Figure 22, Figure 24 (GfK) divided by rated capacities (Figure 33) weighted by the regulation loading factor (71%[201]) (this yields AEc/kg), multiplied with the average load per cycle from row above.

[201] The loading factor is here defined as the average weight (in kg of dry laundry) of the laundry used to test the energy consumption of the drier divided by the rated capacity. The average loading is the average weight of 3 cycles at 100% the rated capacity and 4 cycles at 50% the rated capacity. This yield $\frac{3*100\%+4*50\%}{7} = 71\%$

Parameter	Base case 1: Condenser, Heating element		Base case 2: Condenser, Heat pump		Base case 3: Air vented, Heating element		Base case 4: Air-vented, Gas fired		Sources and notes
	Standard value	Real value	Standard value	Real value	Standard value	Real value	Standard value	Real value	
									This value is multiplied with (100% + Initial Moisture Content (IMC) correction factor[202]) Gas data based on WhiteKnight ECO43.
Average annual energy consumption [kWh]	483	258	212	109	457	269	207	121	The number of cycles per year multiplied with the average energy consumption per cycle

Comparing these values to values reported in the preparatory study, a few things stand out in particular. For all types of driers, the rated capacity has increased from 5.4kg up to 7.8kg. The load has increased as well, from 3.4kg to 4.4kg[203]. Cycle time has increased for all drier types. This can partly be explained by the increase in capacity, but also due to the fact that the general drying temperature seems to be lower for heat pump driers, as the cycle time has increased more (in percentages) than the rated capacity (see Figure 33 and Figure 34).

Comparing to standard values used in current legislation, the 'real' number of cycles per year and the average load per cycle are lower, so the average energy consumption per cycle and per year are also lower.

5.1.2 Raw material use and manufacturing

Besides the energy consumption during the use phase, the materials in the product contain a considerable amount of embedded energy e.g. calorific value and the energy used to mine the raw materials and produce the finished materials. Furthermore, materials create interactions with the environment by using resources, some scarce or critical, and emitting substances that create a range of environmental impacts. The EcoReport Tool (2013) contains a detailed list of materials and processes for which defined environmental indicators are provided as default values. These values are used to calculate the environmental impacts imposed by the materials.

The material composition and weight of tumble driers are expected to be very similar to those presented in the preparatory study. However, the values have been updated based on inputs from stakeholders provided during this review study. In particular, the weight

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[202] See section 5.1.4.
[203] See section 3.1.2 "Loading of the drier" for detailed discussions.

for printed circuit boards are updated. Also, condenser tumble driers with heat pump technology are well established on the EU market, which was not the case at the time of the preparatory study.

The final material composition[204] used in EcoReport Tool is presented in Table 45.

Table 45: Material composition of base cases

Material Type	Materials[205]	Base cases 1: Condenser, Heating element – (kg)	Base case 2: Condenser, Heat pump (kg)	Base cases 2 and 3: Air-vented heating element and gas-fired (kg)
Bulk Plastics	4 -PP	12.8	13.9	9.30
TecPlastics	12 -PA 6	0.68	1.2	0.9
Ferrous	24 -Cast iron	26.29	24.9	21.3
Non-ferrous	27 -Al sheet/extrusion	2.01	4.8	0.76
Non-ferrous	31 -Cu tube/sheet	2.17	5.1	2.0
Coating		0	0	0
Electronics	98 -controller board (PCB)	0.405	0.525	0.405
Misc.	various other materials	2.8	6.8	2.8
Misc.	various other materials (Refrigerant)	not relevant	0.30	not relevant
Total		**47.16**	**57.55**	**37.45**

It should be noted that the weight of the refrigerant in the condenser heat pump base case is included in the category "various other materials". EcoReport Tool cannot properly calculate the impacts of refrigerants (or the impacts of leakage), therefore these impacts are calculated separately and incorporated back in to the EcoReport result in this review study[206]. See more details about the method in Annex IV: Method to calculate refrigerant's Global Warming Potential in EcoReport tool

[204] The weight of electronics shown in Task 4 BOMs was assessed too high (i.e. above 5, 6 and 13 kilos respectively of electronics for air-vented heating element, condenser heating element and condenser heat pump driers). Therefore, the electronic fraction has been corrected so it only consists of the printed circuit boards. Half of the remaining fraction is assumed to be part of the ferrous fraction which is the casing of the motor, and the other half of non-ferrous – e.g. copper and aluminium in motors. The non-ferrous fraction distribution between copper and aluminium is based on the preparatory study: Condenser – 48 % aluminium and 52 % copper; Air-vented - 27 % aluminium and 73 % copper.

[205] In EcoReport tool format as indicated in MEErP. PP=Polypropylene, PA 6=Polyamide 6, Numbers are material identification numbers in EcoReport tool format.

[206] (the impacts imposed by refrigerants are simply added to the results).

Regarding gas-fired tumble driers, no data have been available, so the material composition is assumed to be identical for all air-vented driers regardless the energy source[207].

The estimation of consumption of critical raw materials and other materials of high importance are mainly focusing on copper in the motor, wires and heat exchanger (for some condenser drier) and the gold in the printed circuit boards. The copper is included in the calculated material composition in Table 45. The amount of e.g. gold in the printed circuit boards is included in the "electronics" fraction. Based on stakeholder inputs[208] there are two printed circuits boards in an average tumble drier which have a combined weight of 525 grams for condenser driers and 405 grams for air-vented driers.

The average composition of a printed circuit board is assumed being as follows[209]:

- 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 tumble driers contain gold in the range of 0.12 grams to 0.16 grams originating from the printed circuit boards. The grade[210] of printed circuit boards in tumble driers can be discussed, but the complexity of tumble drier is increasing which imposes use of higher grades of printed circuit boards (which will increase the content of gold). In general, there are many different grades for printed circuit boards for different electronic or electrical products depending on the level of complexity of the purposes and tasks.

The environmental impacts and commodity prices of gold and copper are:

- Gold – 250 GJ/kg, 22500 CO_2-eq/kg[211] and 35150 EUR/kg[212]
- Copper – 50.9 MJ/kg, 2.7 CO_2-eq/kg[213] and 5.9 EUR/kg[214]

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[207] Current best guess
[208] Data collection questionnaire on resource efficiency from stakeholders to this study, November 2017
[209] http://www.wrap.org.uk/sites/files/wrap/Techniques%20for%20recovering%20printed%20circuit%20boards%2C%20final.pdf
[210] 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.
[211] http://ec.europa.eu/environment/integration/research/newsalert/pdf/302na5_en.pdf
[212] Price assessed in November 2017 at: http://www.infomine.com/investment/metal-prices/gold/1-day-spot/
[213] EcoReport tool
[214] Price assessed in November 2017 at: http://www.infomine.com/investment/metal-prices/copper/1-year/

Manufacturing

The impact of 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 in the EcoReport Tool. The only adjustable input regarding manufacturing is the percentage of sheet metal scrap. The default value is 25%, which is kept in this study. Changing this value will only have a very limited impact on the life cycle environmental impacts.

5.1.3 Distribution of base cases

The distribution phase is included in the calculations of the environmental impacts but have a very limited impact on the results of the overall analysis. This phase includes the distribution of the packaged product and covers all activities from OEM (Original Equipment Manufacturer) components to the final delivery to consumer[215]. However, the only parameter that can be changed in the EcoReport Tool is the volume of the final package. The transport volume is previously discussed in Task 4, and the volume of the package for all base cases is assumed to be[216]:

$$Volume_{full\ size} 85\ cm\ \times 65\ cm \times 65cm = 0.36\ m^3$$

These values have been used for EcoReport Tool.

5.1.4 Use phase of base cases

Conditions of use

The most important parameters identified in Task 3 were the usage frequency in terms of cycles/week and loading in terms of kg of laundry dried per cycle.

Different studies were assessed, including the preparatory study of household washing machines and washer driers. The conclusions from this study were that the nominal capacity of the washing machines and the loading in kg were not strongly correlated. This means that users did not differ in their washing behaviour according to the nominal capacity of the washing machine.

The most recent available study – and the only one focusing only on drying behaviour – is the APPLiA consumer study from 2018. This is chosen as the primary source for user behaviour parameters in this study.

The APPLiA study did however report a larger average load (4.4kg), compared to the washing machine study average load (3.3kg). This could be due to the differences in what

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[215] Excluding packaging
[216] The volume of the packaged product is assumed to be same as the standard dimensions of tumble driers including five additional centimetres due to packaging such as polystyrene.

was covered by the different studies and the fact that households owning a tumble drier are on average 0.1 person larger than households without, but it could also be because of the differences in the study methodologies (consumer questionnaires compared to measurement studies where the actual loads where measured).

As the previous tumble drier preparatory study has used the load from the previous washing machines study, the differences in the real life tumble drier load (from 3.4kg to 4.4kg) could be attributed to the differences in the data sources used. The assumption that the load is independent of the nominal capacity is thus still valid.

In summary, the loading input used in this study is 4.4kg, and the cycles per year are 107. This is very different compared to the values used in the current regulation which uses a ~71% loading parameter, and 160 cycles/year. The EEI calculation method in the current regulation assumes the tumble drier load in kg of laundry to be directly dependent on the nominal capacity, and thus that the amount of laundry increases at the same rate as the nominal capacity does.

The initial moisture content of the laundry to be dried is set to 60% in the current regulation. This is based on an average spin speed of 1000 RPM. The APPLiA consumer study from 2018 found an increase in applied washing machine spin speeds from 1000 RPM (assumed to be the average in the current regulation) to 1130 RPM equivalent to a 13% increase. Furthermore, the 2017 washing machine and washer-drier preparatory study[217] concluded that the spin speed and the residual moisture content of the laundry is correlated and showed a steady increase in average spin speeds from 1997 to 2010. The study furthermore showed distributions of the spin-drying efficiency classes and showed that the majority of the washing machines sold in 2013 were B class spin-drying efficiency, corresponding to a residual moisture content between 45% and 54%. This is however the maximum spin speed (based on the standard cotton washing cycle), and not the average.

Widespread data on the residual moisture content on laundry to be dried in tumble driers are not available, thus a desktop study was made to evaluate this effect. Based on the product datasheets of five different tumble drier models, a correlation between the washing's residual moisture content of the laundry and the applied spin speed[218], was established. This can be seen on Figure 60. The increase in spin speeds thus reduces the initial moisture content for the normal cotton cycle from 60% to 56%, and for the synthetics from 45% to 42%.

[217] Ecodesign and Energy Label for Household Washing machines and washer dryers – Preparatory study, final report, JRC, 2017
[218] Based on tumble driers' product fiches.

The effect on the energy consumption is based on a simple linear interpolation between the reported values in the product sheets for the five selected tumble drier models. The average reduction in energy consumption due to lower initial moisture contents was found to be 6.8%. This value has been used throughout tasks 5 through 7 as a correction factor on the energy consumption, to better reflect the real-life consumption of tumble driers.

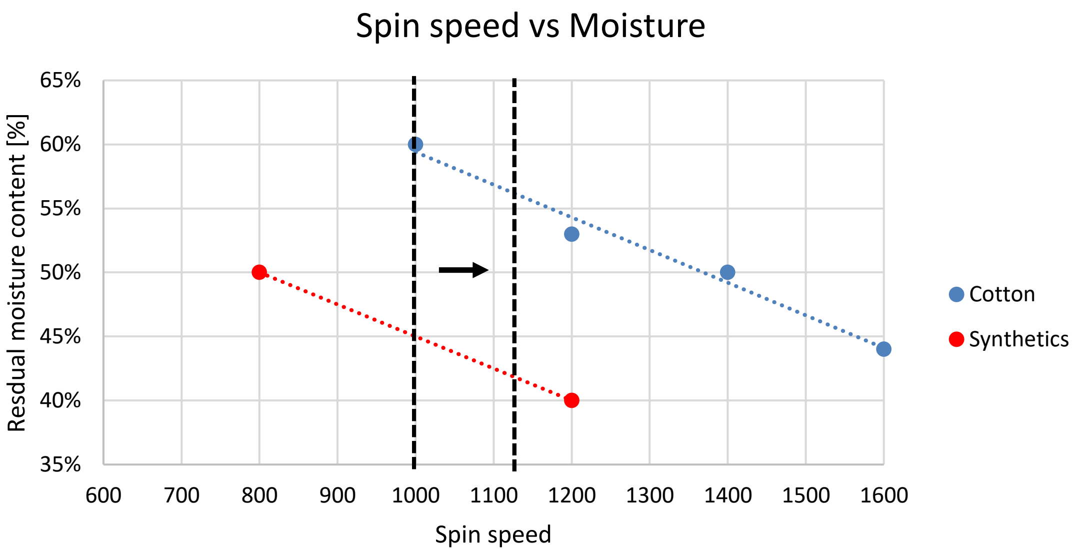

Figure 60: Residual moisture content as a function of the spin speed in the washing machine for cotton and synthetics. The black dotted lines visualise the change in average spin speeds. *Source: Desktop study 2019*

Energy use

Electricity

The electricity consumption of the tumble driers is primarily related to the on-mode of the driers, which accounts for about 98% of the annual energy consumption of heat pump and heat element driers[219]. The rest is attributed to energy consumptions in left-on and off-modes. All reported values are based on the standard cotton programme, which has to be the most efficient according to the regulation (per kg of dried laundry). The total energy consumption is hence based on the driers being used in the most efficient programme (i.e. standard cotton programme). In real life, users can dry other materials using different programmes that might have an effect on the energy consumption. The APPLiA consumer study investigated the distribution of programmes used. The results can be seen in Figure 61. The standard cotton programme (normal dry) is the most commonly used programme, followed by synthetics (normal dry). The very/extra dry programmes (lower final moisture content, higher energy consumption) and the iron dry programmes (higher final moisture content, lower energy consumption) are almost used equally.

[219] APPLiA Model database, 2016.

A large part of the programmes, however, is associated with synthetics or delicates/wool which programmes normally have a lower maximum capacity and different drying characteristics (e.g. lower drying temperatures). Synthetics are not able to contain as much water as cotton which means that at an equivalent (in kg) of synthetics and cotton spun at the same speed contain different amounts of water and thus require different amount of energy to dry.

A desktop study was made in order to evaluate the effect of the different drying programmes. Energy consumption values were found for cotton normal dry, cotton iron dry and synthetics normal dry at different initial moisture contents. No data on the energy consumption for "delicates/Wool", "time-controlled drying" (as this is entirely dependent on the user), and the "extra dry" programmes was available. For the time-controlled drying, the change in the energy consumption was evaluated based on the APPLiA 2017 model database on the average increase in energy consumption for driers with and without moisture sensors (e.g. automatic and non-automatic tumble driers). An increase of 21% in energy consumption per kg was found.

Energy consumption for the "Synthetics iron dry" programme was based on the average reduction of energy consumption per kg between cotton standard dry and iron dry programmes, as no data was available from the product fiches for this programme.

For the "extra dry" programmes, a 5% increase in energy consumption was assumed. Note that the standard cotton programme is defined as drying a laundry load from 60% to 0% moisture content, so the "extra dry" programmes should in theory not be needed if the moisture detection system of the drier worked flawlessly. No data for the Delicates/Wool programme was found, and no change in energy consumption per kg of laundry was assumed for this programme.

The effect of the programmes is summed up in Figure 62 which shows the change in energy consumption compared to the standard cotton programme. The increase in energy consumption is based on the kWh/kg-laundry, and not per cycle. This is because the found average loading load was for the *average* load across all used programmes. The option to differentiate the load based on the programmes used is thus not possible based on the available data.

The results show, that even though the standard cotton programme might be the most efficient programme in terms of energy consumption per kg of water evaporated, the variations in the initial water content of the laundry (which is lower for synthetics) and the final target moisture content (e.g. iron dry programmes) mean that the total real energy consumption of the tumble driers are most likely lower than if just evaluated based on the standard cotton cycle programme. Using a weighted average based on usage frequency of the programmes (from Figure 61) the combined effect of the programmes reduces the total real energy consumption of tumble driers during use by 7.4%. This is however based on a very limited amount of data and with large variations between the different drier types and models, and this value will thus not be used in future calculations. It will instead be evaluated in a sensitivity analysis were the effects can be seen.

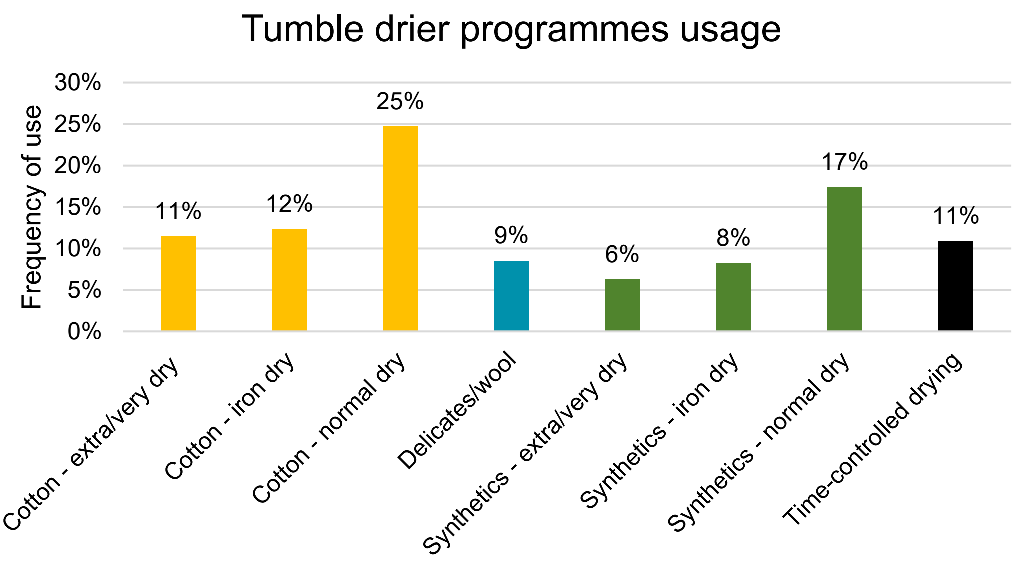

Figure 61: Frequency of use per drying programme. ***Source: APPLiA***

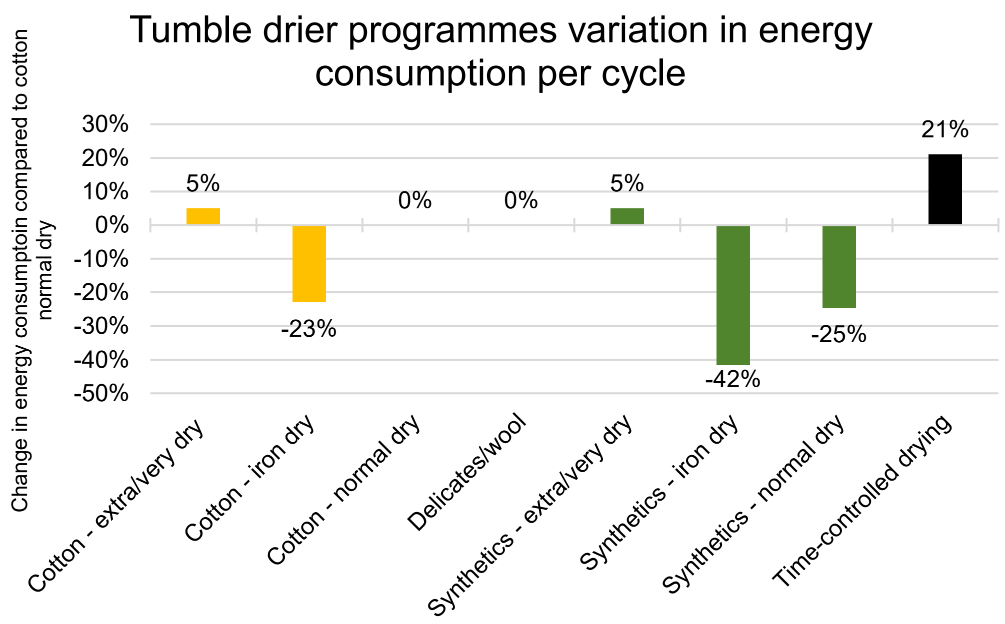

Figure 62: Change in energy consumption per programme. Positive values indicate an increase in energy consumption, negative values indicate a reduction. ***Source: Desktop study, APPLiA***

Using the values listed in Table 43 and Table 44 and linking them to the current and future stock estimations from Table 10 and Figure 17, the EU energy consumption has been calculated. Table 46 lists the energy consumption for the three different modes available in current tumble driers.

Table 46: Electric consumption and hours in different operation modes based on "real values" from the APPLiA consumer study[220].
Source: GfK, APPLiA, Viegand Maagøe.

Parameter	Base case 1: Condenser, Heating element	Base case 2: Condenser, Heat pump	Base case 3: Air vented, Heating element	Base case 4: Air-vented, Gas fired
On-mode: Consumption per cycle [kWh]	2.35	1.07	2.34	1.32
On-mode: No. of cycles / year [#/Year]	107	107	107	107
Left on-mode: Consumption per hour [Wh]	1.19	1.20	1.13	0.03
Left on-mode: No. of hours / year [#/Year]	37.4	43.3	16.0	0
Off-mode: Consumption per hour [Wh]	0.30	0.27	0.15	0.03
Off-mode: No. of hours / year [#/Year]	8493	8426	8525	8592

Natural gas

The energy consumption of gas-fired tumble driers is based on the same assumptions as the other base cases. Since data is very limited for gas-fired driers, values used are based on the performance of a single drier-model[221]. This accounts for 54% of the EU market share in 2016. The value in kWh of gas is equal to the on-mode consumption shown in Table 46 for base case 4, multiplied with 2.5 as per the regulation.

Repair and maintenance

The repair and maintenance are not directly included in the EcoReport Tool, only as a slightly increased material consumption (1% additional materials).

5.1.5 End-of-Life phase of base cases

Some of the energy contained in the materials (embedded energy) can be recovered at End-of-Life when products are either reused, recycled, or incinerated. When products are landfilled this energy may be lost if methane is not recovered. It is therefore important to describe the most likely End-of-Life scenario to quantify the impact of the material consumption.

The recycling rate depends on how the tumble driers are collected and sorted at End-of-Life. As presented in task 3, the collection rate for EU was just below 40% for large

[220] Note that the values for gas-fired driers are converted from primary to electric energy in the regulation.
[221] White Knight ECO43A

household appliances in 2014 which could pose a challenge for resource efficiency. The collection rate should be improved to 65 % in 2019 according to EU targets.

After collection, the tumble driers are handled together with other electronic appliances as described in task 4 (section 4.5.1). Tumble driers containing refrigerants (heat pump driers) are handled separately with other appliances containing refrigerants such as refrigerators and air conditioners. These appliances are treated at specialised shredders which can handle the refrigerants.

The end-of-life routes have been presented in Table 40 including recycling rates of critical materials. The recycling rate of copper and electronics are estimated to be 94 % for non-ferrous (copper) and 50 % for electronics (including the gold in printed circuit boards). However, if printed circuit boards are removed before shredding and treated separately the recycling rate of gold is assumed to be above 90 %. According to stakeholders the printed circuit boards are placed behind the control panel, so the printed circuit boards are assumed to be easy to replace during repair, but not removed at End-of-Life, since the product is shredded[222].

5.1.6 Life Cycle Cost (LCC) inputs for base cases

This section presents the annual sales, stock, purchase price, installation costs, repair and maintenance costs, unitary rates for energy, discount, inflation, interest and escalation rates, as well as product service life. These values have been derived and presented in task 2 and task 3.

Data on the annual sales and the stock are used for the calculation of the EU totals in the EcoReport Tool. EU 28 annual sales and total estimated stock for all tumble driers are presented in Table 47.

[222] Printed circuit boards

Table 47: EU 28 annual sales and estimated stock of tumble driers[223]

	2010	2015	2020	2025	2030
EU28 annual sales, (1000) units					
Base Case 1	2539	1778	1685	1549	1115
Base Case 2	341	2222	3052	3597	4459
Base Case 3	1110	745	587	387	0
Base Case 4	0.6	0.4	0.6	0	0
Total	**3991**	**4756**	**5339**	**5534**	**5574**
EU28 estimated stock, (1000) units					
Base Case 1	31258	29095	25174	21453	18783
Base Case 2	442	7268	21183	34891	44662
Base Case 3	19610	15160	10666	7627	4727
Base Case 4	11	8	8	7	3
Total	**51321**	**51531**	**57032**	**63978**	**68175**

The annual sales and stock are used to calculate the aggregated impacts of tumble driers in the scenario analysis. To calculate the Life Cycle Cost (LCC) of a product, the following formula is used in the EcoReport tool:

$$LCC = PP + PWF \times OE + EoL$$

Where:

- LCC is Life Cycle Costs
- PP is the consumer purchase price and the installation costs
- OE is the operating expense
- PWF[224] (Present Worth Factor)
- EoL is End-of-life costs (disposal costs, recycling charge or benefit (resale)).

Below, the different parameters used to calculate the LCC are presented.

The average consumer purchase price including VAT is calculated from the data on unit sales and total market value collected by GfK which is listed below for each base case:

- BC 1: 340 EUR
- BC 2: 615 EUR
- BC 3: 228 EUR
- BC 4: 343 EUR

As seen in task 2, repair and maintenance costs can be difficult to quantify as some repairs are expensive and some products are never repaired. In the previous preparatory study, the repair and maintenance costs are assumed to be 5 EUR annually. This value is used

[223] Most of numbers are rounded up

[224] The Present Worth Factor (PWF) is described in the MEErP methodology when making Life Cycle Costs and is meant to be used in all the preparatory and review studies that follow MEErP for Ecodesign Regulations when calculating the LCC of the base cases. PWF is used to calculate the operational expenses of the future in today's value. That is why the discount rate and the escalation rate of electricity prices are used in the formula $PWF = \{1 - 1/(1 + r)^N\}/r$ from MEErP.

and corresponds approximately to a value between 1 % and 2 % of the purchase price depending on the base case. The lifetime of all base cases is assumed to be 12 years.

Regarding electricity and gas prices, the EU Commission have decided that data from PRIMES[225] should be used. Prices and projection are presented in task 2. The energy prices used are:

- Electricity: 0.194 EUR/kWh
- Gas: 0.072 EUR/kWh

The present worth factor (PWF) is automatically calculated in the EcoReport tool. The formula to calculate the present worth factor is:

$$PWF = \{1 - 1/(1 + r)^N \}/r$$

Where:

- N is the product life-time
- r is the discount rate minus the growth rate of running cost components (e.g. energy and water)

The discount rate is assumed to be 4 % and the escalation rate (annual growth rate of running costs) are assumed to be approximately 1% (based on the electricity and gas prices[226]). The calculated PWF for all base cases are 9.97 years.

Table 48: Input economic data for EcoReport tool (2016)

Description	Unit	BC 1	BC 2	BC 3	BC 4
Product Life	years	12	12	12	12
Annual sales	mln. Units/year	1.75	2.58	0.7	0.001
EU Stock	mln. Units	27.7	12.5	13.2	0.009
Product price	EUR/unit	340	615	228	343
Installation/acquisition costs (if any)	EUR/unit	25	25	75	100
Electricity rate	EUR/kWh	0.193	0.193	0.193	0.193
Repair & maintenance costs	EUR/unit/year	5	5	5	5
Discount rate (interest minus inflation)	%	4	4	4	4
Escalation rate (project annual growth of running costs)	%	1	1	1	1

[225] PRIMES 2016
[226] Recent years and projections

5.1.7 Environmental Impact of base cases

The environmental impacts of the four base cases are presented and discussed in this section.

- The following impacts are generated by the EcoReport tool:
  - 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 tumble driers (materials, manufacturing, distribution, use, disposal and recycling).

The total energy consumption and Global Warming Potential (CO_2-eq) are presented below in Figure 63 to Figure 70 for the different base cases. Only these two environmental impacts are presented as these are possible to interpret without data uncertainties and interpretation. The rest of the environmental impact categories are presented in Annex V.

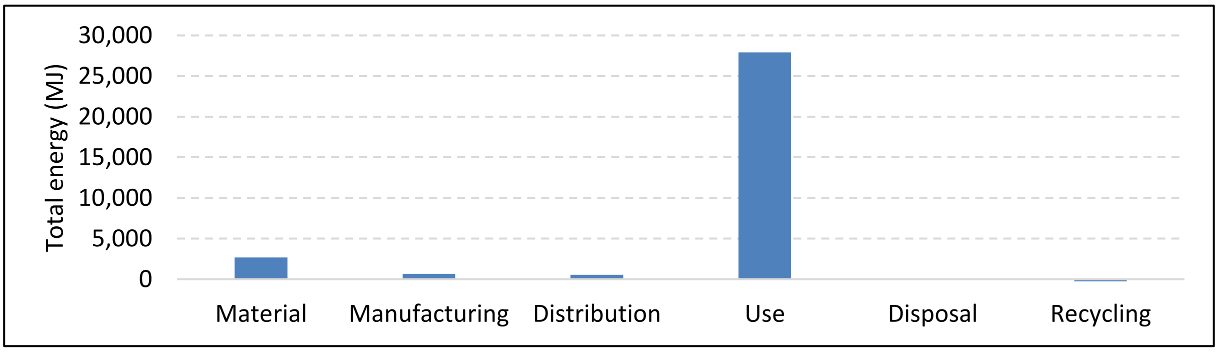

Figure 63: Total energy consumption BC 1 Heating element condenser

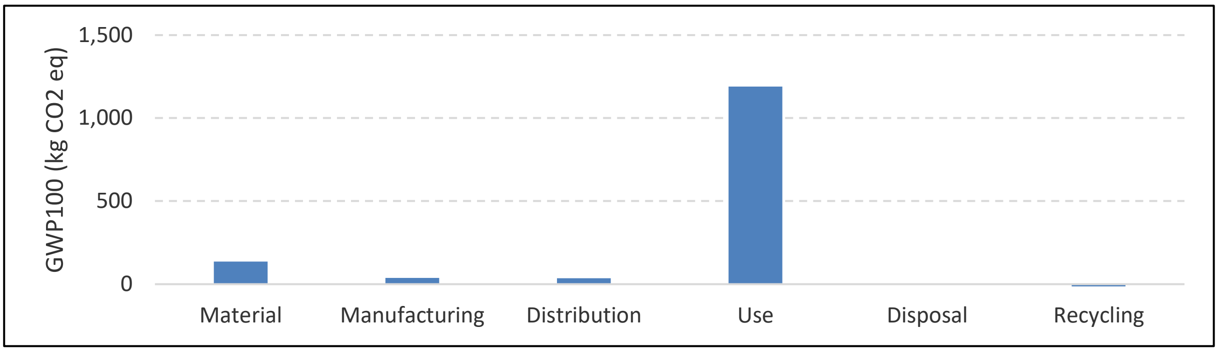

Figure 64: Global warming potential BC 1 Heating element condenser

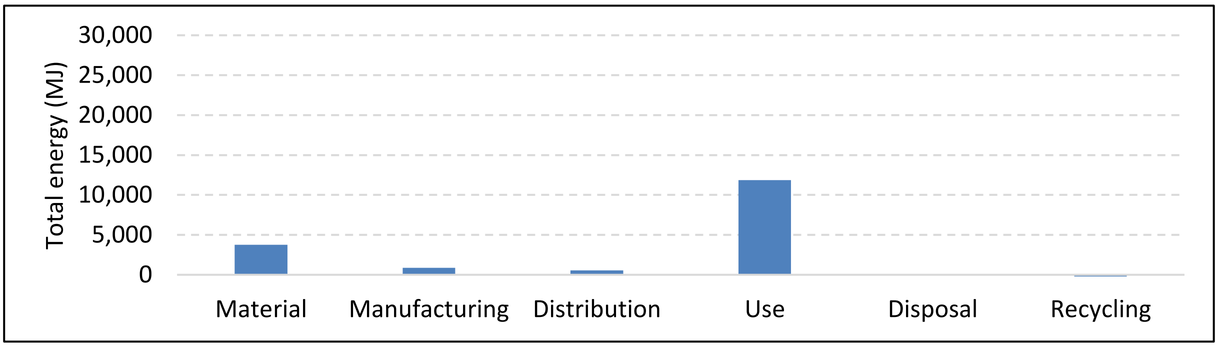

Figure 65: Total energy consumption – BC 2 Heat pump condenser

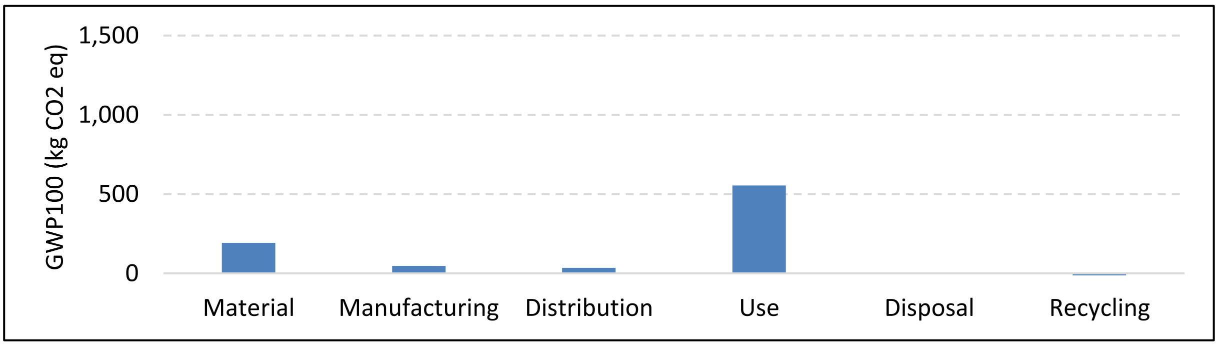

Figure 66: Global warming potential – BC 2 Heat pump condenser

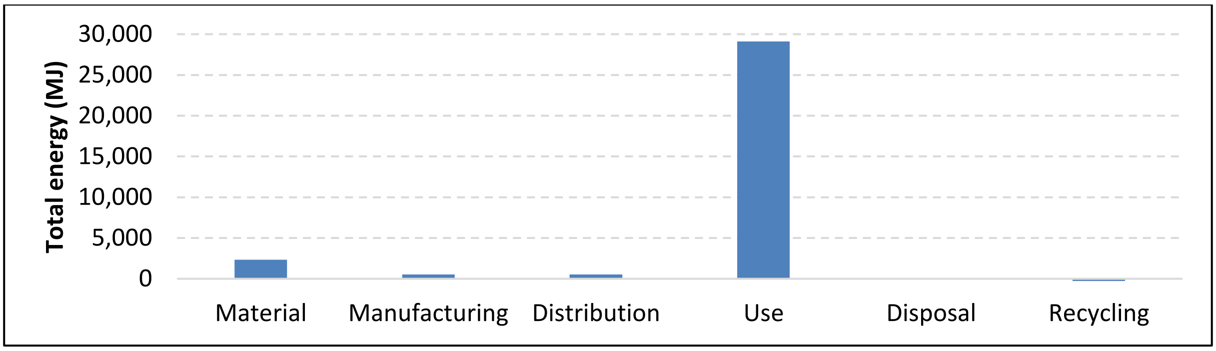

Figure 67: Total energy consumption – BC 3 Heating element Air-vented

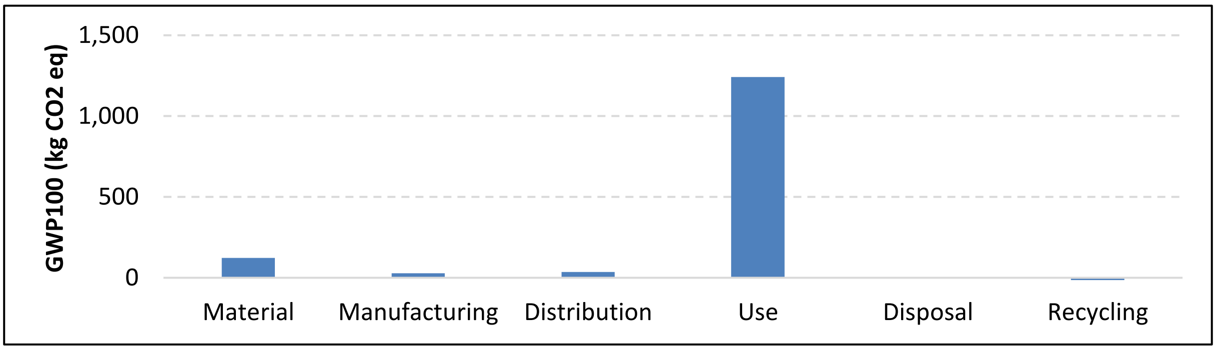

Figure 68: Global warming potential – BC 3 Heating element air vented

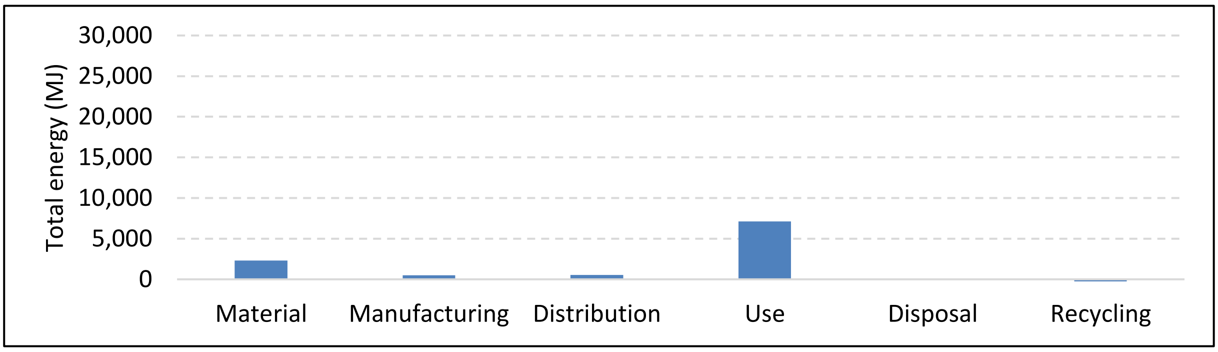

Figure 69: Total energy consumption – BC 4 Gas fired air-vented

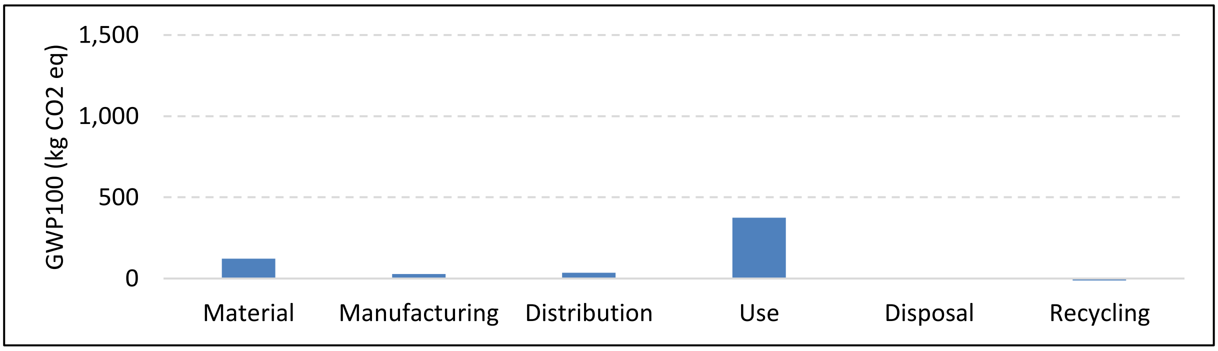

Figure 70: Global warming potential – BC 4 Gas fired air vented

The total energy consumption and the global warming potential are closely related. In all base cases the largest energy consumption comes from the use phase independently on the type of tumble drier. In all base cases, more than 72 % of the energy consumption and more than 73 % of the global warming potential appear in the use phase.

In general, the use phase is responsible for the highest environmental impacts calculated in the EcoReport tool. The detailed results with all the reported environmental impacts from the EcoReport tool are presented in Annex V.

The use phase has the highest impact in:

- BC 1: 7 out of the 15 impact categories
- BC 2: 6 out of the 15 impact categories
- BC 3: 9 out of the 15 impact categories
- BC 4: 4 out of the 15 impact categories

The consumption of materials of high importance is also determined for the base cases, in particular gold and copper. The derived impacts regarding energy, global warming potential and market value in EUR are:

- For BC 1:
  - 0.1215 grams of gold, 30.4 MJ, 2.7 kg CO_2-eq. and 4.2 EUR
  - 2170 grams of copper, 110 MJ, 5.9 kg CO_2-eq. and 12.8 EUR
- For BC 2:
  - 0.1575 grams of gold, 39.4 MJ, 3.5 kg CO_2-eq. and 5.5 EUR
  - 5100 grams of copper, 259.6 MJ, 13.8 kg CO_2-eq. and 30.1 EUR
- For BC 3:
  - 0.12 grams of gold, 30.4 MJ, 2.7 kg CO_2-eq. and 4.3 EUR
  - 0.755 grams of copper, 38.4 MJ, 2.04 kg CO_2-eq. and 4.5 EUR
- For BC 4:
  - 0.12 grams of gold, 30.4 MJ, 2.7 kg CO_2-eq. and 4.3 EUR
  - 0.755 grams of copper, 38.4 MJ, 2.04 kg CO_2-eq. and 4.5 EUR

Both copper and gold have limited impacts compared with the impacts from energy consumption in the use phase. Copper is responsible for less than 0.5 % of the emission of CO_2-eq over the lifetime and gold has an even lower impact.

5.1.8 Market Economics and LCC for base cases

The life cycle costs (LCC) of the three different base cases calculated in the EcoReport tool are presented in Table 49.

Table 49: Life cycle cost (LCC) of the four base cases

	BC 1	BC 2	BC 3	BC 4
Product price EUR	340	615	228	343
Installation/acquisition costs [227] EUR	25	25	75	100
Gas EUR	0	0	0	94
Electricity EUR	407	210	518	28
Repair & maintenance costs EUR	50	50	50	50
Total Life cycle costs EUR	**911**	**900**	**871**	**615**

For BC 2 and BC 4 the highest expenses are related to purchase price as the drier types represented by these base cases are expensive to buy or install compared to driers represented in BC 1 and BC 3. They do, however, have lower running costs as the BC 2 drier is the most efficient in terms of energy consumption during use and BC 4 drier has low running costs due to using gas. The low running costs do not counteract the high purchase price of BC 2 and they hence have a higher LCC than BC 3 and BC 4. The high running cost and medium purchase price means that BC 1 have the highest LCC, while the low running cost means BC 4 have the lowest LCC.

It should be noted however that the additional energy consumption from other secondary energy systems are not accounted here, which may be especially high for the air vented models. These data are not included due to the large variation in the building stock in Europe, where air-vented models may infer extra energy consumption in a wide diverse range of forms depending on the type of buildings. Moreover, the sale of these driers will continue to decrease, and thus this impact is becoming less important. Note also that no data has been available on gas-fired dries, so BC4 results present higher uncertainty due to more assumptions made.

5.2 EU-28 totals

The EU totals are the environmental impacts and the life cycle costs upscales to EU-28 level. For the EU totals the following is calculated:

- **Environmental impacts during the entire lifetime of tumble driers sold in 2017** are calculated by multiplying the annual sales with the impacts of each of the base cases.
- **Environmental impacts of tumble driers (EU-28 stock)** are calculated by multiplying the current stock of the different bases with the impacts of each of the base cases.

[227] Combined price for transporting and installing the appliance in such a way the end-user can use it right away. For gas-fired driers this includes the gas connection.

- **Environmental impacts of tumble driers as a share of EU total impacts** are calculated as the ratio of impacts from tumble driers compared to EU totals (total impacts of all energy-related products in 2011[228]).
- **Annual life cycle costs in EU-28** are calculated based on the life cycle costs per product multiplied by the annual sales of each of the base cases.
- **The EU consumption of critical raw materials in tumble driers** is calculated by multiplying the current stock with the amount of gold and copper in each of the base cases.

The main conclusions are:

- The combined energy consumption of all tumble driers sold in 2017 will account to 119 PJ during their lifetime resulting in 5.4 mt CO_2-eq. emitted. The highest impacts are connected with heating element condensing driers, because of their higher energy consumption at the use phase.
- The annual energy consumption of all tumble driers in EU (2017) is calculated to 143 PJ which leads to 6.5 mt CO2-eq released to the atmosphere. This means that tumble driers are responsible for 0.19 % of the energy consumption (0.51 % of the electricity consumption) in the EU and 0.13 % of the CO2-eq. Tumble driers are also responsible for 0.31 % of the particulate matter and 0.13 % of the acidifying agents released within EU.
- The highest costs are also related to heating element condensing driers because of a combination of high sales and energy consumption during use phase. The detailed results are presented in Annex VI.

The EU consumption of raw materials of high importance is also determined for the base cases for the EU stock[229]. For each of the base cases the amount of gold and copper is calculated and the derived impacts regarding energy, emission of CO_2-eq and value are presented below.

- For BC 1
  - 3.4 tonnes of gold, 0.841 PJ, 75725 tonne CO_2-eq. and 118 million EUR
  - 60109 tonnes of copper, 3.06 PJ, 162294 tonne CO_2-eq. and 355 million EUR
- For BC 2
  - 2.0 tonnes of gold, 0.492 PJ, 44297 tonne CO_2-eq. and 69.2 million EUR
  - 63750 tonnes of copper, 3.245 PJ, 172125 tonne CO_2-eq. and 376 million EUR
- BC 3
  - 1.6 tonnes of gold, 0.40 PJ, 36168 tonne CO_2-eq. and 57 million EUR
  - 9989 tonnes of copper, 0.51 PJ, 26969 tonne CO_2-eq. and 59 million EUR
- BC 4

[228] EcoReport tool contain EU totals from 2011.
[229] In 2016

- 0.001 tonnes of gold, 0.000026 PJ, 24 tonne CO_2-eq. and 0.04 million EUR
- 6.5 tonnes of copper, 0.00033 PJ, 17.5 tonne CO_2-eq. and 0.04 million EUR

The impacts of the critical raw materials are limited[230] compared to the other impacts of tumble driers in other life cycle stages. The value for the amount of gold and copper present in the EU stock are significant. The combined impact and value of gold and copper in all tumble driers (stock) are presented in Table 50.

Table 50: The combined impact and value of gold and copper in all tumble driers (stock -2017)

	Total Energy (PJ)	GWP100 (mt CO_2-eq.)	Total (mln. EUR)
Gold	1.89	0.17	265
Copper	4.36	0.23	505
Total	6.24	0.40	770

Gold and copper are accountable for an energy consumption of 6.24 PJ and an emission of 0.4 million tonne of CO2-eq. The combined value of copper and gold in the EU stock amounts to 770 million EUR.

Based on stakeholder inputs the PCBs are located easily available for repair, but it is still assumed that the printed circuit board is shredded at End-of-Life due to its small size. This means that most of the copper are recycled and the value is recovered while only 50 % of the gold is recovered. However, the estimation for gold is connected with high uncertainty due to the unknown material composition.

[230] 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.

6. Design options

The aims of this task are to:

- Identify the design options that can deliver potential improvements concerning use of energy and resources.
- Assess quantitatively, until the extent possible, the environmental improvements and additional consumer costs per option.
- Identify the Least Life Cycle Cost (LLCC) point of the different design options and aggregate in clusters, focusing on those with the best balance of environmental benefits and costs.
- Identify any long-term technical potential based on BNAT described in task 4.

6.1 Design options

The design options for the four base cases presented in task 5 are shown in Table 52, summarising their potential effect on energy consumption, improvement costs and other potential effects. The potential effects shown have been calculated for the whole drier, based on energy reductions per component and/or system which have then been calculated for the whole machine.

Design options 7 and 9 have been removed based on input from stakeholders.

Design option 7 was based on the assumption that larger machines result in higher annual energy consumptions, however, the calculated effect was only a maximum of a 1.5% increase based on APPLiA's model database and only for some tumble drier models. This introduces uncertainty to the calculated effect and considering the small effect and the lack of further evidence, this design option was removed after input from stakeholders.

Data from previous tasks indicates that a tumble drier loaded at 50% of the rated capacity will use more energy per kg of laundry than the same drier loaded at 100% (see Figure 44). This is to some extend due to the loss associated with heating up the tumble drier itself which does not depend on the amount of laundry loaded in the machine. This loss is directly dependent on the thermal capacity of the drier, which (according to stakeholders) does not vary much among driers of the same type (e.g. heat pump condenser) at different rated capacities. This means that two machines at e.g. 7kg and 9kg can behave almost identical at 4.4kg of load as they have very small physical differences. The difference between the rated capacities is primarily due to different ways to control the cycle (software based) and with varying heat throughputs of the heat pump circuit – the physical dimensions and drum size are in most cases identical. Therefore, design option 7 was not really about technological improvement but more about other factors which at the end did not provide any significant improvement, as stated in previous paragraph. However, for heating element condenser driers, increased specific energy consumption in rated capacities over 8kg were observed (see Figure 44). Instead of tackling this as design option, it is proposed to implement a new formula for calculating Standard Energy Consumption per cycle based on a heat pump driers data fit. In this way, other drier types will be penalised when establishing the Energy Efficiency Index (EEI). This is explained in detail in section 7.2.3.

Design option 9 was based on the premise that consumers would fill the driers up to full capacity if the drier was equipped with a consumer feedback system. This option was considered unrealistic, since the consumer would probably not fill the drier with a higher load than the load of the previous wash.

The presented options have been evaluated by three different parameters:

- The potential effect on energy consumption, which was estimated as described in next the paragraphs
- Extra costs for consumers, which are primarily coming from costs of improving the product design for manufacturers. The improvement costs for consumers have been calculated as the observed retail price based on manufacturers cost[231].
- The potential effect on resource consumption.

The potential effect on energy consumption has been estimated considering the effect presented in Table 52 based on inputs from task 4 and coupled with the usage patterns from task 3.

The effect on energy consumption has been quantified considering the part of the tumble drier the design option is affecting, i.e. the heating system (heat pump circuit, heating element, gas burner) or the drum/fan motor. The preparatory study states that a typical induction motor for driving the drum and the fan(s) is between 150-250W. Input from stakeholders indicated this is still valid. A 200W induction motor is thus used for future references. Assuming that this motor is running constantly during the cycle, the cycle-time data presented in task 2 (Figure 34 - Figure 37) can be used to establish the energy consumption by the drum/fan motor (see Table 51)[232].

[231] Table 5.1 from Washing preparatory study (Page 377). Formula taken from EUROSTAT.
[232] For instance, if a design options reduces the energy consumption of the drum/fan motor by 6%, the total energy consumption reduction is 36% x 6% = ~2% of the total energy consumption for the condenser driers.

Table 51: Energy consumption used by drum/fan motor. Based on cycle time data from GfK (2013-2016).

	Condenser heating element	Condenser heat pump	Heating element air-vented	Gas-fired air-vented
% of energy consumption used by drum/fan motor	16%	50%	15%	29%

Both the effect on energy consumption, other potential effects and improvement costs are based on input from stakeholders and information gathered during tasks 1 to 4. Design options including their potential improvements as well as manufacturing costs have been circulated to stakeholders, which have been asked to give input on the validity and size of the values.

Table 52: List of design options with descriptions and input parameters. Descriptions on specific calculation methods are found in subsequent sections 6.1.1 - 6.1.11.

Design option #	Description	Effect on energy consumption during use phase per base case[233]				Other potential effects per unit[234]	Cost of improvement for manufacturers [EUR/unit] [235]
		1	2	3	4		
1	Increased drum and fan motor efficiency by replacing asynchronous induction motor with permanent magnet synchronous motors (BLDC)	-2.3%	-7.4%	-2.3%	-2.3%	No impact on the overall material consumption – however a small increase in scarce resources (assumption 0.01%-0.05% increase)[236]	16
2	Increased compressor motor efficiency by replacing asynchronous induction motor with permanent magnet sync. motors (BLDC)	Not applicable	-6.1%	Not applicable	Not applicable	No impact on the overall material consumption – however a small increase in scarce resources (assumption 0.01%-0.05% increase)	16
3	Multi motor setup to have a better on/off control of the different subsystems (e.g. drum motor, process-air fan motor, condenser fan motor) thus decreasing electricity consumption	-0.8%	-2.5%	-2.3%	-2.3%	No significant impact on materials consumption. Two smaller motors might have larger material consumption compared to one large, but this would not always be the case. Therefore, this increase considered negligible.	10
4	Longer cycle time with lower drying temperatures	Negligible	-5.0%	Negligible	Not applicable	No impact on the material consumption	0
5	Improved condensation rate/cycle time/condensation efficiency by improving heat	-0.3%	Not applicable	Not applicable	Not applicable	0.05% - 0.1% increase in overall material consumption due to the mixing of non-compatible alloys regarding the recycling process – and a	3

[233] Per unit of base case. Base case 1: Condenser tumble driers (heating element); Base case 2: Condenser tumble driers (heat pump); Base case 3: Heating element air-vented; Base case 4: Gas-fired air-vented. Potential effects have been established by input from stakeholders from tasks 1 to 4 and additional input during further consultation.
[234] Based on assumptions considering input from stakeholders.
[235] ibid

Design option #	Description	Effect on energy consumption during use phase per base case[233]				Other potential effects per unit[234]	Cost of improvement for manufacturers [EUR/unit] [235]
		1	2	3	4		
	exchangers (air to air) with copper fins instead of aluminium					small increase in scarce resources (Al to Cu assumption 0.05%-0.1% increase)	
6	Improving the heat pump circuit characteristics by reducing condensation/evaporation pressure difference (and thus electricity consumption) and by using more effective heat exchanger (refrigerant-to-air), e.g. using copper fins instead of aluminium	Not applicable	-2.5%	Not applicable	Not applicable	0.05% - 0.1% increase in overall material consumption due to the mixing of non-compatible alloys regarding the recycling process – and a small increase in scarce resources (Al to Cu assumption 0.05%-0.1% increase)	3
8	Improved energy efficiency of condenser driers by changing heating technology from heating element to heat pump for condenser driers	-61.7%[237]	Not applicable	Not applicable	Not applicable	25%-30% increase in material consumption[238]	98[239]
10	Reduced GWP by using natural refrigerants instead of F-gasses	Not applicable	0%	Not applicable	Not applicable	Reduced GWP from refrigerants No impact on the overall material consumption	0
11	Reduced use of virgin materials and environmental impacts by displaying content of recycled plastics of drier	No effect	No effect	No effect	No effect	-10% of virgin plastic used	0
12	Increased durability and reparability of tumble driers by easy access of critical parts by	No effect	No effect	No effect	No effect	Longer lifetime to 14 years	None[240]

[237] Based on the average difference in energy consumption per cycle between condensing driers with a heating element and with a heat pump as heat source.
[238] Based on BOMs of base case 1 and base case 2
[239] Based on the difference in sales price between condensing driers with heat pump and with heating element (Table 15) divided by the combined sales margins for manufacturs, wholesale and retail. (615-340)/2.8.
[240] For consumer, there will be increased reparation costs from 5 to 10 EUR /year/unit (140 EUR/unit)

Design option #	Description	Effect on energy consumption during use phase per base case[233]				Other potential effects per unit[234]	Cost of improvement for manufacturers [EUR/unit] [235]
		1	2	3	4		
	professionals and consumers and ensuring availability of spare parts after 2 years						
13	Increased dismantling and recyclability at End-of-Life by a modular design which enhances recovery of critical materials, plastics and metals	No effect	No effect	No effect	No effect	Higher reuse and recycling rates at the driers' end-of-life	5[241]

[241]It is expected that purchase price will be higher at the beginning of the period following the implementation of the regulation and that it will stabilize afterwards

6.1.1 Improved drum and fan motor efficiency by replacing asynchronous induction motor with permanent magnet synchronous motors (BLDC)

Besides the heat generation system, the motor running the drum and the fan(s) is the main electric consuming component in driers. The current used average motor type is an AC asynchronous induction motor (see Table 37).

Synchronous permanent magnet motors (such as brushless DC motors) can be up to 20% more efficient than the AC induction motors[242,243], and switching to these types of motors can thus reduce the overall energy consumption of the drier. Current BAT-driers are usually equipped with these kinds of motors which indicates that the technology is well proven and tested. The listed savings in Table 52 are based on an assumed 15% reduction in the energy consumption at the fan/drum motor sub-system, which is then used to calculate reduction of the total energy consumption of the drier. This results in the assumed effect on energy consumption per base case (see Table 52)[244].

The improvement costs for the drum and fan motor were initially based on 2017 washing machine preparatory study[245] which reports improvement costs between 1EUR and 10EUR per unit. However, further input from stakeholders indicated a higher consumer cost of 45EUR per unit. Therefore, the improvement cost for manufacturers has been set as 16EUR per unit, which translates into approximately 45EUR per unit consumer cost.

6.1.2 Improved compressor motor efficiency by replacing asynchronous induction motor with permanent magnet synchronous motors (BLDC)

Similar to the fan/drum motor, the motor used in the compressor unit are on average induction motors (See Table 37). Using a BLDC motor in the compressor unit instead, can reduce the energy consumption of the heat pump circuit by 15%, which corresponds to an 8% total reduction in energy consumption[246]. Considering some heat pump driers on the market are already equipped with these motors, the actual reduction becomes 6.1%[247], which is then used to calculate reduction of the total energy consumption of the drier (see Table 52).

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242 https://www.machinedesign.com/motorsdrives/whats-difference-between-ac-induction-permanent-magnet-and-servomotor-technologies

243 https://e2e.ti.com/blogs_/b/industrial_strength/archive/2018/02/06/cut-the-power-and-complexity-of-your-appliance-designs

244 15% reduction in all energy consumption related to running the fan/drum motor from Table 51 e.g. for condensers with heating elements, it is a 15% reduction of 16% of the total energy consumption: 15%*16% = ~2% reduction of the total energy consumption.

245 Ecodesign and Energy Label for Household Washing machines and washer dryers – preparatory study, JRC, 2017, p.427, table 6.4

246 15% energy reduction of ~50% of the total energy consumption (attributed to running the compressor from Table 51): 15%*50% = ~8%.

247 Assuming 20% of heat pump driers are already using BLDC motors for the compressor. ~8%*(100%-20%) = ~6%

The improvement costs for the compressor motor are based on the same assumptions as in the previous design option, using 16 EUR per unit as improvement costs for manufacturers.

6.1.3 Multi motor setup to have a better on/off control of the different subsystems (e.g. drum motor, process-air fan motor, condenser fan motor)

In some premium driers the fan/drums are powered by separate BLDC motors, instead of using a common motor as found in most driers on the market. This could enable the motors to be run independently of each other. The fan could for instance run at 100% capacity even though the drum is changing spin directions or running at below 100% spin speed if delicate items are tumbled. A 5% reduction in energy consumption is assumed which is then scaled to the total energy savings at a drier level (see Table 52)[248]. This is *only* the effect of the multi-motor setup, and not the effect of using more efficient motors.

The improvement cost is expected to be lower than of changing motor technology, thus it has been assumed as 10EUR per unit.

6.1.4 Longer cycle time with lower drying temperatures

Current tumble driers are built and optimised based on a number of parameters, including production cost, drying performance, ease of use, energy consumption, and cycle time. According to the legislation, the energy consumption and cycle time of the most energy efficient program (standard cotton cycle) is to be shown on the energy label, which 4 out of 5 users consider when buying a new tumble drier[249].

Currently, 89% think the energy efficiency of the drier is important when buying a new drier, while 82% think the cycle time is important[249]. This means that manufacturers optimise for both of these parameters, as they are both considered important by consumers. In some cases, cycle time might not be important for users. For instance, if they start the drying cycle at night time, or before leaving for work in the morning. If the driers could be optimised for having the lowest possible energy consumption instead of a mix between energy efficiency and cycle time, an overall reduction in energy consumption could be reached.

For heat pump driers, the drying temperature could be lowered. This would reduce the energy consumption of the heat pump circuit. This is because the efficiency/COP[250] of a heat pump circuit is proportional to the difference between the evaporation and condensation temperature/pressure – a higher temperature or pressure means the

[248] This is similar to the calculations in section 6.1.1 but with 5% instead of 15%.
[249] APPLiA and InSites Consulting. (2018). Tumble dryer usage and attitudes: A survey in 12 European countries (not publicly available).
[250] https://en.wikipedia.org/wiki/Coefficient_of_performance#Derivation

compressor needs to do more work, and thus lowers the COP. Assuming an evaporation temperature of 10°C, and a condensation temperature of 65°C, a reduction of the condensation temperature from 65°C to 45°C would increase the theoretical efficiency by 48%[251].. This would increase the cycle time as the drying temperature would be lower, which in turn increases the overall energy consumption of the fan/drum motor. An optimal balance between the cycle time and the condensation temperature has been found to avoid an increase of energy consumption. Assuming an average fan/drum motor size of 200W, this would be below 6 hours[252]..

The drying temperature can also be reduced for driers equipped with heating elements, and this will reduce the heat loss of the drier during the cycle. However, this will result in only a small increase in the energy efficiency compared to the heat pump driers, as the drying temperature is not correlated to the efficiency of the heating element. The effect of reduction of the drying temperature is therefore considered negligible for heating elements driers.

Gas driers are not considered for this design option, as the combustion is naturally linked to a certain temperature and is assumed to be difficult to throttle.

A 5% reduction in overall energy consumption is assumed for base case 2[253], which is then used to calculate reduction of the total energy consumption of the drier (see Table 52).

No improvement costs are assumed, as no additional components are needed.

6.1.5 Improved condensation rate/cycle time/condensation efficiency by improving heat exchangers (air to air) with copper fins instead of aluminium

Heating element condensing driers use an air-to-air heat exchanger to condense the moist process air. Increasing the effectiveness of this heat exchanger increases the condensation rate, and thus reduces the average humidity ratio of the process air. This in turn speeds up the drying time, as the water absorptivity ratio of the process air is proportional to humidity ratio of the air.

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[251] Based on an assumed evaporation temperature of 10C and that a heat pump circuit can reach 40% of the Carnot efficiency. The COP of the heat pump heating at 65C =2.46, at 45C = 3.64, = 48% difference.

[252] 200W at 6 hours = 1.2 kWh. The current average energy consumption per cycle for heat pump driers at 4.4kg is 1.1kWh, so the optimal point is thus less than 6 hours.

[253] The decrease from 65C to 45C reduces the heating power by roughly 36% due to a lower temperature difference, and thus increases the cycle time equally. This increase the power consumption by the fan motor. Assuming 50% of the current energy consumption comes from the fan/drum motor (from Table 51) this gives a current consumption of 0.55 kWh of drum motor/cycle, and 0.55 kWh of compressor/cycle. With the reduced temperature this changes to 0.75 kWh of drum motor/cycle, and 0.29 kWh of compressor/cycle. In total = 1.04 equal to a 5.7% reduction. 5% is thus used as a conservative estimate.

Ways to increase the effectiveness of the heat exchanger can be by either increasing the physical size of the heat exchanger, by increasing the air-flow across the heat exchanger, or by using a more heat conductive material for the fins (e.g. copper instead of aluminium).

Reducing the cycle time means that less time is spent for the process air to escape the unit during the cycle. This increases the condensation efficiency. Furthermore, a shorter cycle means less time is spent running the fan/drum motor, thus reducing the overall energy consumption. A 2% reduction of the energy consumption of the fan/drum motor is assumed and resulting in an overall reduction of the total energy consumption of the drier by 0.3%. (see Table 52).

An improvement cost of 3 EUR per unit is assumed due to the higher cost of copper and aluminium.

Note that the design options described here, and the design option described in section 6.1.4 regarding longer cycle times, are two different ways to increase the efficiency. Using longer cycle times in general, means to increase the efficiency of the heat source (e.g. the heat pump circuit) by running it "slower". The effect in this section refers to running the tumble drier at the same load/rate, but at a higher condensation efficiency.

6.1.6 Improving the heat pump circuit characteristics by reducing condensation/evaporation pressure difference and by using more effective heat exchanger

For heat pump driers, the efficiency of the heat pump circuit is directly proportional to the energy consumption of the drier. A heat pump circuit consists of three main components (compressor, evaporator, condenser), and the total efficiency is dependent on all three elements. As explained in 4.1, the heat pump circuit efficiency is inversely proportional to the difference between evaporation and condensation pressures and temperatures. Having more effective heat exchangers means improving either the heat transfer potential or reducing pressure drop in the heat exchanger. Both effects allow the compressor to reduce the pressure differential across the compressor, which results in a more efficient process with a lower energy consumption.

The most commonly found heat exchanger in current models on the market is of the fin-and-tube type, with copper tubes and aluminium fins. A simple improvement option is to use copper fins instead of aluminium fins, which is commonly used by other industry sectors. The heat exchanger could thus be made more effective, or the flow-through area of the refrigerant could be made shorter, reducing the pressure loss in the heat exchanger.

It is assumed that an improvement of up to 5% can be achieved for the heat pump circuit. This has been used to calculate reduction of the total energy consumption of the drier (see Table 52).

An improvement cost of 3 EUR per unit is assumed due to the higher cost of copper.

6.1.7 Improved energy efficiency of condenser driers by changing heating technology to heat pump for condenser driers

As presented in tasks 2 to 4, condensing driers with heat pump technology are far superior in terms of energy efficiency, with heat pump driers on average using less than half of the energy per kg-laundry compared to heating elements driers (see Figure 44).

Hence, using heat pump technology would result in significant reduction of energy consumption. The effect on total energy consumption is based on the average difference in specific energy consumption in percentage (i.e. -61.7% in 2021)

The improvement costs are based on the difference in unit price between condensing heat pump driers and condensing heating element driers (i.e. 98 EUR for manufactures).

6.1.8 Reduced GWP (Global Warming Potential) by using natural refrigerants instead of F-gasses

The most commonly used refrigerants for heat pump tumble driers are hydrofluorocarbons such as R134a, R407C, and R410A. Recently, driers with R290 (propane) have emerged on the market.

Using R290 have some general advantages:

- It has very low GWP (3) and 0 ODP[254] (for reference, the GWP of R134a is 1430)
- The temperature per pressure difference (dT/dP) is higher than for R134a[255], which means that a lower pressure difference is needed and thus a more efficient heat pump cycle is possible
- It is cheaper

Disadvantages include:

- The pressure needed to reach for instance a 70°C condensation temperature is higher for R290 compared to R134a[256]
- It is flammable and potentially explosive

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[254] http://www.linde-gas.com
[255] For instance, the difference in condensation and evaporation temperatures are higher for R290 than it is for R134a for equal pressure differences. *Source: CoolProp*
[256] Saturation pressures for 70°C is 21.2bar for R134a, and 25.9bar for R290. *Source: CoolProp*

Overall, the disadvantages might result in added product costs, as the components in the heat pump circle have to sustain higher pressures and added safety precautions have to be taken. The advantages however might result in a more energy efficient cycle with a significantly lower GWP.

Some sources report that using natural refrigerants can alter the efficiency of a vapor-compression cycle by up +/-10%[257]. Models with R290 are found currently on the market which are able to achieve an A+++ energy label[258]. Natural refrigerants are thus currently being tested in heat pump tumble driers and are considered suitable as a replacement option for HFC refrigerants. It is thus assumed that there will be no effect on the overall energy consumption.

The majority of the improvement cost is assumed to be associated with testing and not as much for research and development costs to develop new heat pump circuits. Propane is considerably cheaper than R134a, which nullifies the increased cost of development.

6.1.9 Reduced use of virgin materials and environmental impacts by displaying content of recycled plastics of drier to the consumers

As shown in task 5, plastics (in particular polypropylene) constitute about 25-30% of the base cases' bill of materials. Polypropylene is a rigid plastic which, if collected and sorted properly, is recyclable[259]. The economic viability of recycling depends on how much of a homogeneous fraction is available which is to a great extent related to the waste collection system and not directly influenced by product policy measures as discussed previously.

The amount of virgin plastics and the associated environmental impacts of the driers can be reduced if more recycled plastics are used in the product. It is assumed that about 10% less virgin plastics can be used in the driers, and that the initial costs of incorporating recycled plastics in the driers will be nullified by the savings from buying cheaper recycled plastic. No expected effect on the driers' energy consumption and efficiency is expected.

6.1.10 Increased durability and reparability of tumble driers by easy access of critical parts by professionals and ensuring availability of spare parts after 2 years

Accessing critical parts by professional repairers can ensure tumble driers are kept well-functioning during their lifetime, and even prolong it. As shown in section 3.2.2, 75% of consumers answering APPLiA's survey are ready to repair their tumble driers. However, Table 31 shows that it is not always easy to access these components.

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[257] http://conf.montreal-protocol.org/meeting/oewg/oewg-40/presession/Background-Documents/TEAP_DecisionXXIX-10_Task_Force_EE_May2018.pdf
[258] According to stakeholders, and according to a desktop study.
[259] https://www.azocleantech.com/article.aspx?ArticleID=240

Figure 55 shows that ensuring availability of spare parts for a certain number of years, ensuring an easier disassembly of products, and making disassembly information available to professionals provide the largest environmental benefits of the products assessed. Ensuring access to critical components in the drier for professionals and making sure that spare parts are available will not only contribute to well-functioning of the drier during its lifetime avoiding replacement of the product but it would also prolong the driers' lifetime. It is not possible to know with certainty for how long the lifetime will be extended, but it is assumed that because tumble driers are long-lasting products, the effect from making spare parts and repairability information available would be limited. It was assumed that the life time extension would be 2 years (from 12 to 14 years). This information was presented to stakeholders and no further changes were proposed. Improvement costs to manufacturers for designing products easier to disassemble are estimated at 20 EUR per unit, which may be counteracted in the long term by the fall of spare parts prices due to higher market availability. However, this long-term effect has not been included in the improvement costs.

No effect on the driers' energy consumption and efficiency is expected.

6.1.11 Increased dismantling and recyclability at End-of-Life by a modular design which enhances recovery of critical materials, plastics and metals

Designing driers for an easier dismantling at their End-of-Life increases the possibilities of reuse of more components and recycling of more materials rather than shredding and incinerating/landfilling (see below):

- For base case 1, reuse would increase from 1% of the product to 7% and recycling from 71 to 74% (mainly more plastics being recycled)
- For base cases 2 and 3, reuse would increase in the same way as for base case 1 and recycling from 73 to 75% (mainly more plastics being recycled)

Improvement costs are assumed to be associated with designing the driers more modular and the initial investment are estimated to be 5 EUR per unit.

No effect on the driers' energy consumption and efficiency is expected.

6.2 Potential environmental improvements and consumer costs

Using the EcoReport tool, the design options presented in section 6.1 have been ranked per base case in order to identify those with the largest life cycle environmental benefits[260] and the lowest life cycle costs (LCC). Both have been calculated throughout the product's

[260] The environmental benefits presented are Total Energy Demand and Global Warming Potential, which are considered the most representative of a tumble drier's life cycle environmental impacts.

lifetime including all life cycle stages as assessed in the EcoReport tool. Those options presenting smaller benefits and higher costs are to be discarded.

6.2.1 Base case 1 (BC1) – Condenser heating element tumble driers

Table 53 presents the design options relevant for base case 1, ranked according to their life cycle costs. They have been compared to the environmental impacts and life cycle costs of the base cases presented in task 5. The environmental improvements and consumer costs are presented as net benefits/savings (negative number) or burdens/costs (positive number). Environmental improvements are presented as Total Energy [261] and Global Warming Potential.

Table 53: Potential environmental improvements and life cycle costs at product level for the different design options - Relevant for base case 1 (BC1) – Condenser heating element driers

Design option	Description	LCC	TOTAL ENERGY	GLOBAL WARMING POTENTIAL
8	Improved energy efficiency of condenser driers by changing heating technology to heat pump for condenser driers	-3.3%	-54.9%	-53.7%
11	Reduced use of virgin materials and environmental impacts by displaying content of recycled plastics of drier to the consumers	0.0%	-0.5%	-0.3%
5	Improved condensation rate/cycle time/condensation efficiency by improving heat exchangers (air to air) with copper fins instead of aluminium	0.8%	-0.3%	-0.3%
13	Increased dismantling and recyclability at End-of-Life by a modular design which enhances recovery of critical materials, plastics and metals	1.6%	-1.0%	-0.9%
3	Multi motor setup to have a better on/off control of the different subsystems (e.g. drum motor, process-air fan motor, condenser fan motor)	2.6%	-0.7%	-0.7%
1	Increased drum and fan motor efficiency by replacing asynchronous induction motor with permanent magnet sync. motors (BLDC)	3.6%	-2.1%	-2.0%
12	Increased durability and reparability of tumble driers by easy access of critical parts by professionals and ensuring availability of spare parts after 2 years	14.3%	not estimated*	not estimated*

*=potential environmental savings of these option can only be estimated by assessing its long-term effect of prolonging its lifetime after it ends; this cannot be assessed with the Eco-Report tool

Table 53 shows that only for one out of the seven design options identified for condenser heating element tumble driers, there are net consumer costs benefits. Design option 8 shows large net total energy and GHG emissions savings and it is the only design option presenting net consumer costs. This is because of the potential energy savings from switching heating element technology to heat pump technology.

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[261] Total Energy as defined in the EcoReport tool, which is the total energy consumption during the product's entire life cycle.

Design options 11 and 5 show nearly no economic consumer benefits/costs and small relative savings. The same is the case for design options 13 and 3 but at slightly higher relative costs. This show the small relative effect of these options when applied individually. This is not the case for design option 1, which shows larger net environmental benefits. Design option 12 shows larger consumer costs increase, because of the increased repair costs for consumers.

Based on this analysis, it was decided to discard design options 3, 5 and 11 since they present very small potential improvements.

6.2.2 Base case 2 (BC2) – Condenser heat pump driers

Table 54 presents the design options relevant for base case 2, ranked and presented the same way as for BC1. Design options 5, and 8 are not relevant for BC2 as it can be seen in Table 52. Design option 4 has been discarded as, according to input from stakeholders, consumers are not willing to increase the cycle time to longer durations. The APPLiA consumer survey in 2018 showed also that most of the consumers are satisfied with the current duration of their tumble driers’ cycle time.

Table 54: Potential environmental improvements and life cycle costs at product level for the different design options - Relevant for base case 2 (BC2) – Condenser heat pump driers

Design option	Description	LCC	TOTAL ENERGY	GLOBAL WARMING POTENTIAL
4	Longer cycle time with lower drying temperatures	-1.2%	-3.7%	-3.3%
10	Reduced GWP by using natural refrigerants instead of F-gasses	-0.6%	0.0%	-6.2%
11	Reduced use of virgin materials and environmental impacts by displaying content of recycled plastics of drier to the consumers	0.0%	-1.1%	-0.7%
6	Improving the heat pump circuit characteristics by reducing condensation/evaporation pressure difference (and thus electricity consumption) and by using more effective heat exchanger (refrigerant-to-air), e.g. using copper fins instead of aluminium	0.3%	-1.9%	-1.6%
13	Increased dismantling and recyclability at End-of-Life by a modular design which enhances recovery of critical materials, plastics and metals	1.5%	-2.4%	-2.0%
3	Multi motor setup to have a better on/off control of the different subsystems (e.g. drum motor, process-air fan motor, condenser fan motor)	2.5%	-1.8%	-1.6%
1	Increased drum and fan motor efficiency by replacing asynchronous induction motor with permanent magnet sync. motors (BLDC)	3.2%	-5.4%	-4.8%
2	Increased compressor motor efficiency by replacing asynchronous induction motor with permanent magnet sync. motors (BLDC)	3.5%	-4.5%	-3.9%

Design option	Description	LCC	TOTAL ENERGY	GLOBAL WARMING POTENTIAL
12	Increased durability and reparability of tumble driers by easy access of critical parts by professionals and ensuring availability of spare parts after 2 years	10.2%	not estimated*	not estimated*

*=potential environmental savings of these option can only be estimated by assessing its long-term effect of prolonging its lifetime after it ends; this cannot be assessed with the Eco-Report tool

Table 54 shows that for two out of the nine design options identified for condenser heating element tumble driers, there are net consumer costs benefits. However, the net environmental benefits from design option 11 are very small in comparison to the rest of the design options. Design options 3 and 6 show relatively smaller net environmental savings as well.

The rest of the design options show larger net savings although at higher consumer costs. Design option 12 shows larger consumer costs increase, because of the increased repair.

Based on this analysis, it was decided to discard design options 3, 6 and 11 since they present very small potential improvements.

6.2.3 Base case 3 (BC3) – Heating element air-vented driers

Table 55 presents the design options relevant for base case 3, ranked and presented the same way as for BC1 and BC2. Design options 2, 4, 5, 6, 8 and 10 are not relevant for BC3 as it can be seen in Table 52.

Table 55: Potential environmental improvements and life cycle costs at product level for the different design options - Relevant for base case 3 (BC3) – Heating element air-vented driers

Design option	Description	LCC	TOTAL ENERGY	GLOBAL WARMING POTENTIAL
11	Reduced use of virgin materials and environmental impacts by displaying content of recycled plastics of drier to the consumers	0.0%	-0.4%	-0.3%
13	Increased dismantling and recyclability at End-of-Life by a modular design which enhances recovery of critical materials, plastics and metals	1.6%	-0.9%	-0.8%
3	Multi motor setup to have a better on/off control of the different subsystems (e.g. drum motor, process-air fan motor, condenser fan motor)	1.8%	-2.1%	-2.1%
1	Increased drum and fan motor efficiency by replacing asynchronous induction motor with permanent magnet sync. motors (BLDC)	3.7%	-2.1%	-2.1%
12	Increased durability and reparability of tumble driers by easy access of critical parts by professionals and ensuring availability of spare parts after 2 years	15.0%	not estimated*	not estimated*

*=potential environmental savings of these option can only be estimated by assessing its long-term effect of prolonging its lifetime after it ends; this cannot be assessed with the Eco-Report tool

Table 55 shows that none of the five design options identified for heating element air-vented tumble driers present net consumer costs benefits.

Generally, the net environmental savings for total energy and GHG emissions are of smaller relative magnitude as for BC1 and BC2. Design options related to resource efficiency show smaller relative savings than those related to energy efficiency, however, their effect could be increased if they would be clustered. Although the effect of design option 11 is rather small and it has thus been discarded as a potential improvement design option in further analyses.

6.2.4 Base case 4 (BC4) – Gas-fired air-vented driers

Table 56 presents the design options relevant for base case 4, ranked and presented the same way as for previous base cases. Design options 2, 4, 5, 6, 8 and 10 are not relevant for BC4 as it can be seen in Table 52.

Table 56: Potential environmental improvements and life cycle costs at product level for the different design options - Relevant for base case 4 (BC4) – Gas-fired air-vented driers.

Design option	Description	LCC	TOTAL ENERGY	GLOBAL WARMING POTENTIAL
11	Reduced use of virgin materials and environmental impacts by displaying content of recycled plastics of drier to the consumers	0.0%	-1.2%	-0.7%
13	Increased dismantling and recyclability at End-of-Life by a modular design which enhances recovery of critical materials, plastics and metals	2.1%	-2.7%	-2.1%
3	Multi motor setup to have a better on/off control of the different subsystems (e.g. drum motor, process-air fan motor, condenser fan motor)	4.2%	-0.4%	-0.3%
1	Increased drum and fan motor efficiency by replacing asynchronous induction motor with permanent magnet sync. motors (BLDC)	6.7%	-0.4%	-0.3%
12	Increased durability and reparability of tumble driers by easy access of critical parts by professionals and ensuring availability of spare parts after 2 years	12.2%	not estimated*	not estimated*

*=potential environmental savings of these option can only be estimated by assessing its long-term effect of prolonging its lifetime after it ends; this cannot be assessed with the Eco-Report tool

Generally, gas-fired air-vented tumble driers present the smallest potential environmental benefits with higher costs. Table 56 shows that none of the five design options identified for these driers shows net consumer costs benefits, and the potential environmental benefits per unit are small.

Four of the five design options involve net consumer costs, and design options 1 and 3 show very small potential benefits to the environment. However, these are the only design opportunities that could improve the performance of gas-fired tumble driers concerning energy efficiency, and they have thus not been removed.

Based on this analysis, it was decided to discard design option 11 since it presents very small potential improvements. Design options 1 and 3 were kept for BC4 in spite of their small effect, as they are currently the only observed potential technology improvements to reduce energy consumption for gas-fired driers.

6.3 Least Life Cycle Cost (LLCC) analysis

6.3.1 Design options that can be implemented simultaneously (i.e. clustered design options)

Design options can be clustered in order to aim larger potential environmental benefits at lower costs. However, in the case of tumble driers, we observe that the clustering possibilities are quite limited considering their applicability (see previous analysis presented in section 6.1) and the technical possibilities for implementation:

- For Condenser heating element tumble driers (BC1):
  - Design option 1: Energy-related design option to improve energy efficiency of the driers based on improved motor efficiencies.
  - Design option 8: Energy-related design option to improve energy efficiency of the driers based on improved heating technology.
  - Design option 12: Resource-related design options to promote the durability of the drier.
  - Design option 13: Resource-related design options to increase the reuse and recycling of the drier.
- For Condenser heat pump tumble driers (BC2):
  - Design options 1, 2 and 10: Energy-related design options to improve energy efficiency of the driers based on improved motor efficiencies and to provide consumers with more information about the type of refrigerant the drier they purchase uses.
  - Design option 12: Resource-related design option to promote the durability of the drier.
  - Design option 13: Resource-related design options to increase the reuse and recycling of the drier.
- For Heating element air-vented tumble driers (BC3):
  - Design options 1 and 3: Energy-related design option to improve energy efficiency of the driers based on improved motors set-up and efficiencies.

- Design option 12: Resource-related design option to promote the durability of the drier.
- Design option 13: Resource-related design options to increase the reuse and recycling of the drier,

- For Gas-fired air-vented tumble driers (BC4):
  - Design options 1 and 3: Energy-related design option to improve energy efficiency of the driers based on improved motors set-up and efficiencies.
  - Design option 12: Resource-related design option to promote the durability of the drier.
  - Design option 13: Resource-related design options to increase the reuse and recycling of the drier.

The applicability of the above clustered design options is shown in Table 57.

Table 57: Applicability of clustered design options to base cases

Design options	Description	Applicability to BC			
		1	2	3	4
1 + 2 + 10	Increased motor efficiencies (drums, fan's and compressor's) by replacing asynchronous and induction motor with permanent magnet sync. motors (BLDC) and information on refrigerants (for BC2 only) use to inform the customer on alternatives with lower GWP.	Only drum and fan	√	-	-
1 + 3	Increased motor efficiencies (drum's & fan's) + multi motor setup to have a better on/off control of the different subsystems	-	-	√	√
8	Switching heating technology to heat pump for condenser driers	√	-	-	-
12	Modular design for easy access of critical parts for professionals and ensuring availability of spare parts after 2 years	√	√	√	√
13	Modular design for improving dismantling of driers and enhance recovery of materials at end-of-life	√	√	√	√

6.3.2 Ranking of design options

Considering the applicability of the clustered design options, the potential environmental benefits and net life cycle savings/costs are shown in Figure 71, Figure 72, Figure 73 and Figure 74. Negative numbers represent potential environmental reductions (i.e. environmental benefits) and potential life cycle costs reductions to consumers. Positive numbers are additional life cycle costs to consumers for implementing this design improvement in the product. Design option 12 is not shown, since potential environmental savings have not been estimated using the Eco-Report tool. However, this design option is further assessed in Task 7.

Figure 71 shows that, for condenser heating element tumble driers, the largest potential environmental benefits come from design option 8 at a life cycle cost reduction (-3.3%). The other two options present low benefits at slightly higher additional life cycle costs.

Figure 72 shows that, for condenser heat pump tumble driers, the largest potential environmental benefits come from clustered design option to increase motor efficiencies and from showing information to customers about refrigerant used (design options 1+2+10) at an additional life cycle cost of 6.1%. The last on the right related to resource efficiency presents lower benefits but also net lower costs.

Figure 73 shows that, for heating element air-vented tumble driers, the first cluster related to energy efficiency of motors (design options 1+3) present slightly larger potential benefits at an additional life cycle cost of 5.2%, while the other, related to resource efficiency, presents lower benefits although at lower additional life cycle costs.

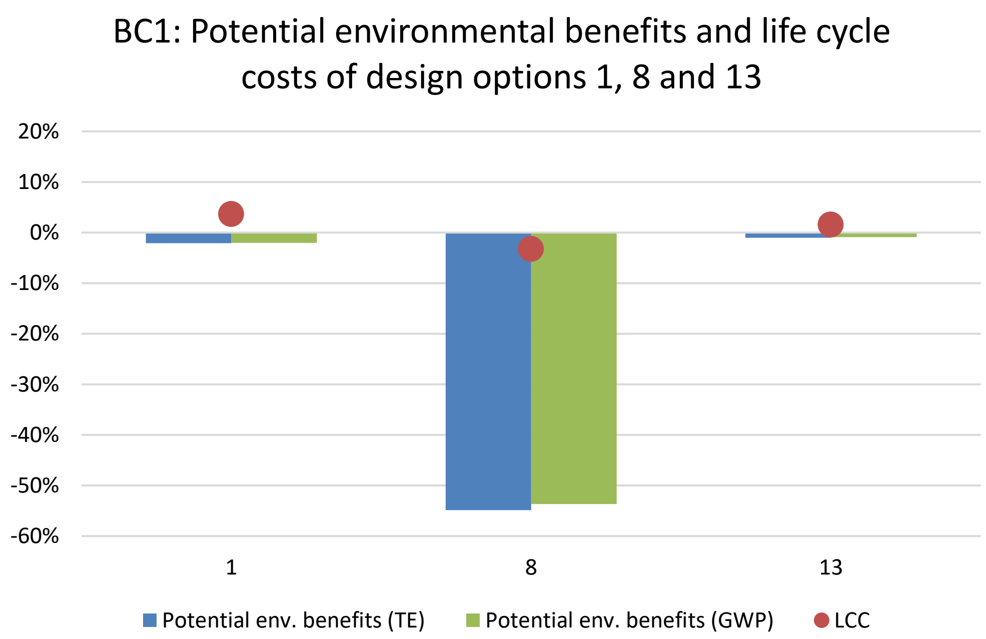

Figure 71: Aggregated potential environmental benefits and life cycle costs of design options for BC1 (negative numbers are net savings compared to baseline) - TE=Total Energy, GWP=Global Warming Potential

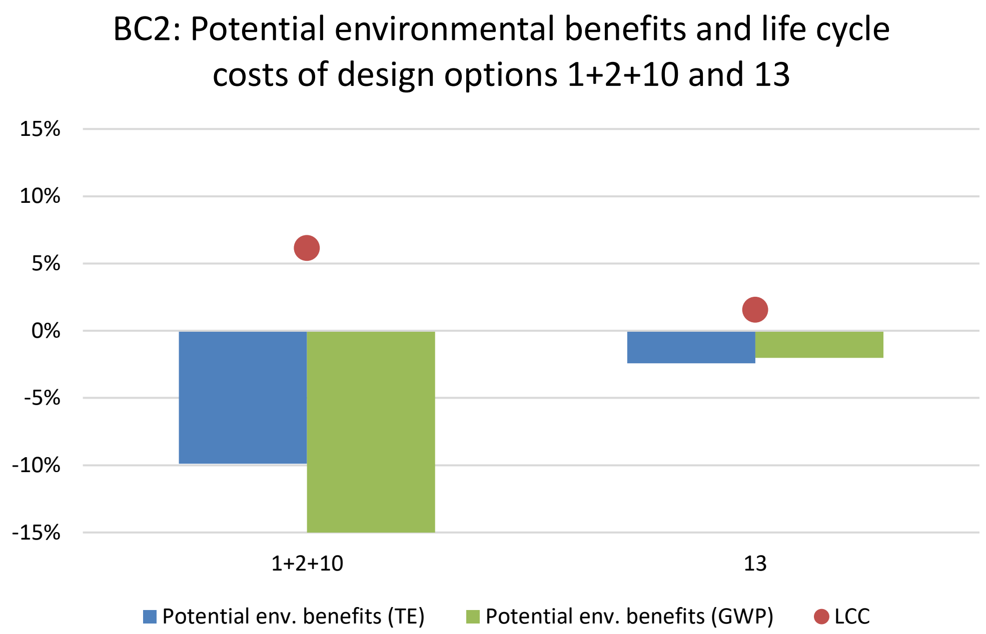

Figure 72: Aggregated potential environmental benefits and life cycle costs of design options for BC2 (negative numbers are net savings) - TE=Total Energy, GWP=Global Warming Potential

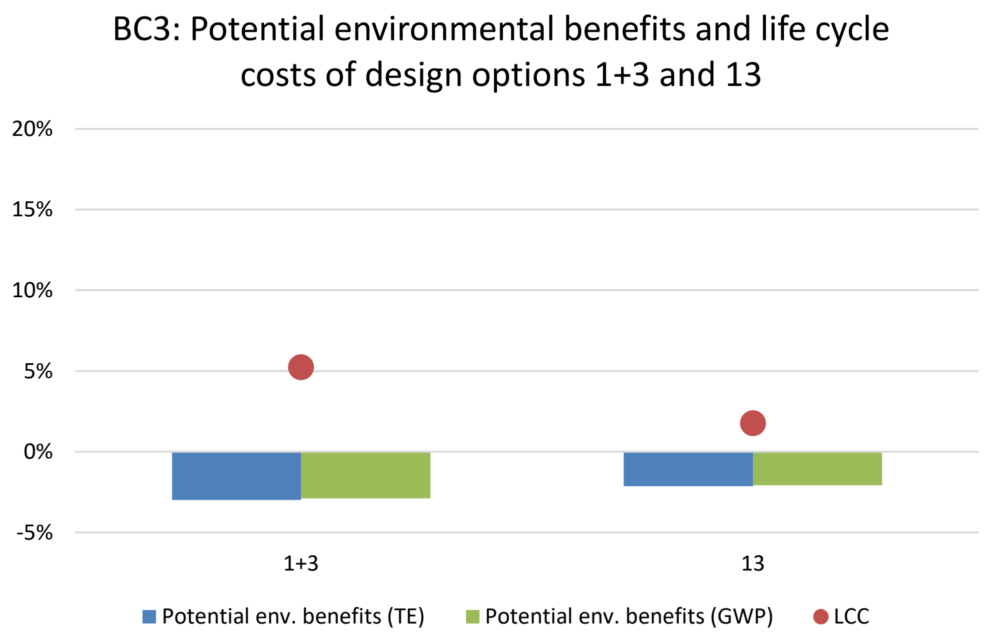

Figure 73: Aggregated potential environmental benefits and life cycle costs of design options for BC3 (negative numbers are net savings) - TE=Total Energy, GWP=Global Warming Potential

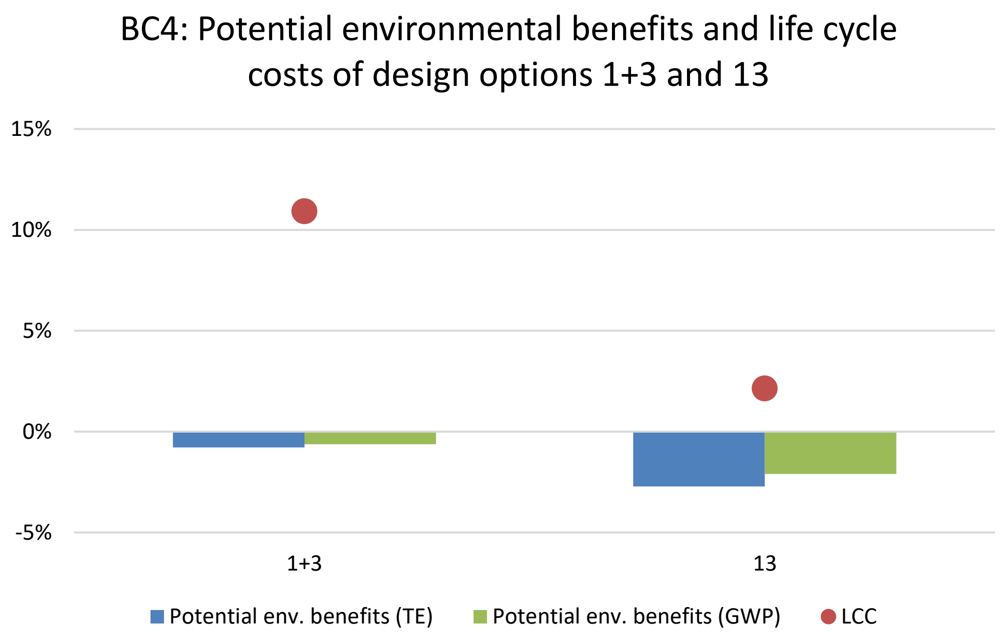

Figure 74: Aggregated potential environmental benefits and life cycle costs of design options for BC4 (negative numbers are net savings) - TE=Total Energy, GWP=Global Warming Potential

Figure 74 shows that, for gas-fired air-vented tumble driers, the largest potential benefits come actually from design option 13 (related to dismantlability at End-of-Life) with low additional life cycle costs (2.1%). The design option related to energy efficiency of motors presents actually small environmental benefits at higher additional life cycle costs. This indicates that the potential for energy savings from a design point of view is limited for these driers while showing some potential for resource savings.

Overall, the potential environmental benefits at product level are much larger for condenser driers than for air-vented driers, however, some environmental improvement potential can be seen concerning resource efficiency. Design option 8 is by far the design option presenting the largest potential environmental benefits in terms of total energy and GWP, and it is the only design option presenting net life cycle costs savings for the consumer (i.e. presents the LLCC). These selected design options are further investigated when using them as starting point to define the policy options in task 7.

6.4 Long-term potentials based on identified BNAT

None of the BNAT presented in section 4.3 are yet considered technologies with the potential to be commercially available in the near nor medium-term future.

The only possible technology presenting a potential is the self-cleaning lint filters feature in some of the upcoming top tumble driers on the market. However, not enough information is available to determine whether this feature makes an actual improvement on energy consumption. The test data so far does not indicate any trend. This could be a possibility for investigation, since some test results indicate large increase in energy consumption if these filters are not cleaned. However, other studies don't provide the basis for the benchmark. It could be good to perform additional tests, but it would be a costly exercise since the driers would have to be tested at different times of their lifetime during long periods.

7. Scenarios

The aims of this task are:

- Evaluate the impact of the existing regulation in the context of the Better Regulation framework, focusing specifically on the regulation's effectiveness, efficiency and relevance.
- Present the policy analysis including stakeholders consultation, policy measures considered for regulating tumble driers and proposed policy options including opportunities and barriers.
- Present the scenario analysis including the effects of no action (Business as Usual, BAU) and of the proposed policy options; this analysis includes the impact to consumer expenditure, business revenue and employment, including a sensitivity analysis on key parameters.
- Present the main policy recommendations per product.

7.1 Evaluation of existing regulation

7.1.1 Introduction

The purpose of this section is to evaluate the effect of the current ecodesign and energy labelling regulations for household tumble driers, and compare the results obtained so far with the expectation in the impact assessment[262]. In addition, it is analysed how well the regulations have been able to solve the market failures identified in the preparatory study and the impact assessment.

The evaluation will focus on answering questions with regards to:

- 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. Has the regulation been cost effective and are the costs justified?
- Relevance of the regulations. Are the regulations still relevant and have the original objectives been appropriate?

The existing regulations are the Ecodesign and Energy Labelling Regulations for household tumble driers respectively Regulations (EU) No 932/2012 and No 392/2012. The aim of the regulations, especially of the energy labelling regulation, was to provide dynamic incentives for suppliers to further improve the energy efficiency of household tumble driers

[262] https://ec.europa.eu/energy/sites/ener/files/documents/td_impact_assessment.pdf

and for end-users to take better informed purchase decisions in order to accelerate market transformations towards energy-efficient technologies.

According to the current energy labelling regulation for tumble driers, energy used by household tumble driers accounts for a significant part of total household energy demand in the Union[263], and the scope for further reducing the energy consumption of household tumble driers was considered important. The Impact Assessment showed that without implementation of the regulations the electricity consumption of tumble driers was predicted to increase from 21 TWh/year in 2005 (or 24 TWh/year in 2010) to 31 TWh/year in 2020 (a large increase in the stock was expected).

Description of the current regulations and their objectives

The ecodesign and energy labelling regulations have been prepared in a parallel process with the aim to assess the possibilities and benefits of updating the already existing energy labelling Directive for electric household tumble driers[264] and implementation of additional ecodesign requirements.

The two regulations are intended to work in synergy; the ecodesign regulation pushing the market towards higher energy efficiency by removing the least efficient tumble driers 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 tumble driers on the market.

The ecodesign regulation for household tumble entered into force in 2012 and set minimum energy performance standards in two tiers from 1st November 2013 and 1st November 2015 respectively. The second tier only concerns condenser driers and makes the energy efficiency requirement more stringent for condenser driers compared to air-vented driers. Tier 1 removed all tumble driers from the market worse than energy efficiency class C and tier 2 all condenser driers worse than energy class B (according to the categorization in Regulation (EU) No 392/2012). The ecodesign regulation also set minimum levels for condensation efficiency (for condenser driers) in the two tiers, at 60% and 70% respectively.

The energy labelling regulation also entered into force in 2012. It included a new energy label with a more ambitious categorisation than in the previous scheme and three new energy classes on top of the A-class (A+, A++, and A+++). The new label was applicable from 29 May 2013.

[263263] 0.7% of the total residential energy consumption, 3.6% of the total residential energy consumption exluding energy used for space and water heating. Based on EUROSTAT and Figure 77 (BAU0), 2016 data.

[264] Commission Directive 95/13/EC with regard to Energy Labelling of household electric tumble driers

See a more detailed description of the current regulations in section 1.2

The objectives of the current regulations appear in the 2012 Impact Assessment for tumble driers.

With regard to energy savings the objective was to achieve energy savings in 2030 of 8.6 TWh/year (3.3 TW/year in 2020) corresponding to a reduction of 25 % (10.6 % in 2020) compared to the BAU scenario in the 2012 Impact Assessment[265]. For the related CO_2-emissions the objective was to reduce the emission with 3.8 million tons CO_2 in 2030 (1.5 million tons CO_2 in 2020) compared to the BAU.

Additional objectives were to:

- remove the least efficient products from market;
- promote market take-up of more energy efficient tumble driers for domestic use;
- address the current regulatory failure (market failure) thereby maintaining and supporting the past market trend towards more energy efficient tumble driers;
- drive further investments in new technologies towards environmentally friendly tumble driers.

The most important regulatory/market failure identified in the 2012 Impact Assessment was the lack of a driver for increasing the market share of the most energy efficient technologies on the market (i.e. heat pump driers).

Household tumble driers were at the time of the 2012 Impact Assessment addressed by the Commission Directive 95/13/EC with regard to Energy Labelling of household electric tumble driers. This Directive has improved the energy efficiency for tumble driers, but it has not been able to achieve more than a small increase in the number of tumble driers in energy class A placed on the market.

According to the 2012 Impact Assessment appliances in energy class A made up only 0.5 % of sales in 2005, the reference year for the preparatory study, increasing to approximately 1.5 % in 2010. The reason for the limited growth in market share of energy class A tumble driers is according to the 2012 Impact Assessment that the only driers able to reach energy class A were heat-pump condenser driers, which were significantly more expensive to produce.

Another aspect pointed out in the 2012 Impact Assessment was that the previous energy labelling scheme was not able to make visible for the consumers the large annual savings

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[265] COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT Accompanying the document Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for household tumble driers. 2012

achieved by choosing heat pump technology in energy class A compared to driers in class B, because heat pump tumble driers are much more efficient than the class A-limit value. In the previous energy label scheme, the B-class threshold was for condensers set at 0.64 kWh/kg and the A class threshold at 0.55 kWh/kg, corresponding to a 14 % reduction in energy consumption. However, the market best heat pump drier (at the time of the 2012 Impact Assessment) consumed 0.27 kWh/kg, which is 58 % less than a B-class drier.

Baseline and point of comparison

The baseline for the evaluation will be the market without the implementation of the current ecodesign and energy labelling regulations but including the effect of the previous energy labelling Directive. This baseline is referred to as Business As Usual Scenario without regulations "BAU0".

The development in the BAU0 scenario is based on the market estimates made in the 2012 Impact Assessment. However, regarding sales data and the size of the stock, new data and estimates from this review study are used.

Figure 75 below shows the difference between the size of the stock in the 2012 Impact assessment and the size of the stock calculated based on new data from this review study. It appears from the figure that the stock based on new data is significantly lower than the stock use in the 2012 Impact Assessment.

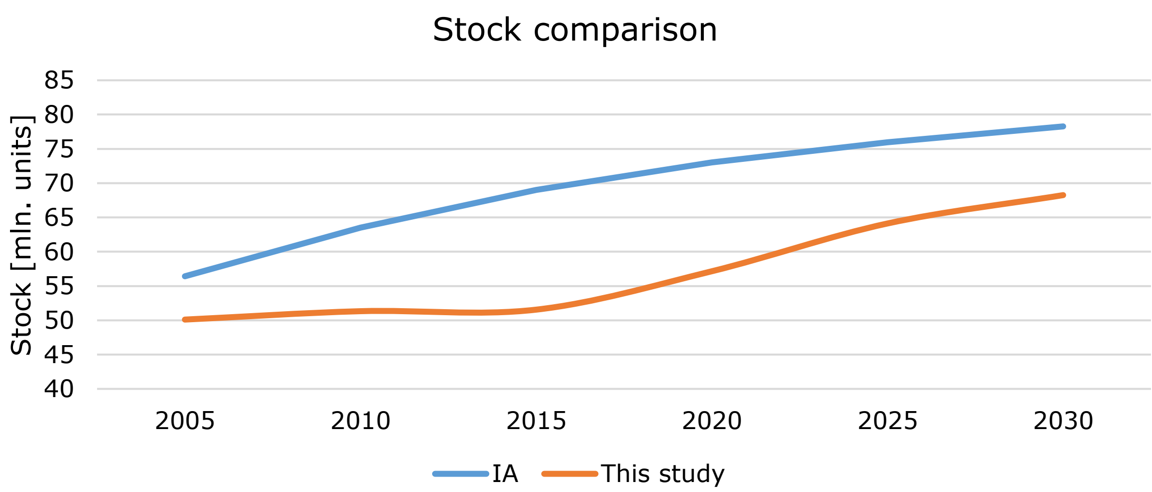

Figure 75: Comparison of size of stock used in the 2012 Impact Assessment and stock calculated based on new data from this study

The following terminology is used in this section dealing with evaluation of the existing regulations:

- IA = data directly from the 2012 Impact Assessment, adjusted to the stock model[266] used in this review study.
- BAU0 = scenario without the current regulations based on inputs from the Impact Assessment but adjusted to the new stock model.
- BAU = scenario with the current regulations and with the most recently available data.

New data is based on GfK market data regarding sales figures, energy efficiency (EEI, label distributions and AEc), prices for tumble driers on the market, cycle times, and condensation efficiencies for the years 2013-2016.

Note that all estimates are based on the user behaviour assumed in the current regulation, e.g. 160 cycle a year, and an average load of 71% of the rated capacity. This is to properly evaluate the estimations from the Impact Assessment as the current regulations were drafted under these values as premise. This means that the total energy consumption will differ from the subsequent analysis in section 7.2-7.4, which uses the user behaviour parameters found from Task 3.

7.1.2 Effectiveness of the regulations

Evaluation question 1: What have been the effects of the regulations?

The regulations have been able to transform the market towards a higher energy efficiency especially for condenser driers. Only small improvements have been achieved for air-vented electric and gas-fired driers. The efficiency improvement for condenser driers is primarily due to a large increase of the market share for heat pump tumble driers.

Market share and price of heat pump driers

In the 2012 Impact Assessment the total market share of heat pump driers was assumed to be 3 % in 2015 with an increase to 4 % in 2020. According to sales data from GfK the market share of heat pump driers has increased much more than foreseen in the 2012 Impact Assessment. In 2015 the share of heat pump driers was 47 % with an estimated increase to 57 % in 2020 (and 80 % in 2030). The differences are visualised in Figure 76. It is likely that this increase to a large extent can be attributed to the more ambitious categorisation of energy classes in the current energy labelling regulation compared to the old energy labelling Directive for tumble driers.

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[266] By using all parameters mentioned in the IA (Unit price, AEc, energy distribution, and so on), but using the stock model used in this review study instead of the one in the IA, in order to be able to compare total savings. Otherwise, the difference between the stock models used in the two studies would be the primary reason for differences in the estimated savings between the IA and this review study.

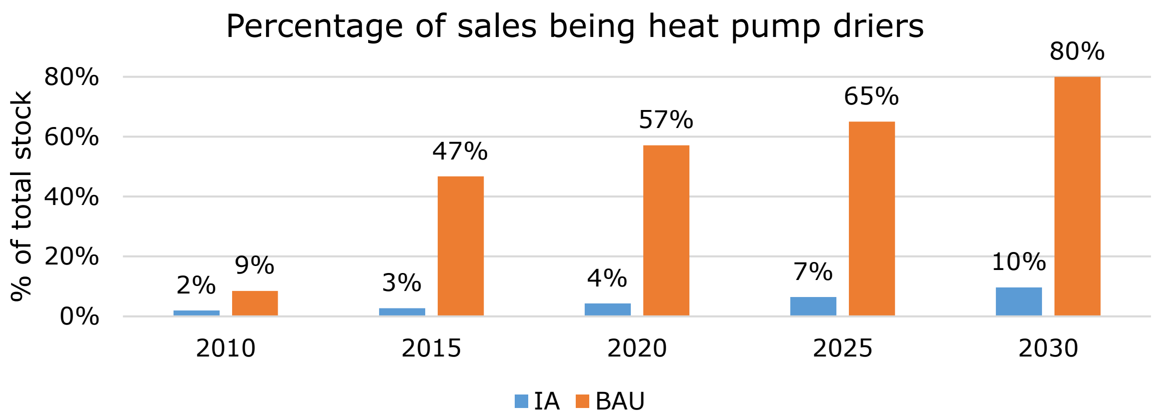

Figure 76: Development in market share of heat pump driers

While the market share of heat pump driers increased rapidly the retail price decreased. The 2012 Impact Assessment did also foresee a price reduction for heat pump driers. In the 2012 Impact Assessment it was estimated that to achieve the LLCC level the consumer purchase costs for heat pump driers should not be above 668 EUR per unit, which was well below the purchase cost of 887 EUR per unit estimated for the heat pump BAT technology in the previous preparatory study. But according to the Impact Assessment a tendency of decreasing prices was seen in some countries such as the Netherlands and Germany. In the Netherlands heat pump driers were at the time of the Impact Assessment available at costs between 529 EUR and 1524 EUR per unit and excluding the most expensive ones, the average price was around 760 EUR per unit and decreasing.

Since 2014 the retail price (consumer price including VAT) for heat pump driers have been close to or below the LLCC level. In 2016 the price was 615 EUR per unit, see Table 58 for details. From 2013 to 2016, all tumble drier types except for heat pump driers have increased. This might be due to the marked shrinking for these appliances combined with the effect of the ecodesign requirements.

Table 58: Unit retail prices in EUR for household tumble driers. *Source: Data from GfK*

Unit prices, EUR		2013	2014	2015	2016
Condenser	Heat pump	734	681	648	615
	Heating element	234	232	357	340
Air-vented	Heating element	225	310	244	228
	Gas-fired	225	310	326	343

Distribution on energy classes

Not only has the market share of heat pump driers increased, but also the share of the more energy efficient types of heat pumps have increased since the implementation of the energy labelling regulation. In 2016 the share of heat pump driers in energy class A++ and A+++ was 76 % compared to only 25 % in 2013. See more details in task 2, Figure 22.

The above-mentioned development in market share for heat pump tumble driers shows that the current energy labelling regulation has been able to address the observed market failure with regard to the lack of driver for promotion of the most energy efficient tumble driers on the market. However, the share of the most energy efficient heat pump tumble driers corresponding to energy class A+++ is still rather low but has increased from 4 % in 2014 to 14 % in 2016 (See Figure 18) of the increasing overall market share of heat pump condenser driers on the driers market (see Table 9). It could therefore be questioned whether the current energy labelling regulation has enough incentive to drive the market to an even higher level of energy efficiency.

For heating element condenser driers (see task 2, Figure 23), the regulations have been able to increase the market share of this type of driers in energy class B from 71 % in 2013 to 93 % in 2016 of the decreasing overall market share of heating element condenser driers on the driers market (see Table 9). The remaining part of the driers is in energy class C. Since 1st November 2015 heating element condenser driers in energy classes C are not allowed to be placed on the EU market. Probably according to this requirement, the market data show a large decrease of condenser tumble driers in energy class C in 2016. But still no heating element condenser driers models in energy class A have been brought on the market.

The most notable technical solution to increase the energy efficiency of condenser driers is changing the heating technology to a heat pump circuit. The marketing of the more efficient heat pump driers has led to a decreased sale of heat element condensing driers because consumers have shifted their purchase to the more efficient types.

For air-vented driers (see task 2, Figure 21) the regulations have only caused minor changes in distribution of the sale on energy classes. There has been a small decrease in the share of products in energy class D, probably due to the implementation of the ecodesign requirements applicable for 1st November 2013, and a small increase on the share of products in energy class B within the decreasing overall market share of air-vented driers market (see table 9). The majority of air-vented driers are however still in energy class C. Air-vented tumble driers in energy class D have not been allowed on the market in the EU since 1st November 2013. The market data therefore suggest that some incompliance exists for this product type.

Total energy consumption - energy savings

The market development for tumble driers have resulted in more energy savings than expected in the 2012 Impact Assessment. The additional savings compared to the BAU0 scenario is estimated to be 2.6 TWh in 2016 increasing to 13 TWh in 2030. See results in Figure 77 and Figure 78 below. The energy savings is higher than estimated in the 2012 Impact Assessment even though the stock used in this review study is smaller than the stock used in the Impact Assessment. The higher savings is primarily due to a much larger increase in the sale of heat pump driers than foreseen in the Impact Assessment.

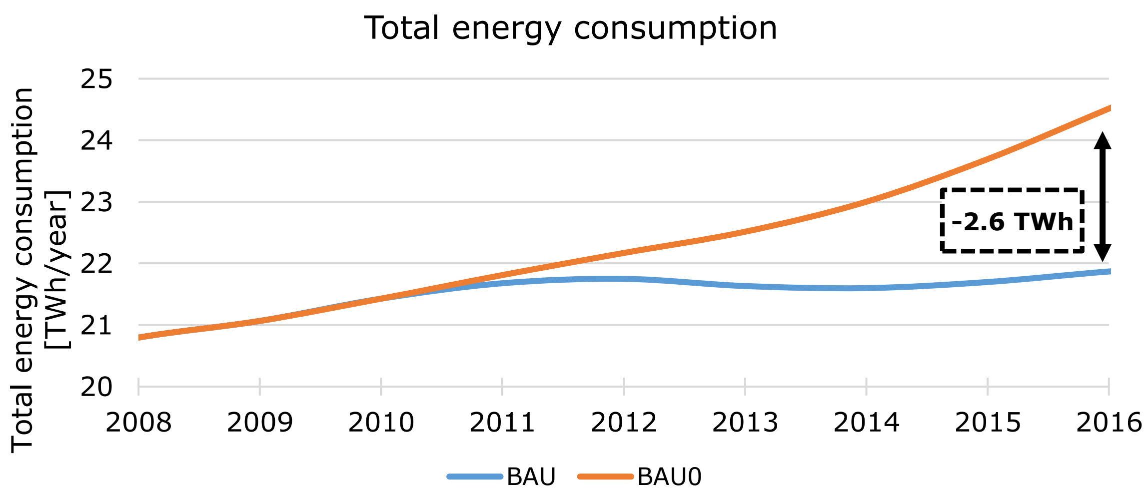

Figure 77: Energy savings by 2016. Comparison of total energy consumption in BAU0 and BAU scenarios

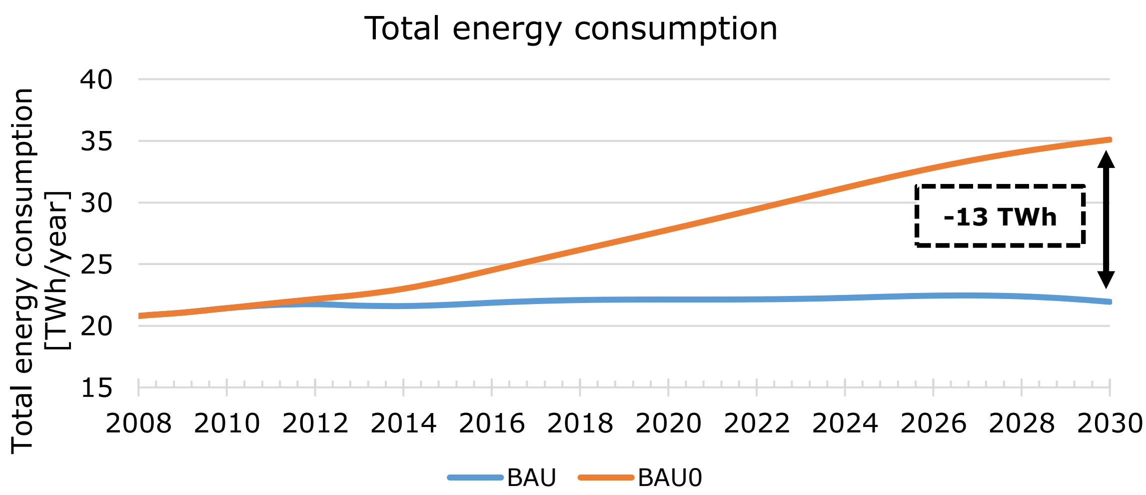

Figure 78: Energy savings by 2030. Comparison of total energy consumption in BAU0 and BAU scenario

The aim of the ecodesign regulation is to remove the least efficient tumble driers from the market. However, the minimum efficiency requirements for tumble driers are not very strict in order to still allow heating element driers to be placed on the European market. Therefore, only a minor share of the achieved savings and the market transformation is related to the ecodesign regulation.

Specific energy consumption

The energy classification used in the old energy labelling Directive was based on the specific energy consumption (i.e. kWh/kg of load). In the current regulations the energy efficiency requirements and the energy classification for the label are based on an estimated energy index (derived from annual energy consumption).

Figure 79 below shows the development in the specific energy consumption for the BAU scenario. It indicates that the old energy labelling Directive has resulted in decreased specific energy consumption, while the current energy labelling regulation (applicable from 29 May 2013) has changed this (positive) development. From the second half of 2013, shortly after the current regulation came into force, the specific energy consumption has increased for heating element condenser and air-vented driers. For heat pump driers, the rate of improvement for the specific energy consumption decreased from 2013 and onwards.

This increase in the specific energy consumption in the period from 2013 to 2016 is remarkable because it has appeared in a period with an increased share of tumble dries in better energy classes.

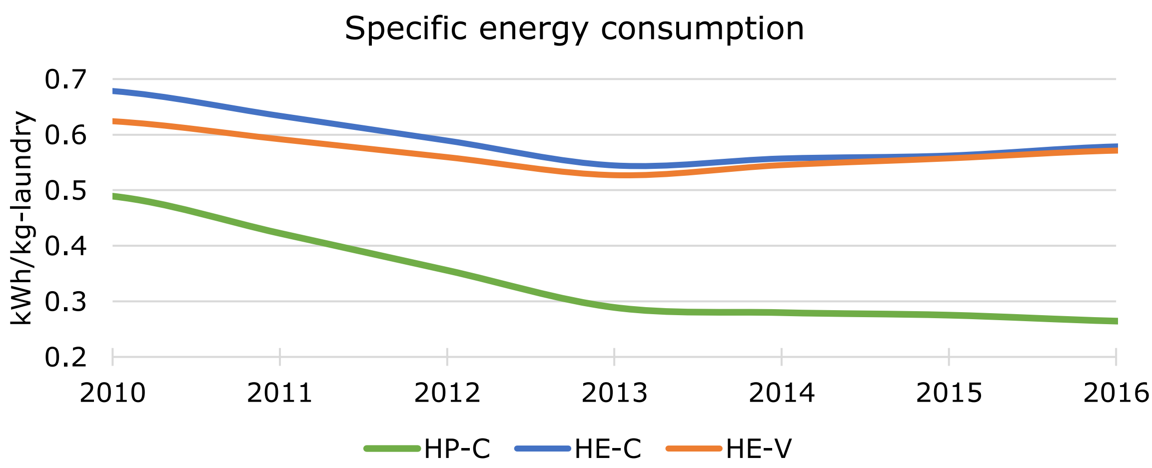

Figure 79: Development in specific energy consumption

In the same period of the time (from 2013 to 2016) the rated capacity of tumble driers has increased for all types except for gas tumble driers. See Figure 80 below.

This may indicate that the rated capacity of tumble driers has been increased to achieve a more beneficial energy label at the expense of an increase of the specific energy consumption per kg of laundry.

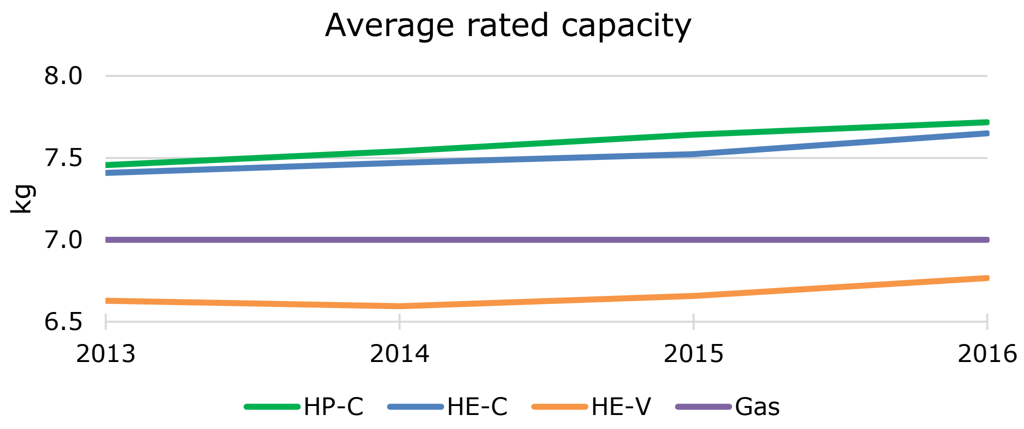

Figure 80: Development in average rated capacity for tumble driers since 2013 (GfK market data from this study)

The development described above indicates that the methods used in the regulations for establishment of the energy requirements in the current regulations drives the market towards higher and higher rated capacity. However, the increase in the rated capacity could also be because the manufacturers consider a high rated capacity as a sales argument.

Condensation efficiency

As no data on the condensation efficiency of the driers were available in either the preparatory study or the 2012 Impact Assessment, the impact from the current regulation is hard to quantify. Furthermore, the 2013-2016 GfK data had high percentage of the reported data labelled as "undefined" in regard to condensation efficiency. Figure 25 in task 2 shows the condensation efficiency of the heat pump driers from 2013-2016. A large increase of models in the A condensing class is seen towards 2016, which have 35% of the sold models in the top class. This effect can probably be attributed to the energy labelling regulation, and the continued development in heat pump technology.

Evaluation question 2: To what extent do the observed effects link to the regulations?

The observed market change is likely to be largely linked with the current regulations, especially the energy labelling regulation.

It is possible that the effects are in part linked to other factors such as general innovation, information and test results from consumer organisations and economic incentives in some Member States. However, as seen from the Figure 76 above, there was only a few energy efficient tumble driers on the market before implementation of the current regulations.

Even in the 2012 Impact Assessment, only a small increase in the market share of heat pump driers was foreseen.

The effect is most significant for condenser driers where the energy labelling regulation has resulted in a shift of technology to efficient heat pump driers for a large share of the market.

For the remaining part of the condenser driers (with heating element technology) the observed effect with regards to energy efficiency is linked to the ecodesign regulation, which have removed tumble driers in energy class C from the market. This development would not have occurred without the regulation.

For heating element air-vented driers the effect with regards to energy efficiency have been very vague. But there is a small trend of an increased market share of air-vented driers in energy class B and a lower share in energy class D, which is probably due to the ecodesign regulation.

Data for gas-fired driers is too poor to identify any developments and is still considered a niche market with below 0.1% of the total sales. No conclusions on the effect of the current regulation on this type of drier can hence be made.

The increase in the market share of heat pump driers at the expense of heating element condenser and air-vented driers is probably a consequence of the energy labelling regulation.

There is probably a very close link between the increased market share of heat pump driers and the reduction in the consumer purchase price. Before adoption of the regulations there was in some countries already a trend towards lower prices, but the very fast reduction of the prices observed is most likely linked to the current energy labelling regulation.

Evaluation question 3: To what extent can these changes/effects be credited to the intervention?

Tumble driers have been covered by the old Energy Labelling Directive[267] since 1995. However, still in 2012 after 25 years the Directive had not been able to increase the share of tumble driers in energy class A. Therefore, it is most likely that the effects seen since 2013 should mainly credited to the new regulations. It is unlikely that the very fast transition to heat pump driers would have happened without the market pull effect of the new energy labelling regulation. The overall picture is that the energy label has been the tool needed for the manufacturer to differentiate the energy efficient heat pump driers and

[267] Commission Directive 95/13/EC with regard to Energy Labelling of household electric tumble driers

made the manufacturers sufficiently confident in that their investments in the heat pump technology could be returned.

However, the transition to heat pump technology have also been supported by information and test results from consumer organisations and financial incentives in some Members States.

Evaluation question 4: To what extent can factors influencing the observed achievements be linked to the EU intervention?

Some factors have influenced the achievement. Without the price reduction for heat pump driers the effects of the regulation would have been less significant. The price reduction (see Figure 82) is probably linked to the energy labelling regulation because it has created the market pull necessary for the manufacturers to start production of heat pump driers in a larger scale and thereby being able to reduce the costs.

The increase of the specific energy consumption (as mentioned above) has reduced the achievements of the regulations. This increase is probably due to the methodology used in the regulations to set the energy efficiency requirements and make the energy classification for the label.

For air-vented driers the regulations have only resulted in small improvement of the energy efficiency. The small improvements are probably due to the ecodesign regulation. However, they have probably remained small due to the fact that no obvious and cost-effective improvement options exist for these types of drier.

Another factor that might have slowed down the achievements of the energy labelling regulation is that a relatively large share of consumers according to the APPLiA consumer study[268] finds part of the information on the label unclear. According to the study 42 % and 35 % of the consumers understand all information on the label for respectively vented driers and condenser driers. Figure 81 below shows which parts of the information the remaining part of the consumers did not understand. It appears that the consumers especially find the information on annual energy consumption and condensation efficiency unclear, but a large share also finds the information regarding type of household drier and cycle time unclear.

[268268268] Tumble dryer usage and attitudes. A survey in 12 European countries. APPLiA, Home Appliances Europe. March 2018.

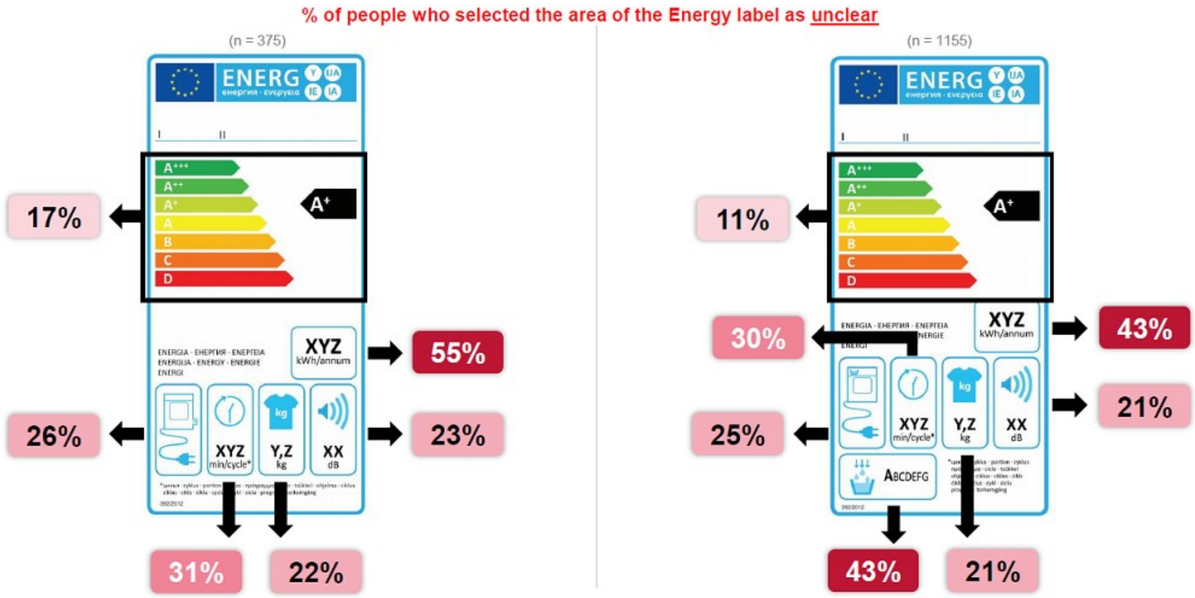

Figure 81: Share of consumers who find information on the energy label unclear. The percentage relates to consumers that did not understand all information on the label

Conclusion on effectiveness

The current regulations have been very effective in increasing the market share of energy efficient heat pump tumble driers. The energy labelling regulation has been more influential than the ecodesign regulation, because the energy label has created the market pull necessary for the observed market transformation from conventional heating elements driers to heat pump driers.

The energy labelling has not been able to increase the efficiency of heating element air-vented driers. Instead the sale of this technology has dropped, and the consumers have to a larger extent bought condenser heat pump driers instead. No conclusions on gas-fired tumble driers can be made. The very low sales numbers and lack of available data, make it insufficient to draw any conclusion.

Unclear information on the label might to some extent have reduced the achievements of the energy labelling regulation.

The increase of the specific energy consumption (as mentioned above) has reduced the achievements of the regulations in terms of energy used per kilo of drying. This increase is probably due to the methodology used in the regulations to set the energy efficiency requirements and make the energy classification for the label.

The achieved savings since the implementation of the current regulations are based on new market estimates around 2.6 TWh in 2016 increasing to 13 TWh in 2030. This is more than the estimated effect in the 2012 Impact Assessment even though a smaller stock is used in the new calculation. It is considered that a large share of the achieved savings is due to new regulations, particularly the energy labelling regulation.

In the Impact Assessment it was estimated that energy savings in 2030 would be only 7.5 TWh/year. See Figure 82 below for a comparison between the IA estimation, and the BAU estimations used in this study.

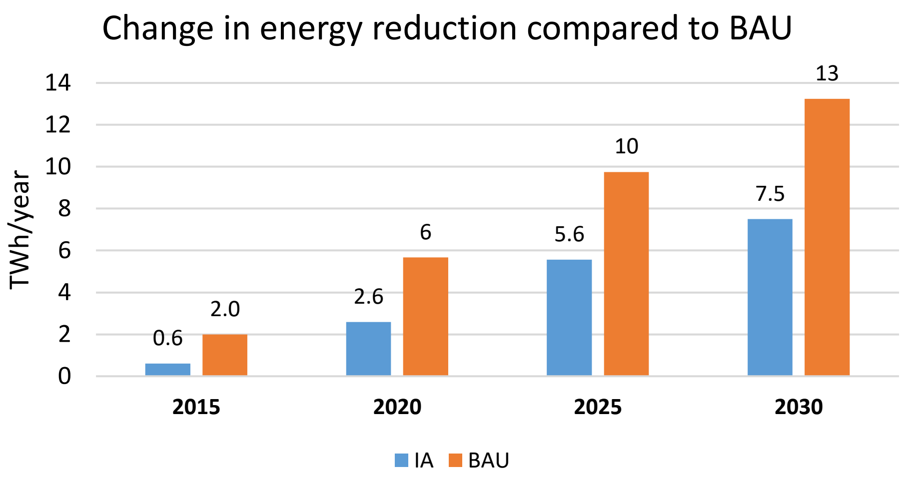

Figure 82: Estimated energy consumption in the 2012 Impact Assessment compared to new estimates based on updated market data

7.1.3 Efficiency

Evaluation question 1: To what extent has the intervention been cost-effective?

As mentioned above the regulations have resulted in substantial energy savings and a market transformation towards more energy efficient tumble driers. The innovation costs have in the first place been paid by the manufacturers, but they have the possibility to pass extra costs to the consumers who will benefit from costs saving linked to higher energy performance of the tumble drier that outweigh the higher upfront costs[269].

The average price of heat pump driers has decreased since implementation of the current regulations but yet the manufacturers turnover has increased because of the sale of heat pump driers has replaced the sale of less expensive types of tumble driers i.e. heating element air-vented and condenser driers. Typically, the manufacturers produce both heat pump and heating element driers. In addition, the innovation costs are probably to a large extent returned by the large increase in sale of heat pump driers. Development in manufacturer turnover appears in Figure 86 under evaluation question 2.

[269] Evaluation of the Energy Labelling and Ecodesign Directives SWD(2015) 143 final

Consumers who have bought the more expensive heat pump tumble driers have benefitted from a reduction in the energy use costs. This means than even though they have purchased a more expensive product they have saved money in the longer term.

Figure 83 shows the development in the average costs of purchase added to the costs of energy use (total costs of ownership) for the average heat pump driers on the market. The reduction in the total costs of ownership in the period until 2013 is mostly due to reduced costs for use of the drier while since 2013 also the purchase costs have been reduced. Note that data between 2010 and 2013 is of poor resolution.

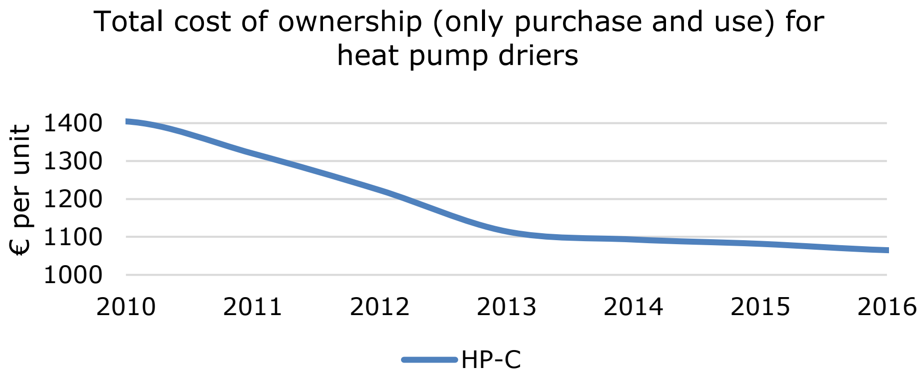

Figure 83: Total cost of ownership (only purchase and use) for heat pump driers per unit, based on 160 cycles/year and the loading as the defined in the current regulation.

The current regulations only apply marginal extra administrative costs on the manufacturers and dealers because tumble driers were already covered by an Energy Labelling Directive before implementation of the current ones. The same is the case for the Member States.

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 2030 the regulation will save energy similar to 13 TWh/year corresponding to 5.4 Mt CO_2 equivalents. The accumulated savings in the period from the implementation to 2030 will in total be around 125 TWh. In addition, the user expenditure has been reduced by 2.2 bln. EUR/year in 2030 compared to the BAU0 scenario as seen on Figure 84.

Manufacturers have been able to pass on the extra cost for development of better performing tumble driers to the consumers, and both manufacturer and retailers have benefitted from increased turnover[270], see Figure 85 and Figure 86 below.

The Member States costs by 2030 are and will be at the same level as before implementation of the regulations, but they will benefit from the energy savings and reduced emissions due to the regulations.

Therefore, the intervention costs seem justified given the improved performance of tumble driers and the associated benefits.

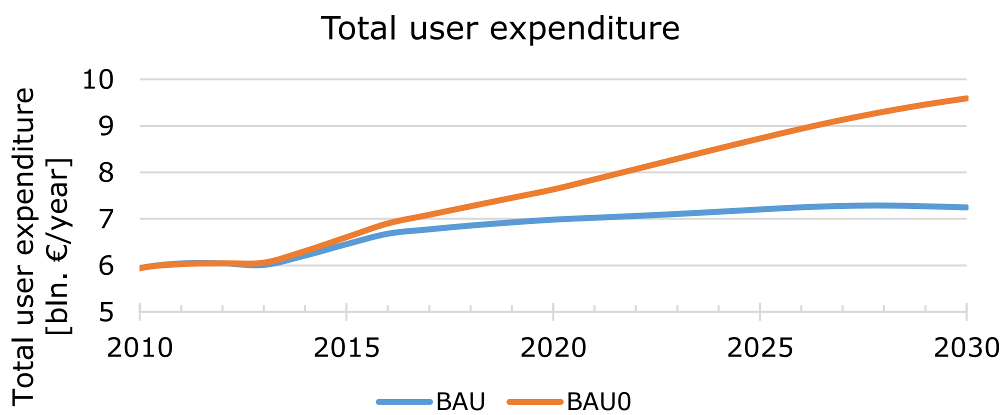

Figure 84: Development in total user expenditure from 2010 to 2030.

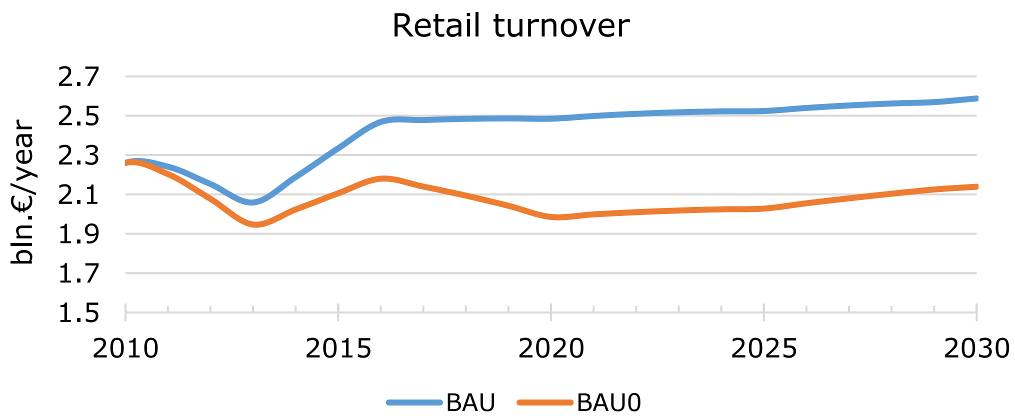

Figure 85: Development in turnover for retailers based on sale prices from GfK

[270] Calculation of turnover in the BAU scenario is based on sales prices from GfK. Manufacturer turnover estimated by assuming a manufacture-wholesale-retail margin factor, resulting in the manufacturersmanufactures turnover being 48% of the retail turnover. For more information, see section 7.3.1 - business revenue.

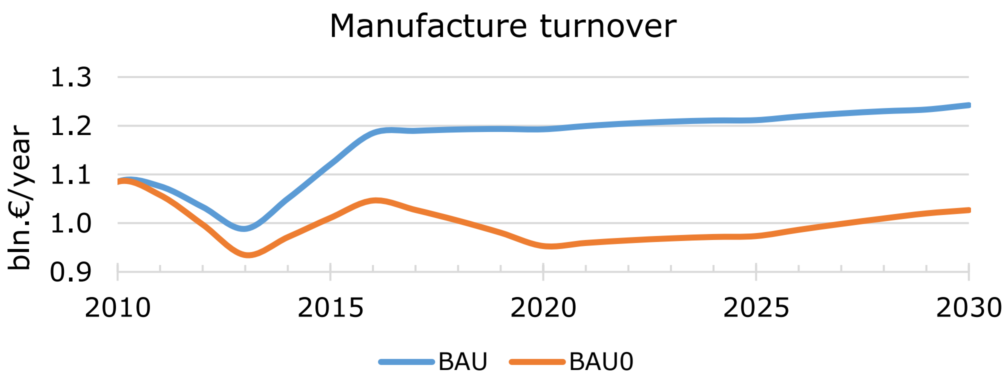

Figure 86: Development in turnover for manufacturers based on sale prices from GfK

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 and energy labelling regulations are implemented in a parallel process and with the use of the same test procedures and calculations methods for proving compliance, makes the regulations more cost efficient for manufacturers.

In addition, an EU wide legislation will be more cost effective from a Member State perspective compared to national legislation.

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 (in the section dealing with effectiveness) also influence the efficiency.

The observed purchase price reduction (since 2013) of heat pump driers is of high importance for the efficiency of the regulations. Without this price reduction the technology shift from conventional tumble driers to heat pump driers would not have been cost effective for the consumers as the TCO would have been significantly higher than the other types (Table 49 lists updated life cycle cost of the four drier type; if heat pump driers increased in purchase price, the life cycle cost or TCO would be higher than the other types)

More efficient heat tumble driers were brought on the market before the implementation of the current regulations and the total costs of ownership has decreased since 2010 because of decreased energy consumption in the use phase. But still the purchase price was high and the sale low. The effect of the current label is that it has increased the sale of heat pump driers and supported development of even more efficient heat pump driers. In addition, the labelling regulation even before it was in force gave the manufacturers confidence in an upcoming rising sale and was a driver for investments in innovation and production capacity.

The reduction in the total costs of ownership before implementation of the current energy label must also be assigned to the previous label even though it was not sufficient to make a strong market pull for the most efficient tumble driers.

The consumer awareness is an important factor to ensure the efficiency of energy labelling also in case of tumble driers. If the consumers were not aware of the energy label, tumble driers with heat pump technology would not have had the necessary market advantage compared to less efficient types of tumble driers on the market and the manufacturers would not have been confident that it would be possible to increase the sale and return their investments in the new technology.

The consumer awareness regarding the energy label is general high for white goods. However, the consumer survey conducted by APPLiA has found that some consumers find part of the label information unclear. This might to some extent reduce the efficiency of the scheme.

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 tumble driers bear the largest share of the costs for development of more efficient tumble driers (heat pump driers), but they have been able to pass the extra costs on to the consumers, without increasing the total costs for end-users over the life time of the products. As shown above the total costs of ownership for heat pump tumble driers have decreased significantly due to the current regulation.

The end-users bear the costs for more expensive heat pump driers, but they are compensated by saved electricity costs over the lifetime of the product.

In addition, it is important to bear in mind that it is voluntary for manufacturers to improve the performance of tumble driers beyond the ecodesign requirements.

Evaluation question 6. Are there opportunities to simplify the legislation or reduce unnecessary regulatory costs without undermining the intended objectives of the intervention?

No possibilities for simplification have been identified so far.

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 obligation to perform market surveillance according to the regulations, the actual level of market surveillance varies between Member States. The differences in market surveillance costs are not linked to the interventions but rather to the priorities of Member States and limited budget for market surveillance.

Conclusions on efficiency

The evaluation assessment has shown that the benefits of the regulations outweigh their 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 for heat pump driers has resulted in increased purchase prices for end-users, but this is offset by the energy savings, which result in larger savings over the lifetime of the heat pump tumble driers i.e. lower total costs of ownership related to purchase and use of the driers.

Member State costs associated with the regulation are primarily related to market surveillance. 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. However, the reduction of the market surveillance costs is not linked to the current regulations but to the provisions in the new framework Regulation on labelling[271].

7.1.4 Relevance

Evaluation question 1: To what extent is the intervention still relevant?

The objectives of the regulations were to reduce the energy consumption of tumble driers and to increase the market share of energy efficient household tumble driers on the EU market.

The objectives have to a large extent been fulfilled, but the regulations are still considered relevant. There is still an untapped saving potential as the market share of the most energy

[271] According the energy labelling framework regulation (EU) 2017/1369

efficient heat pump driers in 2016 were only 7%. In addition, some technology possibilities to increase the efficiency of the top-class driers exist as described in task 4.

Without the energy labelling regulation, the consumers may not continue focusing on buying more efficient tumble driers. That will reduce the manufacturers' incentives to make further improvements of tumble driers.

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 a large increase of the share of efficient/heat pump driers on the market and have additionally reduced the purchase costs.

This means that the identified market failures have been corrected.

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 improvements of energy efficiency at European level for the year 2030 (at least 40 % cuts in greenhouse gas emissions, and at least 27 % improvement in energy efficiency)[272]. On 14 June 2018 the Commission, the Parliament and the Council agreed on an even more ambitious energy efficiency target for the EU for 2030 of 32.5%, with a clause for an upwards revision by 2023[273].

Evaluation question 4: How well adapted is the intervention to subsequent technological or scientific advances?

In 2016, 14 % of heat pump driers on the market were in energy class A+++ and the share has probably increased further. It could therefore be questioned how well the current classification used for energy labelling scheme is able to take into account further subsequent technological advances. There seems to be a need for a more ambitious classification leaving the top-class empty. 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 requirements of the framework energy labelling regulation[274].

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[272] 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
[273] https://ec.europa.eu/energy/en/topics/energy-efficiency
[274] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1369&from=EN

Evaluation question 5: How relevant is the EU intervention to EU citizens

The energy label is highly relevant for the EU citizens. According to the APPLiA consumer survey[275], the energy label is of relevance for a large share of consumers purchasing tumble driers. A share of 33 % anticipates that the label will be a crucial consideration next time they will buy a tumble drier, while 49 % anticipate that the label will be considered among other important items. See Figure 87 below.

The ecodesign regulation is less visible for the consumers, but still of high importance. It provides consumers with better performing products and saves them money by ensuring that products that are too costly to run are not allowed in the EU. It also requires for relevant information (e.g. programme time and energy consumption of the most common programmes; energy consumption in off-mode and left-on modes) to be included in the instruction booklet for users.".

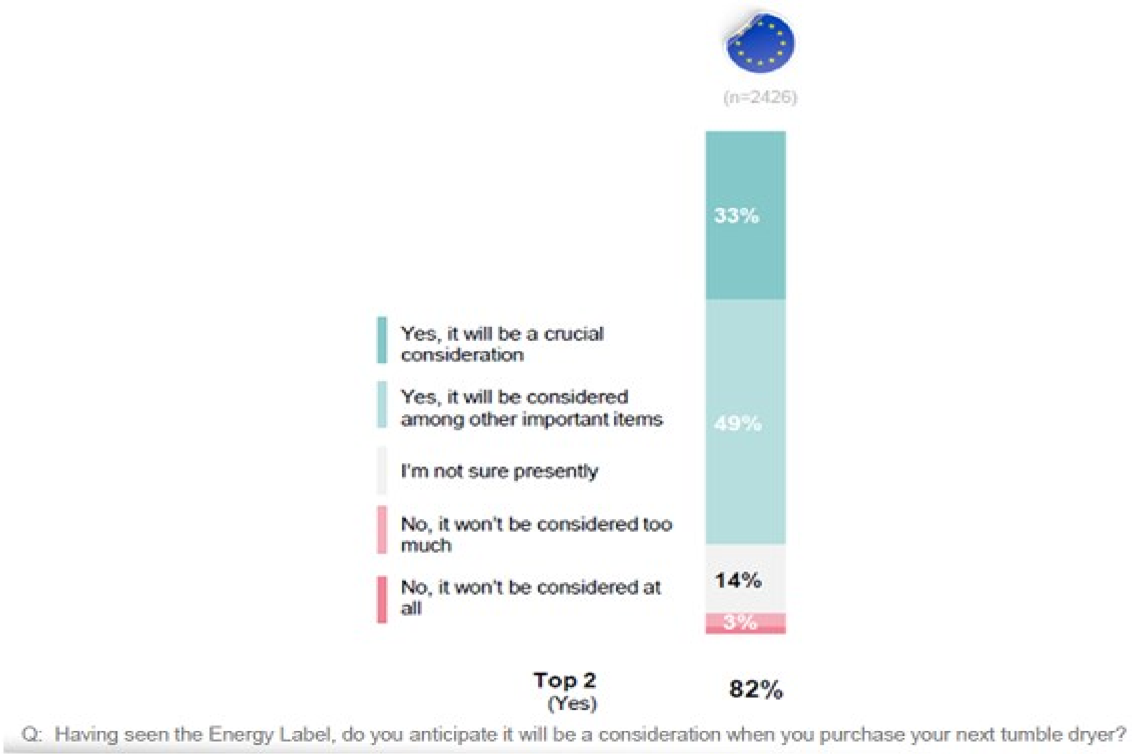

Figure 87: Share of consumers that see the energy label as a consideration, when they purchase their next tumble driers

[275] Tumble dryer usage and attitudes. A survey in 12 European countries. APPLiA, Home Appliances Europe. March 2018.

Conclusion on relevance

The regulations continue to be relevant for reducing the energy consumption of tumble driers and contribute to achieve the EU energy efficiency targets.

The energy labelling regulation has created an effective market pull and has increased the market share of heat pump driers and at the same time reduced the price below the LLCC level.

Furthermore, consumers find the label relevant and a large share anticipate that they will consider the information on the label next time they would buy a tumble drier.

7.1.5 Conclusion Evaluation

The evaluation of the current regulations shows that they have contributed to substantial energy saving and environmental benefits without extra costs for end-users, manufacturers and the society as a whole. Especially the energy labelling regulation have been able to create a market pull for increasing the market share of heat pump driers and drive forward the market transformation from conventional heating element driers to heat pump driers.

However, some aspects can still be improved:

- The sale of the tumble driers in energy class A+++ is still rather low, indicating that the current label lack incentive for promotion of the most energy efficient tumble driers
- There are still inefficient models on the market
- Consumers find some of the information on the current label unclear especially the information regarding the annual energy consumption

In addition, rescaling of the labelling is required according to the new energy labelling framework regulation[276].

7.2 Policy analysis

The policy analysis is based on data obtained from three sources:

- Main conclusions from analyses performed in previous tasks (1 to 6).
- Independent research by the study team (using publicly available materials).
- Input from stakeholders, including manufacturers, non-governmental organisations, standardisation committees and Member States.

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[276] According the energy labelling framework regulation (EU) 2017/1369

7.2.1 Stakeholders consultation

During the entire study, the study team has maintained a dialog with different stakeholders.

Two stakeholders' meetings were held, the first meeting on the 26th of June 2018 and the second on the 4th of December 2018. Experts from Member States, testing facilities, consumer and environmental organisations and manufacturers provided input to the draft interim and final reports which included tasks 1 to 4 and 1 to 7 respectively. Input was received from:

- APPLiA – Home Appliance Europe[277]
- CENELEC TC59X SWG1.9
- Join input from ECOS[278], EEB[279] and Coolproducts[280]
- BSH[281]
- Samsung[282]
- Test Aankoop[283]

Their comments and answers from the study team are found in Annexes VII and X, and they have been incorporated in this final report.

Previous to these meetings, a dialogue was established with APPLiA where input to the first four tasks was provided. A first telephone meeting was arranged in November 2017 to introduce the aims of this review study and the study team, and a follow-up face-to-face (FtF) meeting was held in Brussels where the study team presented data for the first two tasks to collect APPLiA's input and provided input to APPLiA's consumer survey that was used by the study team to carry out task 3 and the evaluation of the impact of existing regulation.

Telephone and FtF meetings have taken place with some individual manufacturers who have provided input to the first four tasks.

7.2.2 Policy measures

The following policy options have been considered for the policy scenarios:

- No action ('Business-as-Usual', BAU)
- Self-regulation

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[277] https://www.applia-europe.eu/
[278] http://ecostandard.org/
[279] http://eeb.org/tag/ecodesign/
[280] https://www.coolproducts.eu/
[281] https://www.bsh-group.com/
[282] https://www.samsung.com/us/home-appliances/
[283] https://www.test-aankoop.be/

- Ecodesign measures
- Energy labelling

No action ('Business-as-Usual', BAU)

If no new action is taken, the existing Ecodesign Regulation 932/2012 and Energy Labelling Regulation 392/2012 for household tumble driers remain in force, leading to the previously estimated 13.2 TWh energy savings in 2030[284] in comparison to BAU0 scenario, due to the combined implementation of ecodesign and energy labelling policy measures.

Tasks 1 to 6 of this review study show that the two regulations in force have worked on pushing and pulling the EU market towards more efficient household tumble driers, in particular the Energy Labelling Regulation. However, further improvement opportunities exist offered by existing BAT. Moreover, this review study has shown that inefficient models are still found on the EU market that could be beneficially addressed by reviewed ecodesign requirements. Furthermore, according to the framework Energy Labelling Regulation published last year, existing energy labels are to be rescaled.

'No action' is not an option. Overall, it is recommended to take action and review existing regulations for tumble driers. BAU is used as a baseline to establish the potential savings, costs and impacts to 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 household tumble driers: none of the relevant stakeholders expressed interest in self-regulation and the minimum market coverage will not be met because the risk of 'free-riders'.

Consequently, self-regulation has not further been considered as policy option.

Ecodesign

The Ecodesign Regulation 932/2012 in force has made a positive impact as presented in section 7.1. However, further improvement opportunities exist as presented in previous tasks.

There is currently a big gap between heat pump condenser tumble driers and heating element tumble driers (both condenser and air-vented) in terms of energy efficiency,

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[284] Based on the user behaviorbehaviour parameters in the current regulation.

annual and specific energy consumption and condensation efficiency, where heating element driers are far more inefficient. More heat pump driers have appeared on the EU market and the trends indicate that the market coverage of heat pump driers will continue increasing until this technology becomes dominant. However, heating element driers will most likely continue to exist. They also present improvement opportunities as presented in task 6, especially condenser driers. Gas-fired air-vented driers do not show significant improvement potentials concerning energy efficiency but there is no indication that shows they will disappear from the EU market[285].

It is therefore proposed to review the current ecodesign requirements to take out of the market the least efficient models and to reflect the current and future technological progress and market trends. This review takes the opportunity to introduce resource efficiency requirements as discussed in previous tasks.

Details about proposed ecodesign policy options are presented in section 7.2.3.

Energy Labelling

As presented in section 7.1 the Energy Labelling Regulation 392/2012 has made a positive impact.

The effect from the regulation on energy efficiency and annual energy consumption is clear, as shown in section 2.3.2. This effect is seen primarily on condenser driers, and particularly for heat pump driers. Condenser tumble driers had 85% of the EU market which is expected to grow to 89% in 2020 (see Table 9).

99% of heat pump condenser driers on the EU market are above energy class A (in 2016), while heating element driers (both condenser and air-vented) have remained in energy class B and C. A small development is seen in heating element condenser driers, while heating element air-vented driers have remained more or less in the same classes as it has been shown in section 2.3.2 (see Figure 19 and Figure 20).

Using the opportunity of rescaling, energy classes could be adjusted to reflect the current market which evidently has evolved since the Energy Labelling came into force. Moreover, other aspects related to consumer use and understanding can be incorporated to make the label easier to understand by consumer at the time of purchase.

It is therefore proposed to review the current energy label to grab the existing potential for cost effective technological improvement and to reflect the current and future

[285] Although input from relevant stakeholders on these driers has been quite limited so care should be taken on drawing final conclusions

technological progress and market trends. Details about proposed energy labelling policy options are presented in section 7.2.3.

7.2.3 Proposed policy options incl. barriers and opportunities

Using information gathered in previous tasks, this section presents an overview of the selected policy options to be investigated under the scenario analyses. The policy options have been developed using the design options in task 6 as starting point, in particular those presenting the Least Life Cycle Cost (LLCC) and the largest environmental benefits. Moreover, other aspects to be reviewed in current regulations have been integrated in the policy options. These are described in the next two sections.

Real life use of tumble driers

The information gathered in previous tasks indicates that some of the parameters in the tumble drier regulations reflecting the consumer behaviour are no longer valid. In task 3 an overview was presented of the difference of the parameter values used in the regulations and current real use values (see Table 44).

In order to reflect real use, the scenario analyses show consumption and emissions values using real use values, in particular regarding loading and cycles per year.

The calculation of annual energy consumption in the regulation is no longer relevant as the number of cycles per year used in the regulations is too high compared to new data, and because the amount of laundry dried per cycle is not assumed to be correlated with the rated capacity as currently assumed in the regulations. At the first stakeholder meeting it was shown that the total annual energy consumption of household tumble driers by 2020 will be less than half of what was initially estimated using standard values from the current regulations. In addition to this, values on annual energy consumption can be difficult to interpret by consumers since they are not aware of the number of times they use the appliance every year. It is thus proposed to show the energy consumption information in the label per cycle rather than per annum. This is also in line with proposed requirements for washing machines. Indication of energy consumption per cycle would require that the Energy Efficiency Index (EEI) is also calculated per cycle.

In order to do this, a new standard energy consumption (SEc)[286] value is needed as reference to the EEI calculation. The APPLiA 2018 model database (provided by APPLiA to the study team) is used as data reference, as it is the only source available with values related to energy consumption, capacity, cycle time, and condensation efficiencies. Note however that this data is model based, and not sales-weighted. The sales data from GfK

[286] Currently used to determine the Energy Efficiency Index (EEI) as EEI = AEc/SAEc x 100

(presented in Task 2) is thus used to weight the different tumble drier types, in order represent both marked forces and technological progress.

The current formula to estimate the weighted[287] energy consumption per cycle (E_{tc}), and the weighted cycle time (T_t), calculates these values based on 3 cycles with full load, and 4 cycles with half-load cycles. It thus assumes that the average cycle is loaded with ~71% of the rated capacity of the tumble drier.

In order to better reflect the average load found in the APPLiA consumer study found to be 62% of the rated capacity, *subsequent figures, tables and chapters will use a loading factor of 62% to estimate the weighted energy consumption.* The proposed new formula for calculating the weighted energy consumption per cycle is:

$$E_{tc} = 0.24 \times E_{dry} + 0.76 \times E_{dry½}$$ [288]

With:

- $\mathbf{E_{dry}}$ being the average energy consumption at full load for the standard cotton program [kWh]
- $\mathbf{E_{dry½}}$ being the average energy consumption at partial (half) load for the standard cotton program [kWh]

Currently, the differences in weighted energy consumption per cycle between driers with and without heat pumps as heating technology is very significant, whereas the difference between condensers and air-vented driers with heating elements is very small. This means two distinct groups exists when looking at the EEI distribution and/or the weighted energy consumption per cycle. Figure 88 lists the weighted energy consumption per cycle as a function of the rated capacity per drier type, where the gap between the technologies can be seen.

[287] "Weighted" refers in this case to the weighing between the energy consumption at full load, and the energy consumption at half/partial load.
[288] $24\% * 1 + 76\% * 0.5 = 62\%$

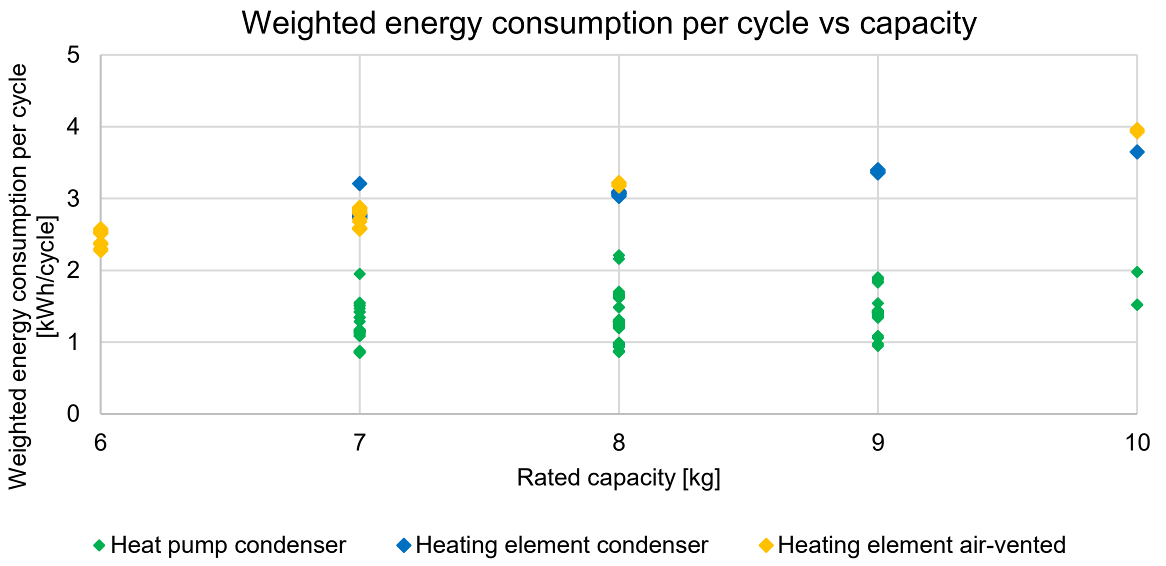

Figure 88: Weighted energy consumption per cycle[289] vs. rated capacity. *Source: APPLiA Model Database*

The SEc can be defined in multiple ways based on the available data at different levels of data representativity.

The new SEc will be based on a power regression ($y = a \times x^b$) made by taking the average weighted energy consumption per cycle of the four tumble drier types (the four base cases from Task 5) per rated capacity, and then using the sales distribution in 2018 (same year as the APPLiA model database) to give a sales-weighted value per rated capacity at 6, 7, 8, and 9kg[290].

The power-regression used in the current regulation will for the sake of ease of implementation and consistency be kept, but with different calculated coefficients. Other options were investigated in terms of doing the regression, such as using a linear regression or using an exponential decay regression ($y = C(1 - \mathrm{e}^{-kt}), k > 0$). The results were however similar, so the power regression was ultimately kept.

The average energy consumption per cycle for each type and rated capacity can be seen in Table 59. A power regression was then made on these values which resulted in the corresponding power regression coefficients: a = 0.44 and b = 0.75.

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[289] 62% loading factor, from the formula on p. 251
[290] Not enough datapoints was available for 10kg driers

A comparison between the SEc calculated by the current regulation (scaled from the energy consumption for 160 cycles/year to energy consumption per cycle) and the SEc calculated using the proposed method is seen on Figure 89.

Table 59: Weighted energy consumption per cycle (E_{tc}) per rated capacity and type and the estimated sales distribution in 2018. Gas driers omitted due to lack of data. HP-C and HE-C at 6kg based on linear extrapolation due to insufficient data points. *Sources. APPLiA, GfK*
HP-C = Condensing heat pump drier, HE-C = Condensing heating element drier, HE-V = air-vented heating element drier.

Rated capacity [kg]	Weighted energy consumption per cycle (E_{tc}) [kWh/cycle]			
	HP-C	HE-C	HE-V	Sales weighted average
6	1.07	2.46	2.47	**1.70**
7	1.20	2.77	2.74	**1.90**
8	1.23	3.07	3.20	**2.08**
9	1.40	3.38	3.54	**2.32**
Sales distribution	59%	31%	10%	

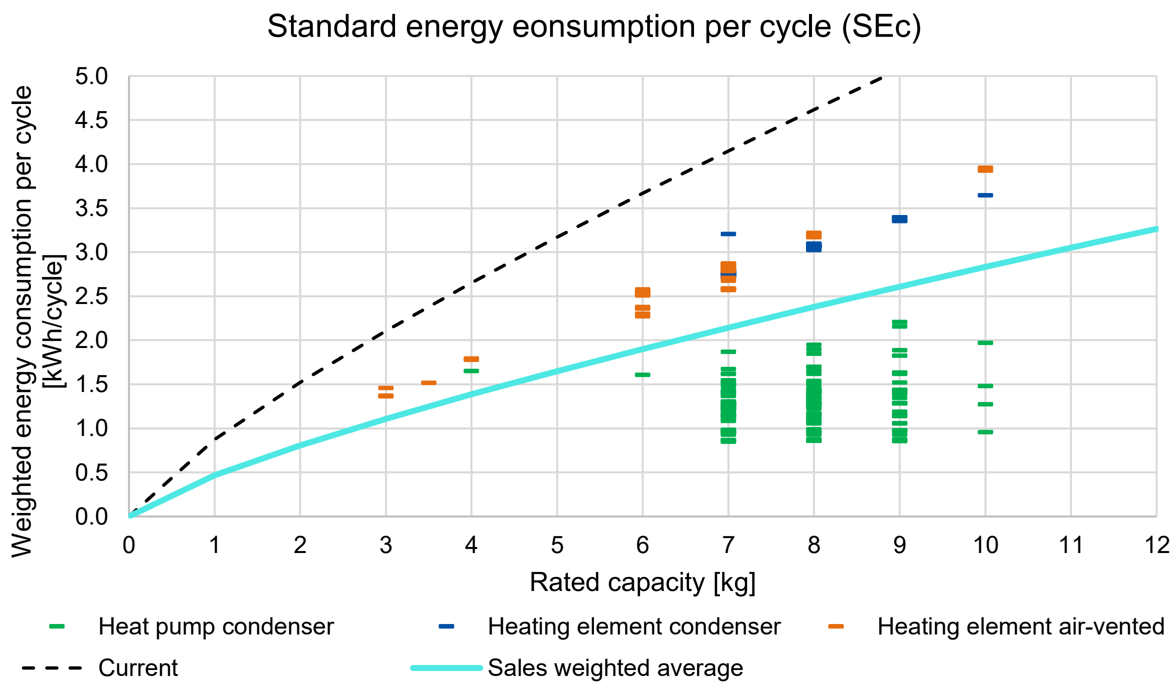

Figure 89: The available data points for the weighted energy consumption per cycle for each drier type, including the new Standard Energy consumption per cycle indicated by the turquoise line.

Compared to the current SEc from the regulation, the proposed SEc formula has a much lower slope (the a-coefficient). This is due to the market mostly consisting of heat pump driers which have a generally lower energy consumption per cycle. The b-coefficient (the exponent) is also lower (0.75 compared to 0.8) which means that the curve of the function-line is declining more rapidly compared to the current formula. This means that the percentual difference between e.g. a 7 kg and 9 kg drier, is higher in the proposed formula compared to the current one. Driers with higher rated capacities will thus have a comparably lower SEc which results in a higher EEI (and thus potential a worse energy label), and thus reduces the incentive for manufactures to produce driers with high rated capacities.

For air-vented driers, a correction factor is used to correct for the tumble driers impact on secondary energy systems (see section 3.1.3), as done in the current regulations. The correction factor in the current regulation corresponds to a ~5% decrease in the SEc value per hour of cycle time for a 7kg drier with a 123min cycle time. The proposed calculation method, instead, imposes this percentage reduction directly, and without lowering the correction factor for driers with longer cycle time. The reduction is increased from the current Regulation from 10% to 17%[291] per cycle based on the conclusions from section 3.1.3 and updated to reflect the change from yearly energy consumption to a per-cycle consumption on the energy label.

Overall, in order to better reflect the real use of household tumble driers in the EEI calculation, it is proposed to modify it as described below.

$$EEI = \frac{Etc}{SEc} \times 100$$

With:

- **EEI** = Energy Efficiency Index
- $\mathbf{E_{tc}}$ = Weighted energy consumption of the active mode per cycle [kWh]
- **SEc** = Standard energy consumption per cycle [kWh]

The SEc is calculated based on the distribution from Figure 89.

For condensing driers:

$$SEc = 0.44 \times c^{0.75}$$

For air-vented driers:

$$SEc = 0.44 \times c^{0.75} \times (1 - \frac{Tt}{60} \times 0.083)$$

With:

- **c** being the rated capacity [kg]
- $\mathbf{T_t}$ being the weighted cycle time [minutes].

[291] 17% per cycle with a cycle time at 123 minutes is equivalent to 17%/(123/60) = 8.3% per hour.

The weighted energy consumption per cycle will, as mentioned, be based on a 62% loading factor. The proposed formula is:

$$E_{tc} = 0.24 \times E_{dry} + 0.76 \times E_{dry½}$$ [292]

With:

- **E_{dry}** being the average energy consumption at full load for the standard cotton program [kWh]
- **$E_{dry½}$** being the average energy consumption at partial (half) load for the standard cotton program [kWh]

Note that no change of the current test method is proposed, only the weighing of the energy consumption per load.

The same is done for the formula to estimate the average cycle time:

$$T_t = 0.24 \times T_{dry} + 0.76 \times T_{dry½}$$

With:

- **T_{dry}** being the average cycle time at full load for the standard cotton program [kWh]
- **$T_{dry½}$** being the average energy consumption at partial (half) load for the standard cotton program [kWh]

Similarly, for the condensation efficiency:

$$C_t = 0.24 \times C_{dry} + 0.76 \times TC_{dry½}$$

With:

- **C_{dry}** being the average condensation efficiency at full load for the standard cotton program [-]
- **$C_{dry½}$** being the average condensation efficiency at partial load for the standard cotton program [-]

These modifications are developed to ensure that calculation methods better reflect the real use.

For gas-fired driers, the calculation of EEI follows the same methodology. The energy consumption per cycle at full and half load ($E_{dry}, E_{dry½}$) is here defined as:

$$E_{dry} = \frac{Eg_{dry}}{f_g} + Eg_{dry,a}$$

[292] $24\% * 1 + 76\% * 0.5 = 62\%$

$$E_{dry½} = \frac{Eg_{dry½}}{f_g} + Eg_{dry½,a}$$

With

- **Eg_{dry}** being the gas consumption at full load for the standard cotton program [kWh]
- **$Eg_{dry½}$** being the gas consumption at partial load for the standard cotton program [kWh]
- **$Eg_{dry,a}$** being the auxiliary electricity consumption at full load of the standard cotton program [kWh]
- **$Eg_{dry,a}$** being the auxiliary electricity consumption at partial load of the standard cotton program [kWh]
- **f_g** being a conversion factor between primary energy and electricity. Currently, this factor is 2.5. This factor is changed to 2.1[293] to better reflect the average EU electricity generation efficiency.

The correction factor for air-vented driers when calculating the SEc also applies for gas driers.

Low power modes

Power consumption requirements for low power modes are not included in the current regulations. Instead, their consumption is integrated in the formula to calculate the annual energy consumption. However, it is proposed to remove these modes from the calculation of the energy consumption per cycle and instead include requirements for low power modes in the ecodesign regulation. Subsequently, this means removing tumble driers from the horizontal standby regulation.

Having requirements instead of integrating low power modes into the calculation of the energy consumption per cycle is considered more relevant because their contribution to the annual energy consumption is very low, and it will ensure that tumble driers remain efficient even when not active.

The proposed requirements, which are very similar to those proposed for washing machines, are as it follows:

(a) Household tumble driers shall have an off-mode or a stand-by mode or both. The power consumption of these modes shall not exceed 0.50W.

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[293] Based on information from the Commission and "Evaluation of primary energy factor calculation options for electricity, Anke Esser (FhG-ISI), Frank Sensfuss (FhG-ISI), 2016"

(b) If the stand-by mode includes the display of information or status, the power consumption of the stand-by mode shall not exceed 1.00W.

(c) If the stand-by mode provides for a connection to a network and provides networked stand-by as defined in Commission Regulation (EU) No 801/2013 [294], the power consumption of this mode shall not exceed 2.00W.

(d) At the latest 15 minutes after the household tumble drier has been switched on or after the end of any programme and associated activities or after interruption of the wrinkle guard function or after any other interaction with the household tumble drier, if no other mode, including emergency measures, is triggered, the household tumble drier shall switch automatically to off-mode or standby mode.

(h) If the household tumble drier provides for a delay start, the power consumption of this condition, including any standby mode, shall not exceed 4.00 W. The delay start shall not be programmable by the user for more than 24 h.

(i) Any household tumble drier that can be connected to a network shall provide the possibility to activate and deactivate the network connection(s). The network connection(s) shall be deactivated by default.

All definitions of the different power modes marked in red, are proposed to follow the same definitions as in the washing machines working documents. They will be harmonised once the latest versions of these working documents are available. Else they will be integrated in the draft working documents for the Consultation Forum.

Proposed Policy Options (PO)

Four policy options have been developed to reflect the progress in technical innovation since the adoption of the current regulation and that can provide potential environmental savings as presented in task 6. In addition, the proposed policy options are to give consumers access to better information in order to increase potential savings. An overview of policy options is presented in Table 60, including implementation dates and a brief overview of their opportunities and barriers.

A later implementation of the Ecodesign energy requirements than of the Energy Labelling requirements is proposed. This is to ensure a transition period where manufacturers get familiar with the new rescaling and energy efficiency calculations, which are different to current ones. Also, this will facilitate the verification process, since the proposed Ecodesign

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[294] Commission Regulation (EU) No 801/2013 of 22 August 2013 amending Regulation (EC) No 1275/2008 with regard to ecodesign requirements for standby, off mode electric power consumption of electrical and electronic household and office equipment, and amending Regulation (EC) No 642/2009 with regard to ecodesign requirements for televisions

energy requirements will be linked to specific class interval limits (more details in section 7.3.3). This transition period is not deemed necessary for the proposed resource efficiency requirements.

Table 60: Overview of Policy Options for energy and resource efficiency

Policy Option	Proposed requirements	Implementation date	Opportunities	Barriers
PO1**a** – Energy market average (based on the average of all drier types on the market)	ECODESIGN • Condenser driers (BC1 & BC2): Revised EEI levels & condensation efficiency requirements reflecting current market + Information requirement on refrigerant used in product manual (only BC2) • Air-vented driers (BC3 & BC4): Revised EEI levels requirements reflecting current market ENERGY LABELLNG • Condenser driers (BC1 & BC2): Revision and rescaling of EEI & condensation efficiency levels from A to G reflecting current market + Information requirement on refrigerant used in product manual (only BC2) • Air-vented driers (BC3 & BC4): Revision and rescaling of EEI from A to G reflecting current market	2021 (Energy Labelling) 2023 (Ecodesign, condensation efficiency)	Give manufacturers increased incentives to promote and produce more energy efficient products. Rescaling of label intervals enables a clearer differentiation between drier types/models and could reduce overall energy consumption. Similarly, new condensation efficiency intervals could reduce the impact on secondary energy systems, as the overall condensation efficiency might improve. Information requirements may reduce the overall GWP impact, as users can easier identify driers using natural refrigerants.	The average drier might increase in price, which might reduce the overall sales and thus reduce business turnover. As the condensation efficiency is inversely linked to energy efficiency, the new condensation efficiency classifications might increase energy consumption. Although this would be marginal since rescaled intervals have been introduced reflecting current driers on the market.
PO1**b** – Energy BAT (based on BAT and improvement option with the LLCC))	ECODESIGN • Condenser driers (BC1 & BC2): Revised EEI levels and condensation efficiency requirements reflecting BAT + Information requirement on refrigerant used in product manual (only BC2) • Air-vented driers (BC3 & BC4): Revised EEI levels requirements reflecting BAT	2023 (Ecodesign, condensation efficiency + EEI requirements)	Setting ambitious ecodesign limits would remove all driers with lower energy efficiencies from the market (i.e. mostly heating element driers), significantly reducing the overall energy consumption and GHG emissions.	Removing all driers with lower levels of efficiency from the market might reduce the total sales of products. However previous experience shows that any lost revenues would likely be compensated by the increase in the average price per product.
PO2 - Energy BAT (based on BAT and improvement option with the LLCC)	ECODESIGN • Condenser driers (BC1 & BC2): Revised EEI levels and condensation efficiency requirements reflecting BAT + Information requirement on refrigerant used in product manual (only BC2) • Air-vented driers (BC3 & BC4): Revised EEI levels requirements reflecting BAT	2021 (Energy Labelling) 2023 (Ecodesign, condensation	In addition to opportunities in PO1, setting ambitious ecodesign limits would remove all driers with lower energy efficiencies from the market (i.e. mostly heating element driers), significantly reducing the overall energy consumption and GHG emissions.	Removing all driers with lower levels of efficiency from the market might reduce the total sales of products. However previous experience shows that any lost revenues would likely be compensated by the

Policy Option	Proposed requirements	Implementation date	Opportunities	Barriers
	ENERGY LABELLNG • Condenser driers (BC1 & BC2): Revision and rescaling of EEI and condensation efficiency levels from A to G reflecting BAT+ Information requirement on refrigerant used in product manual (only BC2) • Air-vented driers (BC3 & BC4): Revision and rescaling of EEI from A to G reflecting BAT	efficiency + EEI requirements)		increase in the average price per product.
PO3 – Dismantling[295] and Recycling	ECODESIGN • All base cases/drier types: Dismantlability features[296] for materials and components referred to in Annex VII to Directive 2012/19/EU	2021	Higher recycling and reuse rates for main materials and components and preventing premature disposal of products.	Products may never be manually disassembled at End-of-Life (products may still be shredded).
PO4 – Reparability and durability	ECODESIGN + Information requirement on refrigerant used in product manual (only BC2) • All base cases/drier types: Critical spare parts[297] shall be available for at least 10 years after placing the last unit of the model on the market, and manufacturers should ensure a maximum delivery time of 15 working days after having received the order + access and Provision of disassembly and repair and maintenance information to all professionals of critical components (in product manual)[298]	2021	Increased awareness about reparability – and options for repair may lead to more repairs – less consumption of raw materials and preventing premature disposal of products – also refurbishment of products may become more economical attractive. May become an attractive business model (circular economy) with loyal customers and increased earnings.	Repair may be unattractive for some customers (some customers may rather buy new appliances than to repair). The price of the spare parts and cost of repair may prevent repair. Risk of high production of spare parts and low sales if spare parts are too expensive (more resources used).

[295] According to JRC report: "Analysis and development of a scoring system for repair and upgrade of products – draft version 2". Published in October 2018 and circulated to stakeholders, 'dismantling' is the irreversible process of taking apart of an assembled product into constituent materials and/or parts. More about the report and study: http://susproc.jrc.ec.europa.eu/ScoringSystemOnReparability/index.html

[296] For example: "Manufacturers shall ensure that joining or sealing techniques do not prevent the dismantling of materials and components referred to in Annex VII to Directive 2012/19/EU."

[297] As defined in section 3.2.2, the critical parts of tumble driers are pumps, motors, fans and heating elements.

[298] For example: "Dismantling of these components shall be ensured by making an exploded diagram of the tumble drier with the location of the materials and components available in technical documentation, and the sequence of dismantling operations needed to access and remove the materials and components, including: type of operation, type and number of fastening technique(s) to be unlocked, tool(s) required, safety requirements and risks (if any) related to the disassembly operations." A caution warning should be included in product manual advising consumers to not disassembly without the help of a professional and an indication made about this preventing any warranty claim. The list of critical parts and the procedure for ordering them shall be publicly available on the free access website of the manufacturer, importer or authorised representative, at the latest two years after the placing on the market of the first unit of a model and until the end of the period of availability of these spare parts.

7.3 Scenario analysis

A scenario analysis is made to evaluate the effect of the policy options at an EU level, based on the best available data sources, assumptions and key parameters gathered from tasks 2 through 6, and from input from stakeholders.

7.3.1 Indicators

All policy options will be evaluated and compared, based on a number of key parameters. Below is a short description of each parameter, the calculation method used for the parameter and sources for used values. All parameters are presented annually for the years 2021, 2025, 2030, 2035, and 2040. Cumulative values are calculated for relevant parameters from 2021 to 2030 and from 2021 to 2040.

All calculations are done up to year 2040. This is to evaluate the full effect of the regulations, which does not appear before the whole stock is replaced, which takes ~15 years, when assuming an average product lifetime of 12 years with a standard deviation of 2 years. Note that no values between 2030 and 2040 are modified (i.e. they are kept constant), which includes the energy label distributions and average rated capacity of sold units, the total sales, and the sales distribution between the four base cases.

The results are presented aggregated, e.g. not divided on the different tumbler types. Instead, the savings potentials attributed to each tumbler type will for some parameters be shown separately.

Energy consumption during use per year in EU 28 [TWh/year]

The calculation of energy consumption during use is based on the average annual energy consumption for each type of drier, coupled to the relevant stock of the relevant year. For instance, heat pump driers sold in 2016 will have an annual energy consumption of 114 kWh/year. These driers will keep consuming 114 kWh/year, until the stock from 2016 is depleted. The energy consumption of new products on the market will either follow the market trends (BAU), or it will follow the new requirements according to the policy options and their date of implementation.

The current regulations use an EEI factor to determine an energy label class. As only distribution data between the different energy label classes was available from this 2013 - 2016, the distribution between the energy classes is converted to an average EEI value. This is done by assuming the average EEI value is only slightly lower than the high limit of the energy class interval[299].

[299] This is for this model determined by the formula $EEI_{average} = EEI_{class\ upper\ limit} - \frac{EEI_{class\ range}}{4}$. E.g. if an arbitrary class interval was between an EEI of 10 and 20, the average EEI of the driers in this interval is assumed to be in 20-(20-10)/4 = 18.

From the EEI value a specific energy consumption (*SpEc*) in terms of energy consumption per kilo of laundry dried can be calculated by knowing the current EEI calculation formula. First by finding the annual energy consumption as per the current definition:

$$\mathrm{EEI} = \frac{\mathrm{AEc}}{\mathrm{SAEc}} \times 100 \ \rightarrow \mathrm{AEc} = \frac{\mathrm{EEI} \times \mathrm{SAEc}}{100} = \frac{\mathrm{EEI} \times 140 \times c^{0.8}}{100}$$

Where:

- c is the rated capacity of the household tumble drier for the standard cotton programme in kg/cycle.
- AEc is the weighted annual energy consumption in kWh/year as defined by the current regulation.

The specific energy consumption is thus the annual energy consumption divided by the cycles per year (160) and the loading from the current regulation (~71% of the rated capacity):

$$\mathrm{SpEc} = \frac{\mathrm{AEc}}{[Dried\ laundry\ per\ year]} = \frac{\frac{\mathrm{EEI} \times 140 \times c^{0.8}}{100}}{c \times 160 \times \left(\frac{3 \times 1 + 4 \times 0.5}{7}\right)}$$

- SpEc is the specific energy consumption in kWh/kg

This thus only requires the EEI value and the average rated capacity to estimate specific energy consumption. For air-vented driers, the correction factor is applied to the SEc definition. The specific energy consumption is then converted to a "real" annual energy consumption by using the loading and cycles/years found from Task 3 (4.4kg and 107 cycles/year):

$$\mathrm{AEc_{real}} = \mathrm{SpEc} \times 4.4 \times 107$$

Energy label distribution data from GfK were used from 2013 to 2016 to determine the efficiency of models placed on the market. For rated capacities, the APPLiA 2016/2017 model database was used as source[300]. For the years 2002 to 2009, values from the impact assessment and preparatory study were used. From 2009 to 2013, the values were interpolated linearly. The average rated capacity per type is found by using the same projection presented in Task 2, in Figure 33.

[300] The model database was used to determine the average rated capacity based on type and energy label, e.g. the average rated capacity of an A++ labelled heat pump drier, and so on.

The energy label distribution from 2017 and onwards varies between the different policy options. They can be seen in Annex VIII.

Global Warming Potential in EU 28[mt. CO2-eq/year]

The global warming potential is quantifying the life cycle greenhouse gas emissions of the whole life cycle of tumble driers, expressed as CO_2-eq. emissions per year. The emissions are based on energy consumption during use, multiplied with emissions factors in CO_2-eq./kWh[301], as well as the emissions related to production, distribution, disposal, and recycling based on values from the Ecoreport tool.

Total Materials Consumption in EU 28 [mt/year]

The total materials consumption is based on the Bill of Materials and scaled up to the whole stock. The reductions in material consumption are based on % reduction values shown in Task 6.

Total user expenditures in EU 28 [bln. EUR/year]

Total user expenditure is a sum of the following parameters:

- Energy consumption costs
  - Calculated as the total energy consumption for the whole stock in EU 28, multiplied with energy costs from PRIMES[302].
- Purchase costs
  - Based on the sales estimations from Task 2, and derived unit prices. The unit prices are based on GfK data from 2013 to 2016. See Figure 90 for the relationship between unit price and energy consumption. No data was available for gas driers. Data for the most common model on the market was used instead[303].
- Repair costs
  - Based on the inputs from task 6 and calculated through the Ecoreport tool.

[301] From Ecodesign Impact Accounting, VHK, 2016.
[302] https://ec.europa.eu/clima/policies/strategies/analysis/models_en#PRIMES
[303] Whiteknight ECO43, source: GfK

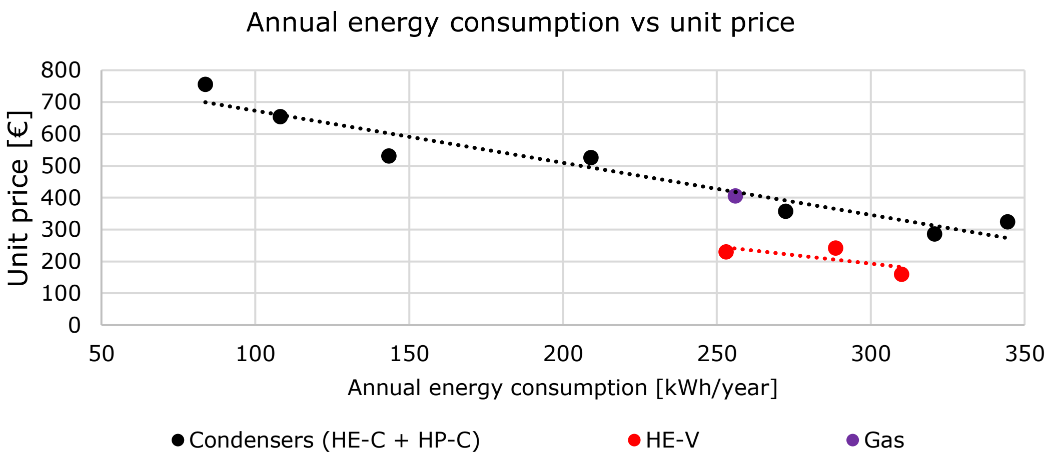

Figure 90: Annual energy consumption vs unit prices. HE-C = Heating element condenser (BC1), HP-C = Heat pump condenser (BC2), HE-V = Heating element air vented (BC3), GAS = Gas-fired air-vented driers (BC4)*. Source: GfK, APPLiA model database 2017*

Business revenue EU 28 [bln. EUR/year]

Business revenue is divided into manufacturer's turnover and retail turnover. The retail turnover is equal to the unit price shown in Figure 90, multiplied with the relevant yearly sales shown in task 2.

The manufacturer's turnover is based on the sales margin from the manufacturer-wholesale-retail chain. The same margins are used as in the washing machine review study[304], which assumes that the observed retail price is 2.8 times the manufacturing cost. Adding profit margins, the manufacturers' turnover is assumed to be 36% of the retail turnover.

Employment

Employment is assumed to directly follow the industry turnover. Increased turnover from more expensive products is thus assumed to increase employment. The total business revenue explained above, is divided by employment figures from EUROSTAT[305] to give estimated values at the total extra employment compared to the baseline scenario.

7.3.2 Description of BAU

For establishing the BAU scenario, the sources cited in the previous section are used to estimate key parameters from 1995 to 2016. For 2017 to 2030, estimations are based on 2013-2016 data. For the annual energy consumption, a projected distribution of tumble driers is used based on the current energy classes. They can be seen in Annex VIII.

[304] Ecodesign and Energy Label for Household Washing machines and washer dryers – Preparatory study, final report, JRC, 2017

[305] V91100 "turnover per person employed". For "Manufacturer of domestic appliances" → 0.260 mln. EUR turnover per employee used.

Note that the EEI calculation method described in the current regulations is used to model energy consumption up to 2040 for the BAU scenario. For the policy options, the rescaled energy label distributions are converted to the new EEI calculation method explained in previous sections but keeping the same calculated average annual energy consumption up to 2021. Changing the EEI calculation method will by itself not have any impact on the annual energy consumption.

The unit prices are linked to the energy class distribution. A shift towards a higher average energy class means an increase in the average unit price, see Figure 90.

7.3.3 Description of policy options for energy and performance

A detailed description of the inputs and assumptions used to evaluate the policy options presented in Table 60 follows in the next sections.

Rescaling - EEI

For policy options 1 and 2 a new EEI formula was presented previously. Consequently, the current energy class intervals will change based on this new calculation method. Figure 91 shows the current EEI levels (for available models on the market) and energy class intervals, with the current EEI calculation method. As it appears the EEI of models available on the EU market are very dependent on the intervals, as the products tend to have EEI levels at, or just below, the interval limits. This is especially true for the heating element condenser driers, where the large majority of models are just below 76, which is the upper interval limit for energy class B and the ecodesign limit according to the current EEI calculation method. Interesting is the fact that many models exist with an EEI above 76. This is likely due to old models still existing on the market.

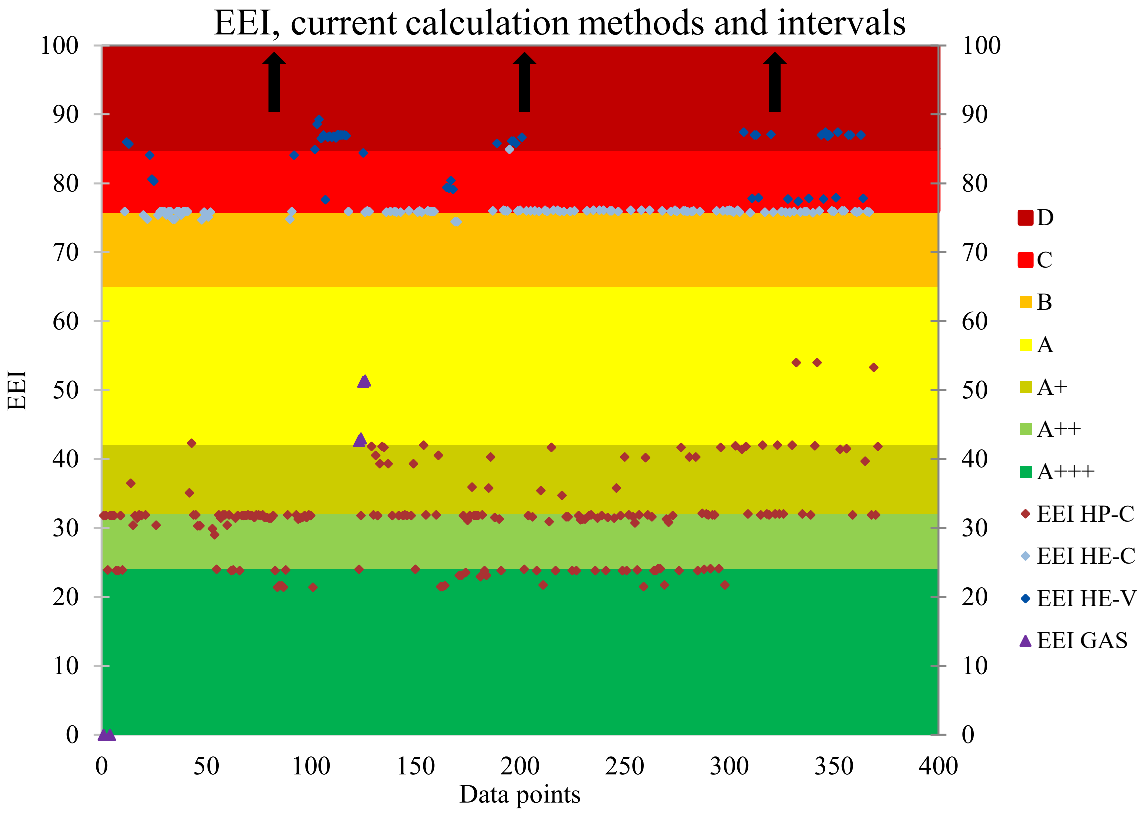

Figure 91: EEI for available models on the market[306] using the EEI calculation method from the current regulation, and the current energy class intervals.
HP-C = Heat pump condenser, HE-C = Heating element condenser, HE-V = Heating element air vented, GAS = Gas-fired air-vented. ***Source: APPLiA 2017 model database***

Figure 92 shows the same intervals, but with the proposed new EEI calculation method. As the new SEc parameter is introduced (see Figure 89), the energy class distribution of all driers will change. As heat pump driers have the greatest market share, the change for these driers will not be significant. For the heating element driers, however, the new EEI calculation method means some models get shifted from energy class B to C. This is due to the new power regression coefficients, were the new SEc has a lower dependency on the rated capacity for the energy consumption per cycle compared to the old calculation method (which was primarily based on heating element driers instead of heat pump driers, and with an exponent equal 0.8 instead of the proposed 0.75), and due to the penalization factor for air vented driers being increased.

[306] For models manufactured by APPLiA members.

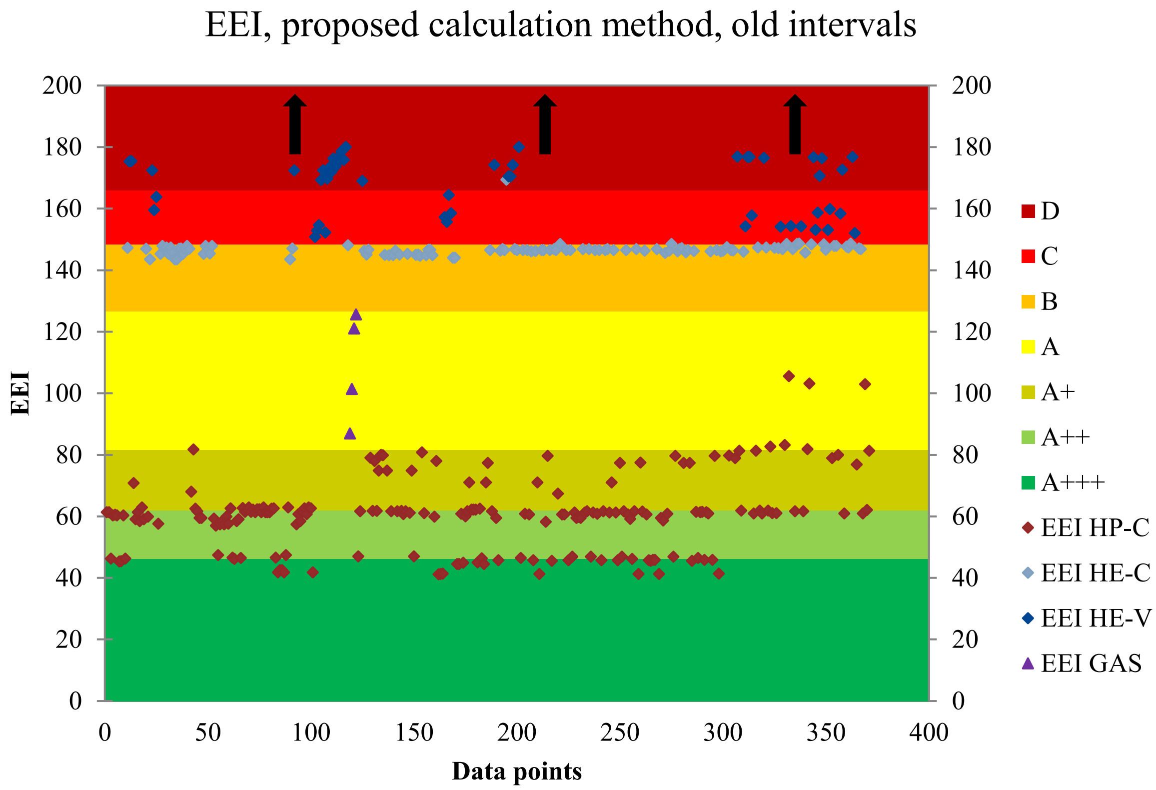

Figure 92: EEI for available models on the market[306], with the proposed EEI calculation method and the current (recalculated) energy class intervals.
HP-C = Heat pump condenser, HE-C = Heating element condenser, HE-V = Heating element air vented, GAS = Gas-fired air-vented driers. *Source: APPLiA 2017 model database*

Figure 93 shows the proposed rescaling of the classes. The A class is empty, following the 2017 framework Energy Labelling Regulation, and the B class only consists of models currently at current A+++ levels.

Classes B to E are spaced to make the differences between the classes easy to identify for consumers. Furthermore, as the heat pump driers have large variations in efficiencies, classes B to E correspond to where heat pump driers currently exist. This increases the number of energy label classes available for the heat pump driers from 4 to 6. This also limits the available classes for the heating element driers, but as limited improvement potentials exist for these drier types (see Task 4 and 6), there is no need for a large number of classes. The F class is very wide due to natural gap between the heating element driers and the heat pump driers and the limited amount of available energy classes.

The A class is placed carefully to be within a reasonable distance of the B class. The currently best A+++ driers incorporate the majority of the identified improvement options from Task 4 and 6. Making the lower A limit higher than the proposed limit at an EEI of 33 (as suggested by some stakeholders) might hinder technological progress if the A class is out of reach even with major technological improvements.

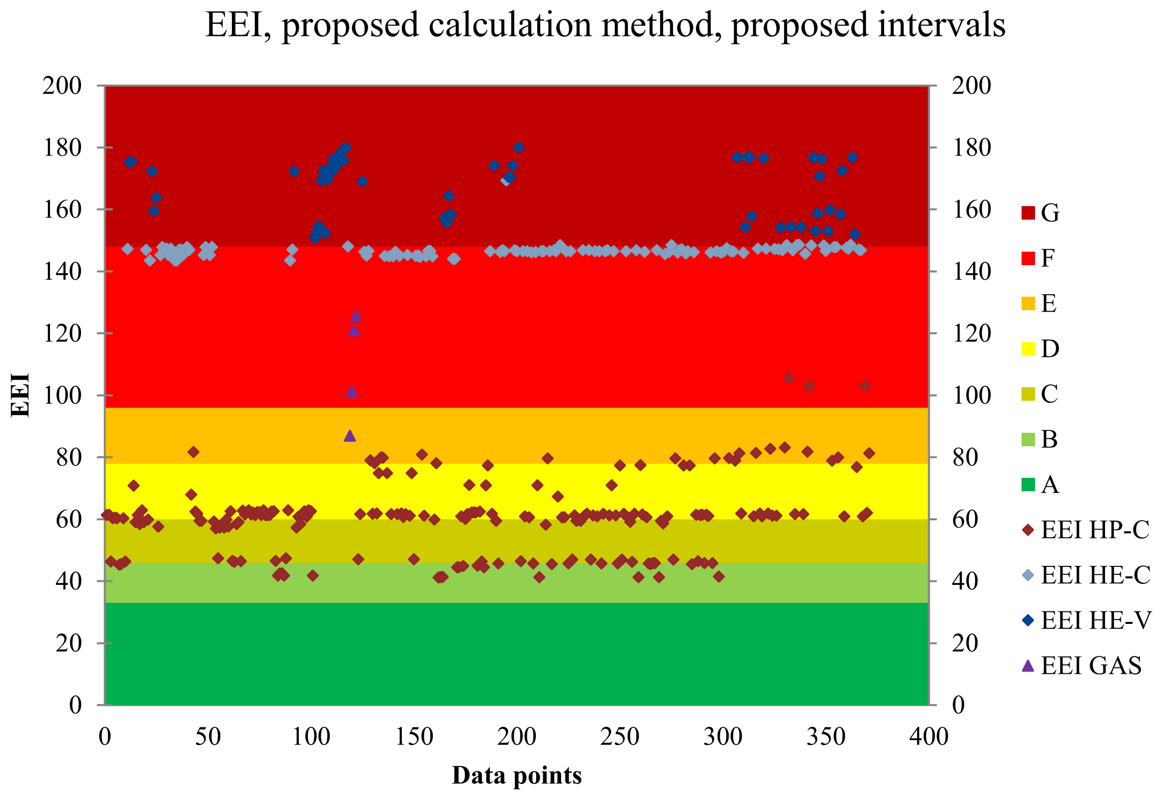

Figure 93: EEI for available models on the market[306], with the current EEI calculation method and the proposed energy class intervals.
HP-C = Heat pump condenser, HE-C = Heating element condenser, HE-V = Heating element air vented. ***Source: APPLiA 2017 model database***

The new classes are shown in Table 61. For a comparison between the current and proposed classes (both calculated with the new EEI formula) see Table 62 and Table 63. Note that the EEI values are higher than the normal 0-100 scale. This is because the SEc was based on the best fit of the current market. Models less efficient than the current average drier on the market will thus have an EEI value above 100. As heating element driers generally use more than twice the amount of energy per kg compared to heat pump driers, they will thus have an EEI more than twice as high.

Table 61: The new proposed energy label classes

EEI Interval
A ≤ 33
33 < B ≤ 46
46 < C ≤ 60
60 < D ≤ 78
78 < E ≤ 96
96 < F ≤ 148
148 < G

Table 62: Current and proposed classes, and the current new distributions of the classes

<table>
<tr><th>Current class</th><th></th><th>Proposed class</th><th>Current classes, distribution</th><th>Proposed classes, distribution</th></tr>
<tr><td></td><td></td><td>A</td><td>-</td><td>0%</td></tr>
<tr><td>A+++</td><td>→</td><td>B</td><td>13%</td><td>11%</td></tr>
<tr><td>A++ (Top)</td><td>→</td><td>C</td><td rowspan="2">27%</td><td>11%</td></tr>
<tr><td>A++ (Bottom)</td><td>→</td><td>D</td><td rowspan="2">27%</td></tr>
<tr><td>A+ (Top)</td><td>→</td><td>D</td><td rowspan="2">14%</td></tr>
<tr><td>A+ (Bottom)</td><td>→</td><td>E</td><td rowspan="2">5%</td></tr>
<tr><td>A</td><td>→</td><td>E</td><td rowspan="2">2%</td></tr>
<tr><td>A</td><td>→</td><td>F</td><td rowspan="2">31%</td></tr>
<tr><td>B</td><td>→</td><td>F</td><td>30%</td></tr>
<tr><td>C</td><td>→</td><td>G</td><td>7%</td><td rowspan="2">15%</td></tr>
<tr><td>D</td><td>→</td><td>G</td><td>8%</td></tr>
</table>

Table 63: Current and proposed energy label intervals (based on proposed EEI calculation method), and the conversion between classes

Current		≤46	47-62	63-81	82-127	128-148	149-166	≥167
		A+++	**A++**	**A+**	**A**	**B**	**C**	**D**
New	**A**	**B**	**C**	**D**	**E**	**F**	**G**	
	≤33	34-46	47-60	61-79	80-97	98-148	≥149	

Rescaling – Condensation efficiency

In line with the re-scaling of the energy classes also the condensation efficiency classes should be re-scaled. Currently, 96% of the available models are in the top 2 classes (A or B)[307], and the full range of classes are thus not utilised.

The current ecodesign requirement corresponds to a condensation efficiency of 70%. This means that the energy labelling is only relevant for tumble driers with condensation efficiencies between 70 – 100%. Rescaling the current classes will result in 4 classes (A through D) were the A class would be almost empty, and with the majority of the models (93%) distributed evenly between classes B and C. The new classes are shown in Table 64. The old and new distributions are shown in Table 65.

[307] APPLiA model database 2017.

Table 64: New proposed condensation efficiency class intervals

Condensation efficiency interval
A ≥ 94
94 > B ≥ 87
87 > C ≥ 80
80 > D

Table 65: New and old distribution of condensation label intervals

<table>
<tr><th colspan="2">Old classes</th><th>New class</th><th>Old classes, percentage of total</th><th>New classes, percentage of total</th></tr>
<tr><td>A</td><td>→</td><td>A</td><td rowspan="2">32%</td><td>4%</td></tr>
<tr><td>A</td><td>→</td><td>B</td><td rowspan="2">47%</td></tr>
<tr><td>B</td><td>→</td><td>B</td><td rowspan="2">63%</td></tr>
<tr><td>B</td><td>→</td><td>C</td><td>44%</td></tr>
<tr><td>C</td><td>→</td><td>D</td><td>5%</td><td rowspan="2">5%</td></tr>
<tr><td>D</td><td>→</td><td>D</td><td>0%</td></tr>
</table>

PO1a – Market average

The PO1a policy options "average EEI" level is equal to the BAU scenario from 1995 to 2020. In 2021, the proposed EEI calculation method is introduced, together with the proposed energy class intervals (Table 61). As previously explained, they are based on the observed current market distribution of energy classes in the last years. It is also proposed to have more classes (7 instead of 5), as the current C and D classes are respectively partially or fully phased out due to current ecodesign limits.

At the time the new Energy Labelling Regulation comes into force (2021), the current ecodesign limit (EEI of 76 in the current calculation method) will not be made more stringent, but merely converted to the proposed EEI calculation method, which corresponds to a new EEI of 148. This will continue once the new Ecodesign Regulation comes into force (2023). No ecodesign limit is thus directly imposed, but as the EEI calculation method will be changed to reflect heat pump driers, the heating element driers will be applied a minor more stringent adjustment which would effectively remove more of these drier types from the market.

This moderate change in this policy option ensures a small decrease in annual energy consumption for new driers sold, but without significantly increasing the consumers purchase costs. Furthermore, it ensures that heating element driers (condensing and air-vented driers) will continue to exist on the market.

A new ecodesign limit for the condensation efficiency at 80% is proposed. This will remove 5% of the driers (85% of these being heating element condensing driers) from the market.

The ecodesign limit at 80% is proposed as a large majority of the driers reach condensation efficiencies higher than 80% which shows that the market is able to reach these efficiency levels. The ecodesign limit could potentially be increased to above 80%, but as the condensation efficiency and energy consumption are correlated this could potentially increase the total energy consumption of tumble driers, see section 4.1.7.

PO1b – BAT

PO1b will investigate the effects of a more stringent ecodesign requirement but without imposing the new EEI calculation method and without rescaling the current energy label classes. The policy option is thus used as an indicator to show the potential of setting a stringent ecodesign requirements without changing the EEI calculation method and subsequent rescaling of the energy label classes.

The PO1b average EEI levels is thus equal to the BAU scenario throughout the time period. From 2023, all heating element driers will be excluded from the market as energy label class B (from the current energy label classes) will be removed. It will thus force consumers to exclusively purchase either heat pump driers or gas fired driers.

PO2 – BAT

PO2 combines PO1a and PO1b. Like the PO1a, the PO2 policy options average EEI levels are equal to the BAU scenario from 1995 to 2020. In 2021, the new EEI calculation method will be introduced, together with the new energy class intervals (Table 61).

At the time the new Energy Labelling Regulation comes into force (2021), the current ecodesign limit (EEI of 76 in the current calculation method) will be merely converted to the new EEI calculation method, which corresponds to an EEI of 148.

However, once the new Ecodesign Regulation comes into force (2023), classes G and F will be removed, by setting the ecodesign limit of EEI at 96. The effect is visualized in Figure 93, where the E/F border indicates the new ecodesign limit. The proposed limit is low enough (on the EEI scale) to ensure that no driers with lower efficiencies than the heat pump driers and gas-fired driers will remain on the market. It will thus force consumers to exclusively purchase either heat pump driers or gas fired driers.

In order to separate the effects of the ecodesign limits, the future energy label distributions are assumed similar to PO1a, with the only change being the ecodesign requirements. Setting strict ecodesign limits could result in a net reduction of sales of all tumble driers in the EU market due to higher product prices, but this effect is not quantified, since there is no evidence so far that this will happen.

Similar to PO1a and following the same reasoning, an ecodesign limit for the condensation efficiency at 80% is proposed. This will remove ~1% of the heat pump driers from the current market[308].

7.3.4 Description of policy options for resource efficiency

In order to only look at resource efficiency aspects, PO3 and PO4 will follow the BAU scenario regarding energy label distribution and unit prices. This means the effect of these scenarios are independent of PO1 and PO2, and thus can be added to those of PO1 and PO2.

PO3 - Dismantling and Recycling

In order to estimate the effects of easier dismantling and higher recycling rates, the Ecoreport tool is used, where environmental impact of the End-of-Life phase is changed by increasing the mass fractions of recycled materials from 29% to 49%[309], reducing the total amount of materials being sent to incineration and placed on landfills. The impacts on Global Warming Potential and Total energy are evaluated through the Ecoreport tool. There is no impact on material consumption.

PO4 – Reparability and durability

For the effect of increased reparability and durability, the average lifetime is changed from 12 years to 14 years. The current stock model calculates the stock based on sales numbers and an average lifetime. Changing the lifetime would thus significantly increase the total stock, which is not likely to happen. Households seldom have more than one tumble drier, which will likely not change just because the tumble drier lasts longer.

In order to quantify the effect properly, the sales figures are scaled instead, meaning that the total stock is unchanged, but the sales figures are scaled down to match the current stock numbers. As the stock model follows a normal distribution (see Task 2), the sales numbers are varied similarly. As the lifetime of tumble driers would be prolonged from already a long lifetime, the full reduction in sales is first seen when the models sold in 2021 are beginning to be replaced, which is around ~2031.

The economic effect of prolonged lifetime from more repair activities is quantified by doubling the annual average repair/maintenance cost of the driers to 10 EUR/unit/year. The increased in repair costs increases the user expenditure but also the business revenue and employment by assuming that manufacturers take all increased repair turnovers. This is because there is no data providing the share of OEM (Original Equipment Manufacturer)

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[308] Based on GfK data. Heat pump driers have a generally higher condensation efficiency compared to heating element condenser driers.
[309] The 20% increase is based on assumptions and a Deloitte study [(Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV]

and non-OEM repairers in the EU market. With this assumption, manufacturers would be the only beneficiaries, and this is reflected in PO4's industry and manufacturers' turnover and employment shown in the following section (7.3.5).

The increase in annual average repair/maintenance costs is explored further in the sensitivity analysis in section 7.4.

7.3.5 Results

In this section, the results of the scenario analyses of the various policy options described previously are shown. Note all cumulative savings are compared to BAU. Cumulative savings are assumed positive when the value is *smaller* than BAU. Cumulative savings up to 2030 means cumulative savings from 2021 to 2030, while cumulative savings up to 2040 are the savings from 2021 to 2040. Besides cumulative savings, the differences in 2030 and in 2040 compared to BAU are also shown. Positive savings thus correspond to a reduction of the various indicators compared to the BAU scenario.

For some indicators, the savings in 2030 are provided by tumbler drier types. Note however for PO1b and PO2 the savings on the heat pump drier are often negative. This is because the combined energy consumption (for instance) for heat pump driers increases as the sales/stock for these increases significantly.

Rebound Effects

Besides the positive influence of the policy options on the environmental impacts of tumble driers the policy options also include the potential for negative side effect referred to as *rebound effects*.

More energy efficient tumble driers with reduced operation costs could lead to an increased use of tumble driers (more cycles per year) and a higher sale (i.e. higher penetration rate). This would in both cases lead to a reduction of the estimated environmental benefits. However, the use of the tumble driers (cycles per year) is closely linked to the use of washing machines[310] and the amount of laundry and therefore no significant increase in the use of tumble driers are expected. Even though the purchase price for heat pump driers has been reduced energy efficient tumble driers are still expensive. The high price will

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[310] The 2017 study on household washing machines and washer-driers [Ecodesign and Energy Label for Household Washing machines and washer dryers – Preparatory study, final report, JRC, 2017] indicates a close to constant penetration rate at 90% (p. 150), and a small reduction in cycles/year (From 4.0 to 3.8 cycles per week, p. 247) which among other thing are likely based on the fact that washing machines are growing in terms of the average rated capacity. The total amount of laundry and use of the washing machines are thus almost constant from 2015 to a projected 2050 (table 2.11, p. 154)

probably limit further penetration of tumble driers in households because often alternative and cheaper solutions for drying of the laundry are available.

For tumble driers (as for many other appliances) sales are increasing. For a small part this is a rebound effect as described above but in general it is more a matter of steadily increased material wealth[311] and because manufactures use the rated capacity as key figure in advertisement when selling tumble driers.

The rebound effect has been investigated by multiple sources but not specifically for tumble driers and significant effects have been observed[312]. As tumble driers are not a need-to-have appliance (such as washing machines) conclusions from these studies are however hard to directly transfer to this study.

All in all, the rebound effect is very hard to quantify as the effect is based on user behaviour. The effect is thus mentioned here but not used in any of the numeric models.

Sales and stock

PO2 will remove all non-heat pump driers from the market and will thus increase the sale of heat pump driers to keep the stock constant assuming same penetration rate as for the BAU scenario. PO4 will reduce the total sale of tumble driers as the lifetime of the driers are prolonged. The resulting sales are compared to the BAU sales in Figure 94 and Figure 95, and the resulting stock for PO2/PO1b (increased share of heat pump driers and decreased share of other types) are compared to BAU in Figure 96 (PO1a stock is equal to BAU). Note the very steep increase of sales of heat pump driers at the time of the ecodesign limit for PO2/PO1b. This is due to the assumption that the total sales will remain unaffected by the new ecodesign limits and thus the 2.1 million non-heat pump driers that would be sold in the BAU scenario are now assumed to be heat pump driers.

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311 Ecodesign Impact accounting. Status report 2016. Prepared by VHK for the European Commission. https://ec.europa.eu/energy/sites/ener/files/documents/eia_ii_-_status_report_2016_rev20170314.pdf

312 *"Capturing the Multiple Benefits of Energy Efficiency",* IEA 2014,

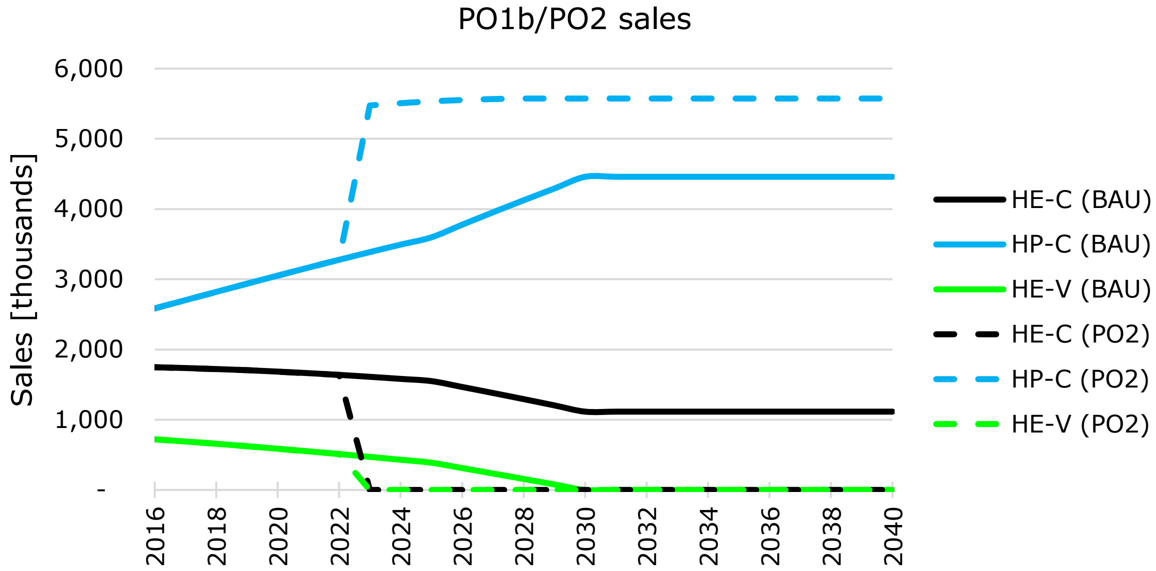

Figure 94: Sales of tumble driers for BAU and PO2. ***Note that the PO1a sales is equal to BAU, and the PO1b sales is equal to PO2.***
HP-C = Heat pump condenser, HE-C = Heating element condenser, HE-V = Heating element air vented.

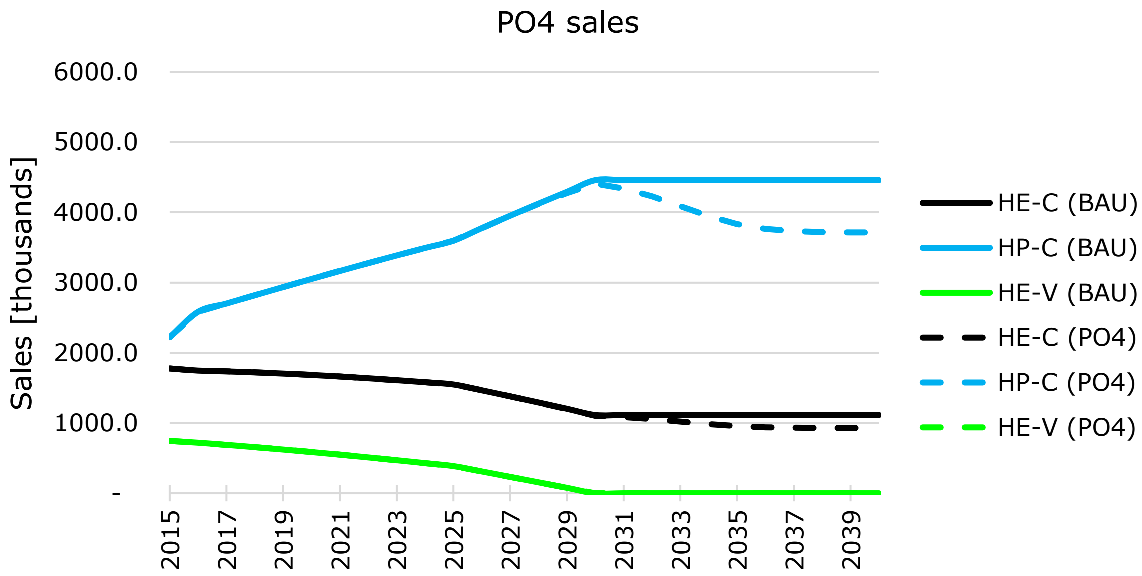

Figure 95: Sales of tumble driers for BAU and PO4.
HP-C = Heat pump condenser, HE-C = Heating element condenser, HE-V = Heating element air vented.

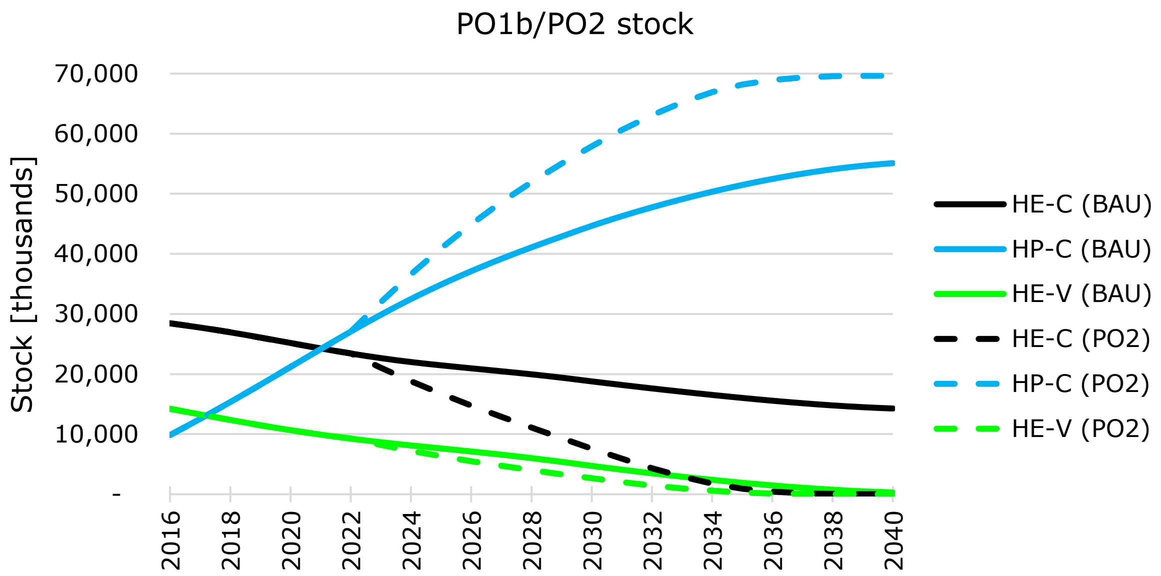

Figure 96: Stock of tumble driers for BAU and PO2. *Note that the PO1a stock is equal to BAU, and the PO1b stock is equal to PO2.*
HP-C = Heat pump condenser, HE-C = Heating element condenser, HE-V = Heating element air vented.

Energy consumption during use

Figure 97 and Table 66 show the total energy consumption in the use phase for tumble driers with the different policy options. Table 67 shows the energy savings distributed per tumbler type.

When evaluating the policy options in 2040 (were the full stock prior to 2021 is replaced), the effects of the ecodesign and energy label can be seen based on the results from PO1a and PO1b.

PO1a (energy label only) can potentially save 1.2 TWh/year in 2040, which is a reduction of ~14% of the total energy consumption compared to BAU. PO1b (ecodesign only) can potentially save 2.4 TWh/year in 2040, which is a reduction of ~26% of the total energy consumption compared to BAU.

PO2 (energy label + ecodesign) is estimated to save 3.9 TWh/year in 2040, which corresponds to a reduction of 43% of the total energy consumption compared to BAU. The savings from PO2 are higher than the combined effect of PO1a and PO1b as the effects are somewhat multiplicative (PO1a estimates the effect on the energy label on *all* the tumble drier types of which the impact on heating element driers are not large, were PO2 only acts on heat pump (and gas driers) which have a large effect).

In short, the isolated effect of the stringent ecodesign limit is 2.4 TWh/year in 2040, and the effect of the energy label is 1.2 TWh/year in 2040, or about half of that of the ecodesign effect. The effect of removing all heating element driers is thus larger than just rescaling of the energy label.

For PO4, the reduced replacement rate due to the increased lifetime increases the energy consumption as the replacement of old inefficient driers with new more efficient takes place at a slower rate. PO3 has no impact on energy consumption during use.

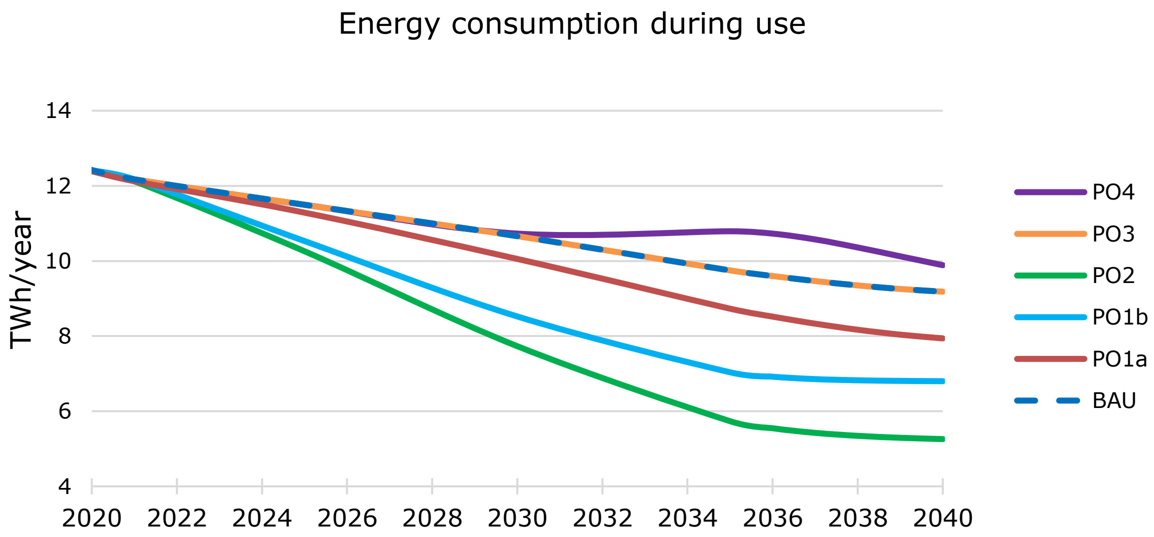

Figure 97: Total energy consumption per year in EU 28 from using the tumble driers for all scenarios from 2020 to 2040

Table 66: Total energy consumption and cumulative savings from using the tumble driers

	Annual energy consumption during use [TWh/year]					Savings compared to BAU		Cumulative savings	
	2021	2025	2030	2035	2040	2030	2040	2030	2040
BAU	12.17	11.50	10.66	9.75	9.18	-	-	-	-
PO1a	12.12	11.29	10.05	8.73	7.94	0.61	1.24	2.80	12.99
PO1b	12.17	10.53	8.52	7.04	6.80	2.14	2.38	10.56	36.00
PO2	12.12	10.26	7.73	5.73	5.26	2.93	3.93	14.16	52.51
PO3	12.17	11.50	10.66	9.75	9.18	-	-	-	-
PO4	12.17	11.50	10.73	10.79	9.89	-0.07*	-0.70*	-0.10*	-7.92*

*=negative savings are increased energy consumption

Table 67: Change of energy consumption during use by tumble type.[313]

	Savings per tumble drier type, energy consumption [TWh/year], 2030				
	PO1a	PO1b	PO2	PO3	PO4
HE-C	0.02	2.95	2.95	0.00	-0.03
HP-C	0.58	-1.32	-0.53	0.00	-0.02
HE-V	0.00	0.51	0.51	0.00	-0.01
GAS	0.00	0.00	0.00	0.00	0.00

Embedded energy

Figure 98 and Table 68 show the embedded energy for materials used to produce the tumble driers.

PO3 shows a high reduction potential, which is due to the better dismantling of the products and thus higher recyclability. PO3 is estimated to save 0.2 PJ/year in 2030 compared to the BAU scenario, equal to a 9% reduction. The large initial drop is due to the flat reduction imposed on all new sold driers after 2021.

PO4 reduces the embedded energy as the total sales are assumed to be reduced. PO2/PO1b has an increase in embedded energy consumption, as heat pump driers have larger material usage than the other drier types. PO1a has no change, as no change in sales distributions are assumed.

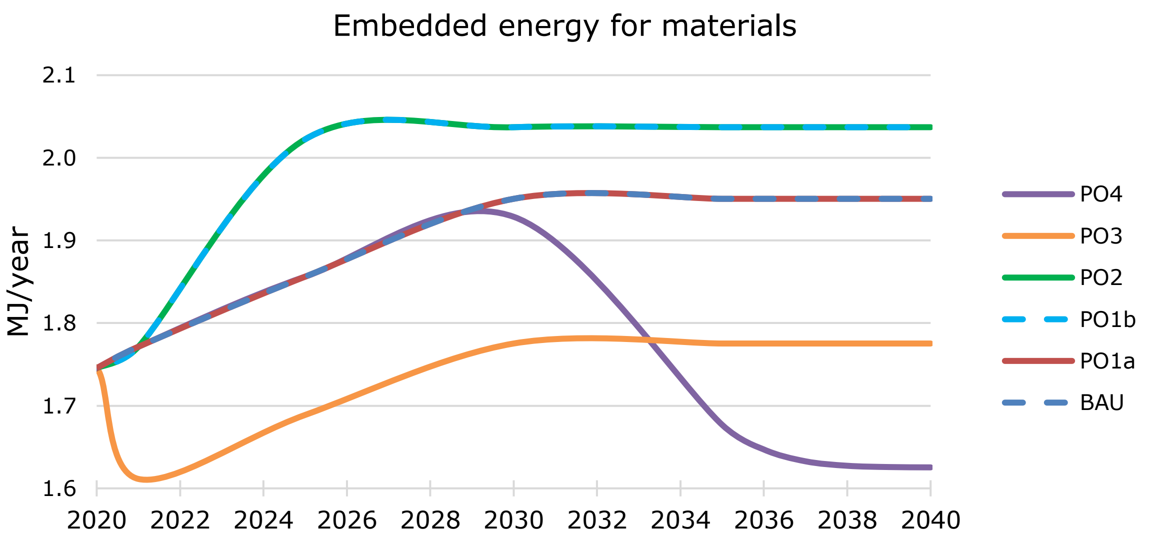

Figure 98: Embedded energy consumption from materials

[313] Note the savings for the heat pump driers are negative for PO1b and PO2 because the combined energy consumption for heat pump driers increases as the sales/stock for these increase significantly.

Table 68: Embedded energy consumption from materials

	Embedded Energy [PJ/year]					Difference compared to BAU		Cumulative savings	
	2021	2025	2030	2035	2040	2030	2040	2030	2040
BAU	1.77	1.86	1.95	1.95	1.95	-	-	-	-
PO1a	1.77	1.86	1.95	1.95	1.95	-	-	-	-
PO1b	1.77	2.02	2.04	2.04	2.04	-0.09*	-0.09*	-1.11*	-1.98*
PO2	1.77	2.02	2.04	2.04	2.04	-0.09*	-0.09*	-1.11*	-1.98*
PO3	1.61	1.69	1.78	1.78	1.78	0.18	0.18	1.68	3.43
PO4	1.77	1.86	1.93	1.68	1.63	0.02	0.32	0.03	2.44

*=negative savings are increased embedded energy

Table 69: Savings of embedded energy by tumble drier type

	Savings per base case, embedded energy [PJ/year], 2030				
	PO1a	PO1b	PO2	PO3	PO4
HE-C	0.00	0.32	0.32	0.03	0.00
HP-C	0.00	-0.41	-0.41	0.15	0.02
HE-V	0.00	0.00	0.00	0.00	0.00
GAS	0.00	0.00	0.00	0.00	0.00

Global warming potential

Figure 99 and Table 70 show the estimated greenhouse gas emissions for the different policy options in mt. CO_2 eq. emissions per year. Table 71 shows the savings distributed on each tumbler type.

The results can be divided into the results for policy options for energy and performance (PO1-PO2), and policy options for resource efficiency (PO3-PO4).

For policy options 1a/b and 2, the greenhouse gas emissions are closely linked to the energy consumption during use, and conclusions from that section can thus also be applied here. Savings of 0.2, 0.7 and 0.9 mt. CO2 eq./year for PO1a, PO1b and PO2 respectively have been estimated for 2030.

PO3 is estimated to save 0.1 mt. CO2 eq./year for 2030. This is due to the higher recyclability, reducing the emissions at the End-of-Life phase and overall emissions for the whole life cycle of the products.

The reduction of GHG emission from PO4 is due to the longer lifetime of tumble driers resulting in lower sales and thus material use. The higher energy consumption due to the less efficient stock however counteracts this leading to a moderate increase after ~2029.

PO3 and PO4 show smaller reductions in GHG emissions than PO1a/b and PO2, because they target different aspects of the products (PO3 and PO4 target reductions at the production and end-of-life of the products, while PO1a/b and PO2 do that for the use of the driers. Therefore, the effects of PO3 and PO4 could in principle be added to the effect of PO1a/b and PO2.

Similar to the energy consumption during use, heat pump driers are responsible for the largest reductions in GHG emission. This is even though these drier types have a larger GHG emissions related to a larger material consumption.

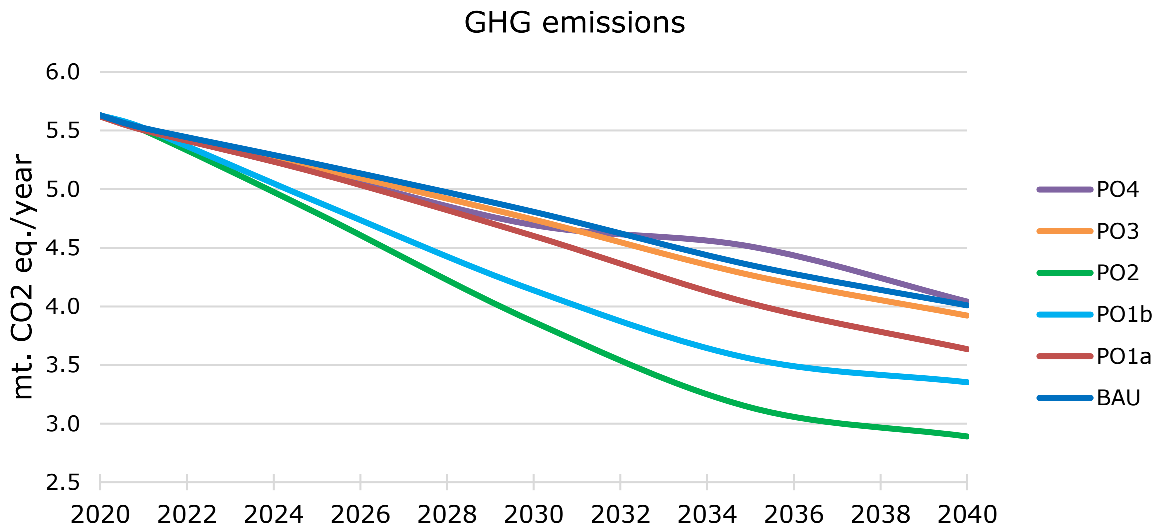

Figure 99: Greenhouse gas emissions for all policy options from 2020 to 2040 in EU28

Table 70: Greenhouse gas emissions and cumulative savings for all policy options

	GHG Emissions [mt. CO2 eq./year]					Savings* compared to BAU		Cumulative savings	
	2021	2025	2030	2035	2040	2030	2040	2030	2040
BAU	5.52	5.21	4.81	4.35	4.01	-	-	-	-
PO1a	5.50	5.14	4.60	4.03	3.64	0.21	0.37	0.98	4.20
PO1b	5.52	4.89	4.14	3.55	3.35	0.67	0.66	3.41	10.84
PO2	5.50	4.79	3.87	3.14	2.89	0.94	1.12	4.67	16.19
PO3	5.51	5.18	4.74	4.27	3.92	0.07	0.09	0.36	1.19
PO4	5.51	5.15	4.69	4.51	4.04	0.11	-0.03*	0.71	-0.04*

*=negative savings are increased GHG emissions

Table 71: Savings of GHG emissions by tumble drier type

	Savings per drier type, GHG emissions [mt. CO2 eq./year], 2030				
	PO1a	**PO1b**	**PO2**	**PO3**	**PO4**
HE-C	0.01	1.17	1.17	0.01	0.02
HP-C	0.20	-0.70	-0.43	0.05	0.09
HE-V	0.00	0.20	0.20	0.00	0.00
GAS	0.00	0.00	0.00	0.00	0.00

Materials consumption

Figure 100 and Table 72 show the total material consumption of tumble driers for all policy options. Note that PO1a & PO3 do not reduce the consumption of materials, as the sales distribution is not changed. PO3 increases the amount of recycled materials, but the total sales and thus material consumption are the same. The increase in materials for PO2 and PO1b is due to heat pump driers having a higher material use than the other drier types. Removing all non-heat pump driers from the market thus increases the total material use.

The savings from PO4 are due to the sales being gradually reduced as tumble driers with longer lifetime begin to enter the market. The effect is first seen around ~2029, as the new models sold after the proposed regulation first begin to be gradually removed from the stock.

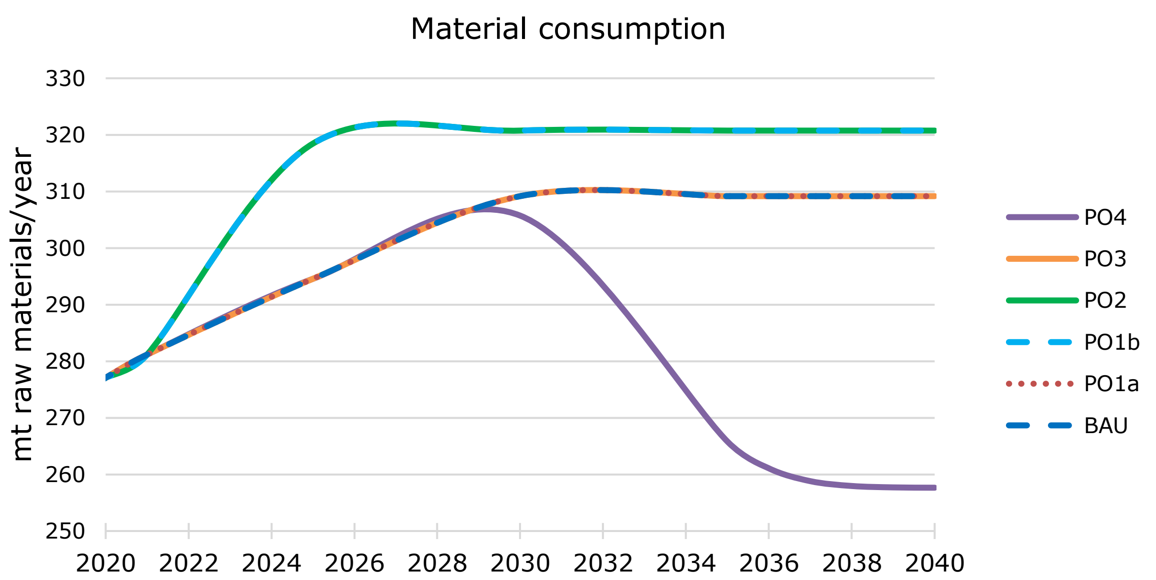

Figure 100: Material consumption for all policy options from 2020 to 2040.

Table 72: Material consumption, and cumulative savings, for all policy options.

	Material consumption [mt./year]					Savings* compared to BAU		Cumulative savings	
	2021	2025	2030	2035	2040	2030	2040	2030	2040
BAU	281	295	309	309	309	-	-	-	-
PO1a	281	295	309	309	309	-	-	-	-
PO1b	281	318	321	321	321	-11.6*	-11.6*	-158*	-274*
PO2	281	318	321	321	321	-11.6*	-11.6*	-158*	-274*
PO3	281	295	309	309	309	-	-	-	-
PO4	281	295	306	266	258	3.4	51.5	5	386

*=negative savings are increased material consumption

Table 73: Savings of total materials consumption by tumble drier type

	Savings per base case, material consumption [mt./year], 2030				
	PO1a	PO1b	PO2	PO3	PO4
HE-C	0.00	0.00	52.6	0.00	0.59
HP-C	0.00	0.00	-64.2	0.00	2.86
HE-V	0.00	0.00	0.00	0.00	0.00
GAS	0.00	0.00	0.00	0.00	0.00

Total user expenditure

Figure 101 and Table 74 show total user expenditures in EU28 for all policy options (total stock). Table 75 shows the savings distributed for each type of tumble driers. Looking at the figures, two major effects are apparent: (1) An increase in the product price appears instantaneous, which is more evident for PO1b and PO2 due to higher average price of heat pump driers, and, (2) the effect from an increase in efficiency (saved costs during use) appears only gradually. In other words, all added expenses associated with buying a more efficient product appear at the year of purchase, whereas the savings from switching stock gradually to more efficient driers are spread out over the whole lifetime of the products.

The first effect is the major increase in user expenditure in 2023 for PO1b and PO2. This is due to the increase in unit price, as sales of heating element driers disappear and are replaced with more expensive types. See Figure 94 above which illustrates the difference in the sales distribution between PO1b/PO2 and BAU.

The initial cost is thus high, but as the market gradually changes to heat pump driers, the lower energy consumption (lower energy costs) counteracts the effects of the higher unit price, and thus lowers total consumer expenditure to a level below BAU in 2029 for PO2. The lifetime of 12 years[314] means that the whole stock is replaced around 2035 where the

[314] And a standard diviation of +/-2 years.

full effect is realized. This means that the cumulative savings are negative in 2030, but positive in 2040.

The second effect is the "break" around 2030 for PO1a, PO3 and PO4. As explained in section 7.3.1, the energy class distribution (and thus unit price) is assumed constant between 2030-2040. Up to 2030, the products are assumed to be gradually more efficient due to the effect of the new energy label. After 2030, the product price is not increasing any more, and the effect of the more efficient products begins to show as the stock is gradually replaced.

PO4 shows a minor reduction in user expenditure. As the lifetime is assumed to increase by ~17% from 12 to 14 years, the sales are gradually being reduced accordingly. Thus, a reduction in total acquisition costs is expected. The increase in repair and maintenance cost and the higher energy costs due to a less efficient stock, however, counteracts this which results in a net reduction in the total user expenditure by 0.09 bln. EUR/year in 2040.

Overall, for PO1a, PO1b, PO2 and PO4, the difference in total user expenditure compared to BAU in 2030 is expected to be -0.05, 0,13, 0.08, and -0.03 bln. EUR/year respectively. For 2040, user expenditure savings of 0.09, 0,19, 0.30, and 0.09 bln. EUR/year are expected. The majority of these savings are associated with heat pump driers.

PO3 do not reduce the total user expenditure as the sales distribution is not changed, and the products are not getting more efficient related to energy consumption.

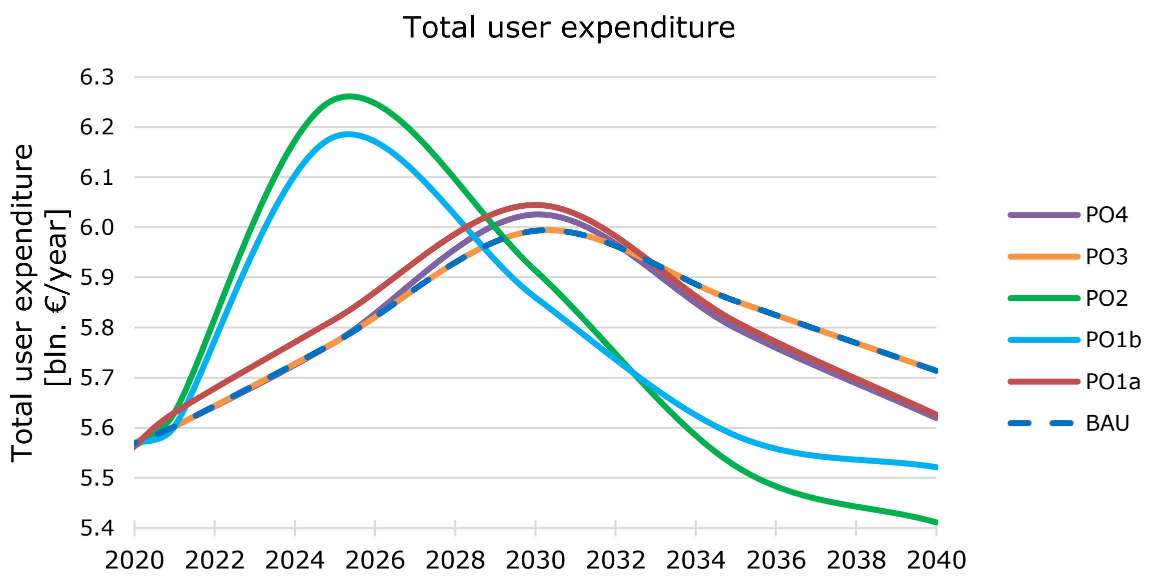

Figure 101: Total user expenditures in EU28 for all policy options from 2020 to 2040

Table 74: Total user expenditures and cumulative savings for all policy options

	Total user expenditure [bln. EUR/year]					Savings* compared to BAU		Cumulative savings	
	2021	2025	2030	2035	2040	2030	2040	2030	2040
BAU	5.60	5.77	5.99	5.85	5.71	-	-	-	-
PO1a	5.63	5.82	6.04	5.81	5.63	-0.05*	0.09	-0.44*	-0.04*
PO1b	5.60	6.18	5.86	5.58	5.52	0.13	0.19	-1.88*	0.39
PO2	5.63	6.26	5.91	5.52	5.41	0.08	0.30	-2.48*	0.36
PO3	5.60	5.77	5.99	5.85	5.71	-	-	-	-
PO4	5.60	5.77	6.03	5.80	5.62	-0.03*	0.09	-0.05*	0.38

*=negative savings are increased user expenditure

Table 75: Savings of total user expenditure by tumble drier type

	Savings per tumble drier type, Total user Expenditure [bln. EUR/year], 2030				
	PO1a	PO1b	PO2	PO3	PO4
HE-C	0.00	1.10	1.10	0.00	-0.01
HP-C	-0.05	-1.09	-1.14	0.00	-0.02
HE-V	0.00	0.12	0.12	0.00	0.00
GAS	0.00	0.00	0.00	0.00	0.00

Industry and manufacturers turnover

Figure 102 and Table 76 show the total retail turnover for all policy options. Similarly, Figure 103 and Table 77 show the total manufacturers' turnover for all policy options.

PO1a/b and PO2 result in an increase in retail turnover due to the products getting more efficient but more expensive. The large increase in turnover for PO1b and PO2 is due to the more stringent ecodesign limits.

PO3 do not reduce the total user expenditure as the sales distribution is not changed.

PO4 reduces the retail turnover as fewer models are sold. For the manufacturers, however, the increase in repair services and sale of spare parts counteracts this and actually increases the turnover. This is however very dependent on the added repair costs, which are investigated in the sensitivity analysis (section 7.4).

Overall, PO1a, PO1b, and PO2 are expected to increase retail turnover by 0.18, 0.32, and 0.52 bln. EUR/year in 2030, equivalent to an increase of 5%, 9%, and 16% respectively. PO4 is expected to reduce the retail turnover by 0.04 and 0.56 bln. EUR/year in 2030 and 2040 respectively.

For manufacturers' turnover, PO1a, PO1b, PO2, and PO4 are expected to increase the turnover by 0.06, 0.11, 0.19, and 0.04 bln. EUR/year respectively in 2030.

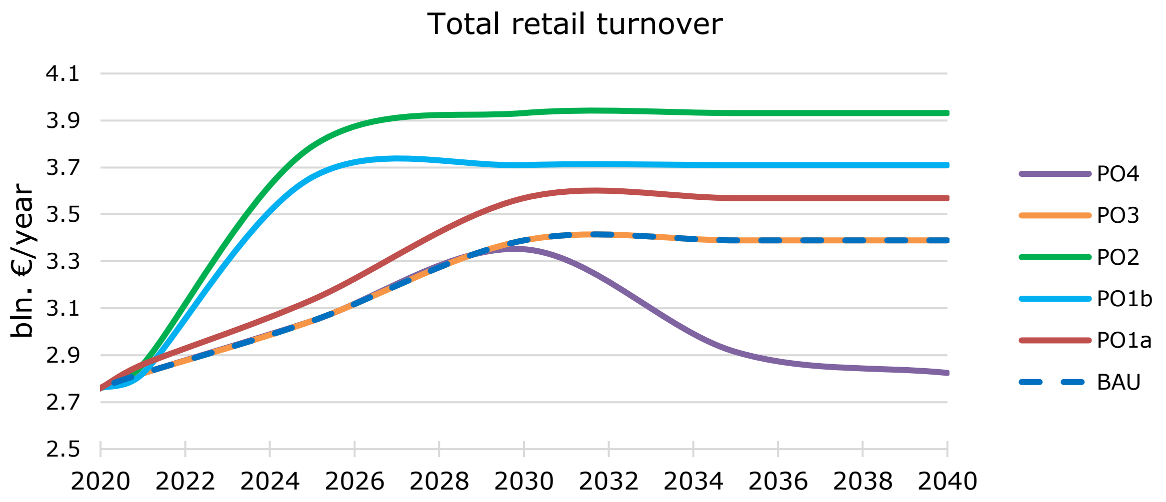

Figure 102: Total retail turnover for all policy options from 2020 to 2040.

Table 76: Total retail turnover, and cumulative savings, for all policy options

	Retail turnover [bln. EUR/year]					Reduction* in turnover compared to BAU		Cumulative savings	
	2021	2025	2030	2035	2040	2030	2040	2030	2040
BAU	2.82	3.05	3.39	3.39	3.39	-	-	-	-
PO1a	2.86	3.14	3.57	3.57	3.57	-0.18*	-0.18*	-1.03*	-2.83*
PO1b	2.82	3.66	3.71	3.71	3.71	-0.32*	-0.32*	-4.11*	-7.32*
PO2	2.86	3.79	3.93	3.93	3.93	-0.54*	-0.54*	-5.47*	-10.89*
PO3	2.82	3.05	3.39	3.39	3.39	-	-	-	-
PO4	2.82	3.05	3.35	2.91	2.82	0.04	0.56	0.05	4.24

*=negative reductions are increased turnover

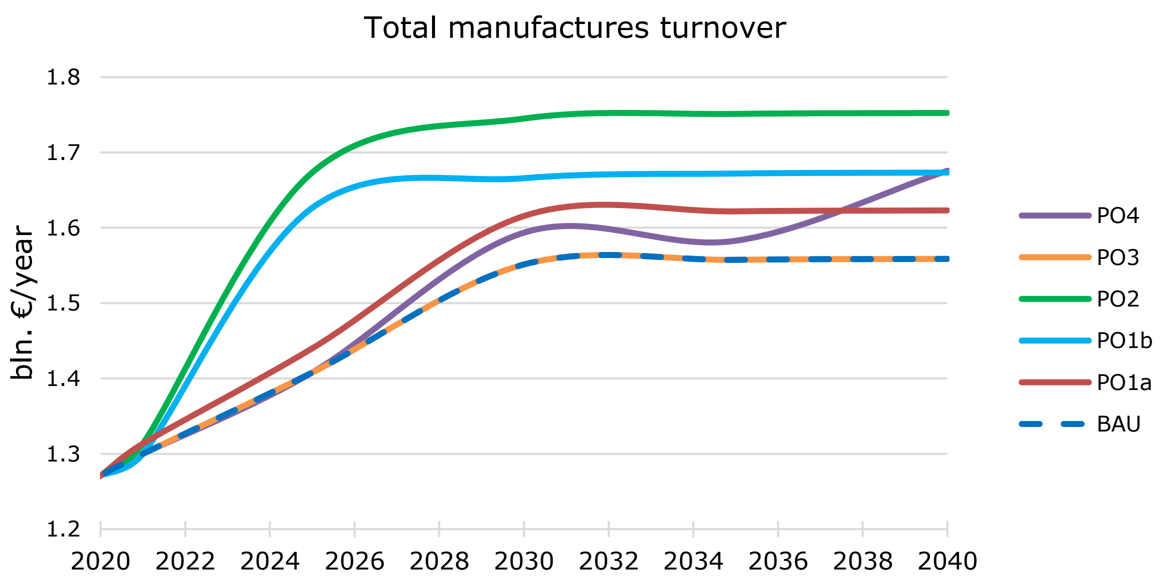

Figure 103: Total manufacturers turnover for all policy options from 2020 to 2040.

Table 77: Total manufacturers turnover, and cumulative savings, for all policy options.

	Manufacture revenue [bln. EUR/year]					Reduction* in turnover compared to BAU		Cumulative savings	
	2021	2025	2030	2035	2040	2030	2040	2030	2040
BAU	1.30	1.41	1.55	1.56	1.56	-	-	-	-
PO1a	1.31	1.44	1.62	1.62	1.62	-0.06*	-0.06*	-0.37*	-1.01*
PO1b	1.30	1.63	1.67	1.67	1.67	-0.11*	-0.11*	-1.47*	-2.61*
PO2	1.31	1.67	1.75	1.75	1.75	-0.19*	-0.19*	-1.95*	-3.89*
PO3	1.30	1.41	1.55	1.56	1.56	-	-	-	-
PO4	1.30	1.41	1.59	1.58	1.68	-0.04*	-0.12*	-0.06*	-0.63*

*=negative reductions are increased turnover

Employment

Figure 104 and Table 78 show the total employment for the different policy options. As employment is directly linked to the total industry turnover, the conclusions from the turnover section above are applicable here as well. In 2030, it is estimated that 35, 62, 104, and 213 jobs are added for PO1a, PO1b, PO2, and PO4 respectively.

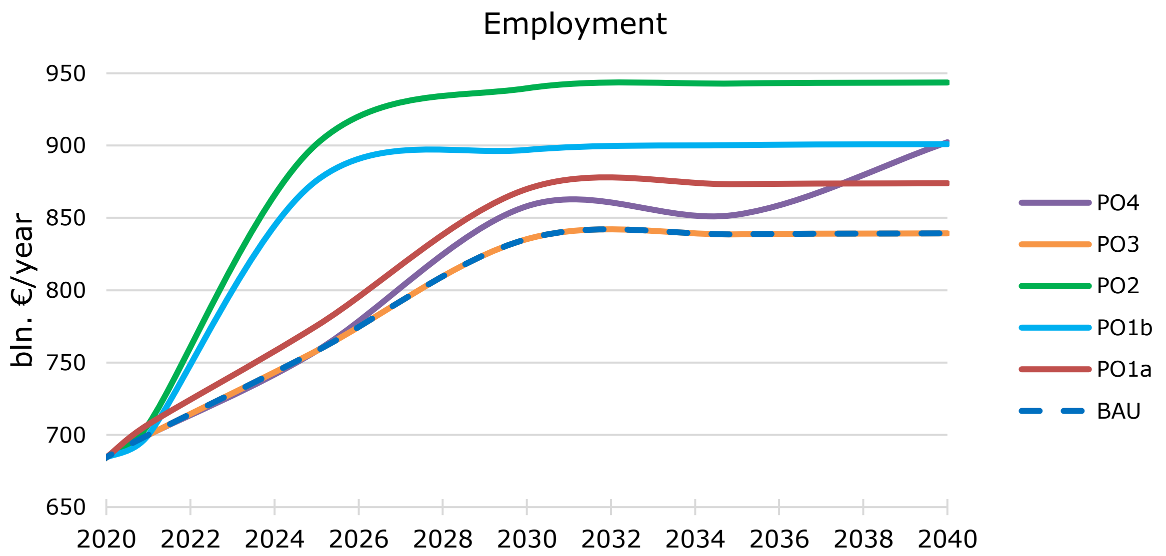

Figure 104: Employment for all policy options from 2020 to 2040.

Table 78: Total employment for all policy options

	Jobs [number/year]					Added jobs compared to BAU	
	2021	2025	2030	2035	2040	2030	2040
BAU	700	758	835	839	839	-	-
PO1a	707	775	870	873	874	35	35
PO1b	700	876	897	900	901	62	62
PO2	707	901	940	943	944	104	104
PO3	700	758	835	839	839	-	-
PO4	700	758	858	852	902	23	63

7.4 Sensitivity analysis

Sensitivity analyses have been done to assess the robustness of the results of the scenario analyses of policy options, if the values of some essential key parameters change (prerequisites and assumptions). The key parameters have been identified based on their importance to the overall results of the scenario analyses, and their uncertainty. Input from stakeholders was also considered. The key parameters are:

1. **The energy class distribution of heat pump driers in the BAU scenario in 2030**. Currently, the energy label distribution of heat pump driers in 2030 are assumed being solely composed of A+++/A++/A+ driers with a sales distribution of 30%/65%/5% respectively. In the sensitivity analysis the sale of A+ models will remain constant at 5%, but the share of the sale of A+++ and A++ will be varied. For modelling purposes, the percentage of driers in energy class A+++ will be varied from 10% to 100%.
2. **The energy class distribution of heat pump driers reaching the new A class in 2030** for PO1a/b and PO2. Currently, the energy class distribution of heat pump driers in 2030 for PO1a/b and PO2 are assumed being solely composed of A/B/C driers with a sales distribution of 30%/45%/25% respectively. In the sensitivity analysis the sale of C class models will remain constant at 25%, but the share of the sale of models in energy class A and B will be varied. For modelling purposes, the percentage of driers in class A will be varied from 0% to 50%.
3. **The penetration rate of tumble driers in 2030**, assuming that it will either decrease from the current 28.3% to 26.9% (-5%) or increase to 31.1% (+10%), following the preparatory study's previous assumption.
4. **The escalation rate of the electricity price**, varying it from the currently used PRIMES estimate (at an average of 0.7%), from 0% (-100%) to the 4% escalation rate defined in the MEErP methodology (+470%).
5. **The added repair and maintenance cost users in PO4**, varying the currently assumed +5 EUR/unit/year in repair and maintenance cost from +0 EUR/unit/year (-100%) to +10 EUR/unit/year (+100%).
6. **The effect of using different programmes** other than the standard cotton cycle, adding a correction factor on the total energy consumption during use of the tumble driers from +8% (an increase of 8% of the total energy consumption) to -12%. The effect of using different programmes has not been included in the scenario analyses presented in section 7.3.

Other parameters were not considered as important or did not present significant uncertainties and were thus not assessed.

The effects are evaluated by assessing the results according to the following indicators:

- Energy consumption during use
- Total GHG emissions
- Total material consumption
- Total user expenditure

The results are presented in absolute numbers in Table 79 to Table 84 for the 6 parameters described above. Columns in bold font correspond to the values used in the scenario analyses and the rest of the columns show the variations during this analysis. The total GHG emissions are not shown as they closely follow the total energy consumption. Furthermore, the total material consumption is only impacted by the penetration rate.

For a graphical representation of the variation of all the parameters and their effect on the chosen indicators, see Annex IX.

Table 79: The effect on relevant indicators by the BAU/PO1b market distribution of A+++ heat pump driers in 2030

BAU percentage of A+++ driers sold in 2030		0%	20%	30%	50%	80%	100%
Total user expenditure [bln. €/year]	BAU	5.97	5.98	**5.99**	6.01	6.04	6.05
	PO1a	6.04	6.04	**6.04**	6.04	6.04	6.04
	PO1b	5.83	5.85	**5.86**	5.88	5.91	5.93
	PO2	5.91	5.91	**5.91**	5.91	5.91	5.91
	PO3	5.97	5.98	**5.99**	6.01	6.04	6.05
	PO4	6.00	6.02	**6.03**	6.04	6.07	6.09
Energy consumption during use [TWh/year]	BAU	10.8	10.7	**10.7**	10.5	10.4	10.2
	PO1a	10.1	10.1	**10.1**	10.1	10.1	10.1
	PO1b	8.8	8.6	**8.5**	8.4	8.1	7.9
	PO2	7.7	7.7	**7.7**	7.7	7.7	7.7
	PO3	10.8	10.7	**10.7**	10.5	10.4	10.2
	PO4	10.9	10.8	**10.7**	10.6	10.4	10.3

Table 80: The effect on relevant indicators by the PO1a/PO2 market distribution of A heat pump driers in 2030

PO1/PO2 percentage of A-class driers sold in 2030		0%	20%	30%	50%
Total user expenditure [bln. €/year]	PO1a	6.02	6.04	**6.04**	6.06
	PO1b	5.86	5.86	**5.86**	5.86
	PO2	5.88	5.90	**5.91**	5.93
Energy consumption during use [TWh/year]	PO1a	10.2	10.1	**10.1**	9.9
	PO1b	8.5	8.5	**8.5**	8.5
	PO2	8.0	7.8	**7.7**	7.6

Table 81: The effect on total user expenditure by the escalation rate in 2030

Escalation rate		0.0%	PRIMES	2.5%	4.0%
Total user expenditure [bln. EUR/year]	BAU	5.78	**5.99**	6.63	7.29
	PO1a	5.85	**6.04**	6.65	7.26
	PO1b	5.69	**5.86**	6.37	6.89
	PO2	5.76	**5.91**	6.38	6.85
	PO3	5.78	**5.99**	6.63	7.29
	PO4	5.81	**6.03**	6.67	7.33

Table 82: The effect on relevant indicators by the penetration rate in 2030

Penetration rate		26.9%	28.3%	30.3%	31.1%
Total user expenditure [bln. €/year]	BAU	5.69	**5.99**	6.41	6.59
	PO1a	5.74	**6.04**	6.47	6.65
	PO1b	5.57	**5.86**	6.27	6.45
	PO2	5.62	**5.91**	6.33	6.50
	PO3	5.69	**5.99**	6.41	6.59
	PO4	5.72	**6.03**	6.45	6.63
Energy consumption during use [TWh/year]	BAU	10.1	**10.7**	11.4	11.7
	PO1a	9.6	**10.1**	10.8	11.1
	PO1b	8.1	**8.5**	9.1	9.4
	PO2	7.3	**7.7**	8.3	8.5
	PO3	10.1	**10.7**	11.4	11.7
	PO4	10.2	**10.7**	11.5	11.8
Total raw material consumption [mt. Raw materials/year]	BAU	294	**309**	331	340
	PO1a	294	**309**	331	340
	PO1b	305	**321**	343	353
	PO2	305	**321**	343	353
	PO3	294	**309**	331	340
	PO4	290	**306**	327	336

Table 83: The effect on the total user expenditure by the added repair and maintenance cost of PO4 in 2030

Added repair cost for PO4 [+€/unit/year]		0	2	4	5	6	8	10
Total user expenditure [bln. €/year]	PO4	5.97	5.99	6.01	**6.03**	6.04	6.06	6.08

Table 84: The effect on total user expenditure and total energy consumption during use by the change in energy consumption due to using programmes other than the standard cotton cycle in 2030

Change in energy consumption due to programmes		+8.0%	+4.0%	+0.0%	-4.0%	-8.0%	-12.0%
Total user expenditure [bln. €/year]	BAU	6.17	6.08	**5.99**	5.90	5.81	5.72
	PO1a	6.22	6.13	**6.04**	5.96	5.87	5.79
	PO1b	6.00	5.93	**5.86**	5.79	5.72	5.64
	PO2	6.04	5.98	**5.91**	5.85	5.78	5.72
	PO4	6.21	6.12	**6.03**	5.93	5.84	5.75
Energy consumption during use [TWh/year]	BAU	11.5	11.3	**11.1**	10.9	10.7	10.4
	PO1a	10.9	10.7	**10.5**	10.3	10.1	9.9
	PO1b	9.2	9.0	**8.9**	8.7	8.5	8.4
	PO2	8.3	8.2	**8.0**	7.9	7.7	7.6
	PO4	11.6	11.4	**11.2**	10.9	10.7	10.5

The results show that the penetration rate of tumble driers in household is by far the parameter that to the largest extent influence and chance the results of the analyses. It directly affects the sales and stock figures which subsequently affect the same way all the parameters. A 10% (e.g. 28.3% → 31.1%) increase in penetration rate of driers in the households roughly corresponds to a 10% increase in the total user expenditure, energy consumption (due to the stock being 10% larger), GHG emissions, and material consumption.

The escalation rate of electricity price is the second most important parameter affecting the total user expenditure. The rate used in the latest studies, PRIMES, corresponds to an average increase in electric price for households at about 0.7% per year. Increasing this rate to 4% (e.g. an almost 470% increase) increases the total user expenditure by an average (across the POs) of 7.3%. The variation between the POs are small (see Table 81), with PO2 being less affected by the escalation rate compared to the other POs as the energy consumption for this policy option is lower.

The market distribution of A+++ heat pump driers in BAU scenario is important for the estimated effect of the proposed energy labelling scheme. Currently it is assumed that 30% of heat pump driers sold in 2030 will be in energy class A+++. Increasing this number effectively increases the assumed progression of the current market and thus reduces the effect the difference between the BAU scenario and PO1a/PO1b/PO2. Increasing the assumed number from 30% to e.g. 80% would reduce the gap in electricity consumption between BAU and PO2 by 0.3 TWh in 2030 (see Table 79). Worth noticing is, that the total user expenditures for BAU exceeds that of PO1a at 80% of higher. This is because a higher market share of A+++ driers would result in higher average acquisition costs and as the energy savings are spread out during the driers lifetime, this means the natural progression of the BAU scenario is thus assumed higher than that of the PO1a scenario.

The share of tumble driers in energy class A in 2030 in the PO1a/PO2 is equally important for total user expenditure and energy consumption during use as it describes the assumed technological progress. Even if the assumed A-label drier distribution is assumed to be 0% the energy consumption during use in 2030 is still lower for PO2 than BAU. This ensures that the currently assumed 30% market share of A driers is not determining any major conclusions, but only the size of the estimated savings potentials.

The added repair and maintenance cost associated with increased lifetime of the driers in PO4 shows that the total user expenditure **in 2030** will be less than BAU only if the added repair and maintenance cost per year is less than 2 EUR/unit/year (for the scenario analyses, this was set as 5 EUR/year for PO4). With an increased value at ~7EUR/unit/year, the user expenditure is expected to be equal to PO1a, and with no changes, it is slightly higher than BAU.

In 2040, where the effect of all the policy options *and* the increased repair cost are easier to fully evaluate, the total user expenditure for PO4 is equal to that of BAU at an added repair cost of ~6.5EUR/unit/year. At 5EUR/unit/year it is equal to PO1a, and at lower than 2EUR/unit/year PO4 shows lower user expenditures than PO2.

The effect of this policy option is thus extremely dependable on the cost of repair and the availability of spare parts, once assessed in a longer timeframe, and these are very important parameters when determining the efficacy of this policy option.

The programmes correction factor is 100% correlated to the energy consumption during use, as this correction factor is a flat percentage applied across all policy options, tumble drier types and years. Imposing a 1% reduction in total energy consumption during use consequently reduces the total user expenditures by ~0.4%. This value varies across the policy options as a reduction in the total energy consumption reduces the incentives to buy more efficient driers up to a point where PO2 is no longer the policy option with the lowest user expenditures in 2030 because the additional cost of the more efficient driers is not countered by the reduction in energy consumption. For the investigated range (+8% to -12% change in the total energy consumption), PO2 still remains the best option regarding user expenditures. For reference, the very limited desktop study conducted in Task 5 concluded that a correction factor of -7.4% annually would be the most reasonable. Using this factor would not change any of the major conclusions.

7.5 Conclusions and recommendations

7.5.1 Policy options

Five policy options have been evaluated based on a number of indicators, three for energy efficiency and two for resource efficiency.

In order to properly evaluate the effect of the policy options, the year 2040 is more relevant as a reference year than 2030. This is due to the long lifetime of household tumble driers (i.e. it takes several years before an effect can be observed in the market). Nevertheless, both 2030 and 2040 are shown and compared as both years are important to consider in this assessment, especially regarding the timeframe of the projected savings.

Table 85 and

Table 86 list the results for some of the indicators discussed in section 7.3.5 and compares the different policy options for 2030 and 2040 respectively. Differences are calculated as the differences between the policy options and BAU. A negative difference thus means a reduction of e.g. energy consumption. Note that all of the savings in 2040 are attributed to base cases 1 and 2, as it is assumed that no air-vented driers will be sold after 2029.

Table 85: Differences of policy options compared to BAU values in 2030 (a negative number means a reduction of the parameter compared to BAU)

Differences compared to BAU, 2030						
	Energy consumption during use [TWh/year]	GHG [mt. CO2 eq./year]	User expenditure [bln. EUR/year]	Retail turnover [bln. EUR/year]	Embedded energy materials [PJ/year]	Jobs
PO1a	-0.61	-0.21	0.05	0.18	-	35
PO1b	-2.14	-0.67	-0.13	0.32	0.09	62
PO2	-2.93	-0.94	-0.08	0.54	0.09	104
PO3	-	-0.07	-	-	-0.18	-
PO4	0.07	-0.11	0.03	-0.04	-0.02	23

Table 86: Differences of policy options compared to BAU values in 2040 (a negative number means a reduction of the parameter compared to BAU)

Differences compared to BAU, 2040						
	Energy consumption during use [TWh/year]	GHG [mt. CO2 eq./year]	User expenditure [bln. EUR/year]	Retail turnover [bln. EUR/year]	Embedded energy materials [PJ/year]	Jobs
PO1a	-1.24	-0.37	-0.09	0.18	-	35
PO1b	-2.38	-0.66	-0.19	0.32	0.09	62
PO2	-3.93	-1.12	-0.30	0.54	0.09	104
PO3	-	-0.09	-	-	-0.18	-
PO4	0.70	0.03	-0.09	-0.56	-0.32	63

The largest savings in energy use, GHG and user expenditure, and the largest increase in retail turnover and jobs, are achieved with PO2. In spite of the initial high cost of consumers' average expenditure (see Figure 101), it is cheaper in the long run because the running costs of heat pump driers are lower than those of element driers, when evaluated over the whole lifetime. This is in spite the heat pump driers are significantly more expensive than the heating element driers. In the contrary, the embedded energy for materials increases for PO2, since heat pump driers use more materials thus more embedded energy than the other driers. In terms of energy efficiency, PO2 shows therefore the most potential savings and increase in turnover and jobs at the lowest costs for consumers.

Regarding resource efficiency, the effect of the two policy options is quite different. PO3, concerning dismantling and recycling presents only GHG emissions and embedded energy savings due to the increased amount of materials sent for reuse and recycling at end-of-life. There is no effect on the other indicators because there is no change in the economic parameters by implementing this policy option. PO4, concerning reparability and durability, presents changes in all parameters. Also, PO4 takes effect differently in 2030 than in 2040 because of the long timeframe evaluated from prolonging the lifetime of the driers and thus using less materials but more energy due to the prolonged presence of older driers on the market. In 2040, consumer expenditure reach net savings and more jobs are generated because of the increased repair activities. Both policy options could be added up and compliment the energy efficiency preferred policy option.

The results from the sensitivity analyses show mostly no significant differences on the effect the evaluated parameters have on each policy option. The evaluated parameters affect all relevant policy options in a similar way and thus they present a good level of robustness. Although the effect of PO4 on user expenditure was found quite dependant on the cost of repair. The penetration and escalation rates create the most significant changes on some of the indicators. However, the observed effects are no more than +/-5%, considering the evaluated parameters intervals. It is thus assessed that the values modelled in the scenario analyses are good representatives of the conditions of the market and are not subject to significant changes on the results. However, the repair costs could be further investigated because of its higher uncertainty and the effect it has on the efficacy of PO4.

7.5.2 Base cases

When looking at the contributions per base case, base cases 1 and 2 (condenser driers) contribute to the largest savings since condenser driers represent the majority on the market of both sales and stock. A trend that will not change in the future. Their relative contributions show that for energy during use and GHG emissions, BC2 is the main source of savings. In some cases, it is BC1 because these products are removed from the market and this creates net reductions. This is the same for total user expenditure.

The contributions from BC3 and BC4 are relatively low since air-vented tumble driers will continue to decrease in sales, and gas-fired products will continue to be a niche product responsible for a very low percentage of the total market. That being said, it is not recommended to exclude them from the current scope as there is no indication they will disappear from the market.

As the gas driers are able to reach the EEI levels of heat pump driers due to the current conversation factor between gas and electricity, they are currently considered quite efficient, and the current models will be able to stay on the market even after imposing the most stringent proposed ecodesign requirements. Excluding them from the scope would not be recommended – even considering the low sales – as they are still considered a good option when replacing a heating element drier. Excluding them would mean removing the energy label from them, and thus making it harder for consumers to identify the real efficiency of a gas-fired drier.

7.5.3 Recommendations

Based on the discussion and analysis throughout the report, the following concrete recommendation are given:

- Change the EEI calculation method from using energy consumption per year, to using energy consumption per cycle.
    - Scale the reference energy consumption per cycle (SEc) according to the available data based on the current technological progress and market share

of each tumble drier type. This will ensure a lower dependency between the rated capacity and the energy consumption per cycle.

- Rescale the energy class intervals from A to G, making sure that:
    - The A class is empty
    - The energy class intervals are placed, as much as possible, evenly so consumers get a better understanding of the differences between classes.
- Rescale the condensation efficiency classes, distributing tumble driers in 4 classes instead of 3, and revise the condensation efficiency requirement to 80% (up from 70%), which would exclude 5% of driers on the market.
- Do not exclude gas fired driers from the scope.
- Change the weighting between full and half-loaded cycles when calculating E_c and T_c to 62% of the rated capacity, instead of the current 71% by changing the calculation formula
- Remove tumble driers from the horizontal standby regulation and add specific standby requirements to the new tumble drier ecodesign regulation. Set proposed maximum consumption levels for low power modes.
- Set ambitious ecodesign limits that ensures that cost effective savings potentials are utilized by removing all heating element driers from the market as they present the largest potential savings.
- Ensure that critical spare parts are available for at least 10 years after the production of a model ceases, to promote a longer average lifetime of the product.
- Technical information on how to disassembly critical components (for repair) and dismantle materials and components (for end-of-life) should be available in booklet/technical documentation.

I. Annex I: Coverage of market data, sales and stock

Coverage

Country	Coverage of GfK data	Population	BNP (bill. EUR)
Austria	90%	8 690 076	349.5
Belgium	88%	11 311 117	421.6
Czech Republic	0%	10 538 275	163.9
Germany	74%	82 175 684	3134.0
Denmark	83%	5 659 715	266.2
Spain	83%	46 445 828	1114.0
Finland	82%	5 487 308	214.1
France	90%	66 759 950	2225.0
Great Britain	95%	65 382 556	2367.0
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	1672.0
Luxembourg	70%	576 249	54.2
Netherland	81%	1 697 9120	697.2
Poland	93%	37 967 209	424.3
Portugal	94%	10 341 330	184.9
Romania	0%	19 760 314	169.6
Sweden	85%	9 851 017	462.4
Slovenia	0%	2 064 188	39.8
Slovakia	0%	5 426 252	81.0
Bulgaria	0%	7 153 784	47.4
Cyprus	0%	848 319	17.9
Latvia	85%	1 968 957	25.0
Lithuania	85%	2 888 558	38.6
Estonia	85%	1 315 944	20.9
Malta	0%	434 403	9.9
Total		**510 221 326**	**14800**
Total coverage	**78.8%**	**402.209.861**	**12247**

Sales data

Tumble drier sales in each category, 1995 to 2030, in thousand units.

Year	HE-C	HP-C	HE-V	GAS-V	Total
1995	2,179	-	1,520	0.9	**3699**
1996	2,273	-	1,586	0.9	**3859**
1997	2,367	-	1,651	1.0	**4019**
1998	2,461	-	1,717	1.0	**4179**
1999	2,556	-	1,783	1.1	**4339**
2000	2,650	-	1,848	1.1	**4499**
2001	2,591	-	1,807	1.1	**4399**
2002	2,175	-	1,734	0.9	**3910**
2003	2,243	-	1,565	0.9	**3809**
2004	2,312	-	1,613	1.0	**3926**
2005	2,380	-	1,661	1.0	**4042**
2006	2,714	11	1,701	1.1	**4427**
2007	2,737	21	1,537	0.6	**4297**
2008	2,707	31	1,356	0.6	**4094**
2009	2,571	38	1,144	0.5	**3753**
2010	2,539	341	1,110	0.6	**3990**
2011	2,385	653	1,022	0.6	**4061**
2012	2,156	947	902	0.7	**4006**
2013	1,927	1,227	782	0.7	**3937**
2014	1,788	1,779	726	0.3	**4293**
2015	1,778	2,222	745	0.4	**4745**
2016	1,747	2,584	720	1.1	**5053**
2017	1,736	2,702	690	1.0	**5129**
2018	1,721	2,820	657	0.9	**5199**
2019	1,704	2,937	623	0.7	**5264**
2020	1,685	3,052	587	0.6	**5324**
2021	1,663	3,166	549	0.5	**5378**
2022	1,638	3,277	511	0.4	**5426**
2023	1,611	3,387	471	0.3	**5469**
2024	1,581	3,493	429	0.1	**5504**
2025	1,549	3,597	387	-	**5534**
2026	1,466	3,777	311	-	**5554**
2027	1,381	3,953	234	-	**5567**
2028	1,293	4,125	156	-	**5574**
2029	1,204	4,292	78	-	**5574**
2030	1,115	4,459	-	-	**5574**

Stock

Calculated stock for all categories, 1995 to 2030, in thousand units.

Year	HE-C	HP-C	HE-V	GAS-V	Total
1995	13,072	-	9,118	5	**22196**
1996	15,342	-	10,702	6	**26050**
1997	17,696	-	12,344	7	**30047**
1998	20,108	-	14,026	8	**34142**
1999	22,518	-	15,707	9	**38234**
2000	24,822	-	17,314	10	**42146**
2001	26,741	-	18,653	11	**45404**
2002	27,826	-	19,627	11	**47464**
2003	28,562	-	20,141	12	**48714**
2004	29,038	-	20,473	12	**49522**
2005	29,376	-	20,709	12	**50097**
2006	29,936	11	20,908	12	**50867**
2007	30,456	33	20,898	12	**51398**
2008	30,885	63	20,665	12	**51625**
2009	31,121	101	20,179	11	**51412**
2010	31,258	442	19,610	11	**51321**
2011	31,191	1,095	18,912	10	**51209**
2012	30,874	2,042	18,070	10	**50996**
2013	30,343	3,269	17,106	10	**50728**
2014	29,710	5,047	16,107	9	**50873**
2015	29,095	7,268	15,160	8	**51531**
2016	28,444	9,849	14,223	9	**52524**
2017	27,736	12,543	13,289	9	**53577**
2018	26,946	15,343	12,369	9	**54667**
2019	26,081	18,233	11,487	9	**55809**
2020	25,174	21,183	10,666	8	**57032**
2021	24,272	24,147	9,923	8	**58350**
2022	23,420	27,062	9,258	8	**59749**
2023	22,655	29,863	8,663	8	**61189**
2024	21,998	32,489	8,124	7	**62619**
2025	21,453	34,891	7,627	7	**63978**
2026	20,952	37,120	7,121	6	**65199**
2027	20,464	39,174	6,588	5	**66231**
2028	19,956	41,081	6,015	5	**67056**
2029	19,400	42,891	5,395	4	**67690**
2030	18,783	44,662	4,727	3	**68175**

II. Annex II: Guidelines supporting the WEEE Directive

The WEEE Directive contains several parts supporting resource efficiency and selective requirements. How the Directive is interpreted and adopted to the member states can vary greatly. Based on WEEE-Directive special articles and annexes are highlighted below to pinpoint which design improvements which could comply with the Directive:

- Article 4, Product design: *"Member States shall, without prejudice to the requirements of Union legislation on the proper functioning of the internal market and on product design, including Directive 2009/125/EC, encourage cooperation between producers and recyclers and measures to promote the design and production of EEE, notably in view of facilitating re-use, dismantling and recovery of WEEE, its components and materials."*
- Article 8, Proper treatment:
    - Member States shall ensure that all separately collected WEEE undergoes proper treatment including the removal of the following components following substances, mixtures and components:
        - Mercury containing components, such as switches or backlighting lamps
        - Batteries
        - Printed circuit boards of mobile phones generally, and of other devices if the surface of the printed circuit board is greater than 10 square centimetres,
        - Plastic containing brominated flame retardants,
        - Chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC) or hydrofluorocarbons (HFC), hydrocarbons (HC),
        - External electric cables,
    - The following components of WEEE that is separately collected have to be treated as indicated:
        - Equipment containing gases that are ozone depleting or have a global warming potential (GWP) above 15, such as those contained in foams and refrigeration circuits: the gases must be properly extracted and properly treated. Ozone-depleting gases must be treated in accordance with Regulation
- Article 15 Information for treatment facilities: *"In order to facilitate the preparation for re-use and the correct and environmentally sound treatment of WEEE, including maintenance, upgrade, refurbishment and recycling, Member States shall take the necessary measures to ensure that producers provide information free of charge*

> *about preparation for re-use and treatment in respect of each type of new EEE placed for the first time on the Union market within one year after the equipment is placed on the market."*

Design for re-use, dismantling and recovery of WEEE all fits in the category of design for repair described in Task 3. The overall purpose of design for repair is to ease the repair process by allowing easy access to critical components. These parts should ideally be easily located and changed if possible. If printed circuit boards are located and removed easily it also fits with the proper treatment definition if this information also are available for the recycling facilities.

III. Annex III; Resources recovered by different types of smelters

In Figure 105 the metal wheel is shown which explains which resources can be recovered by the different smelters. In Table 87 a rough guideline for plastic recyclability is shown.

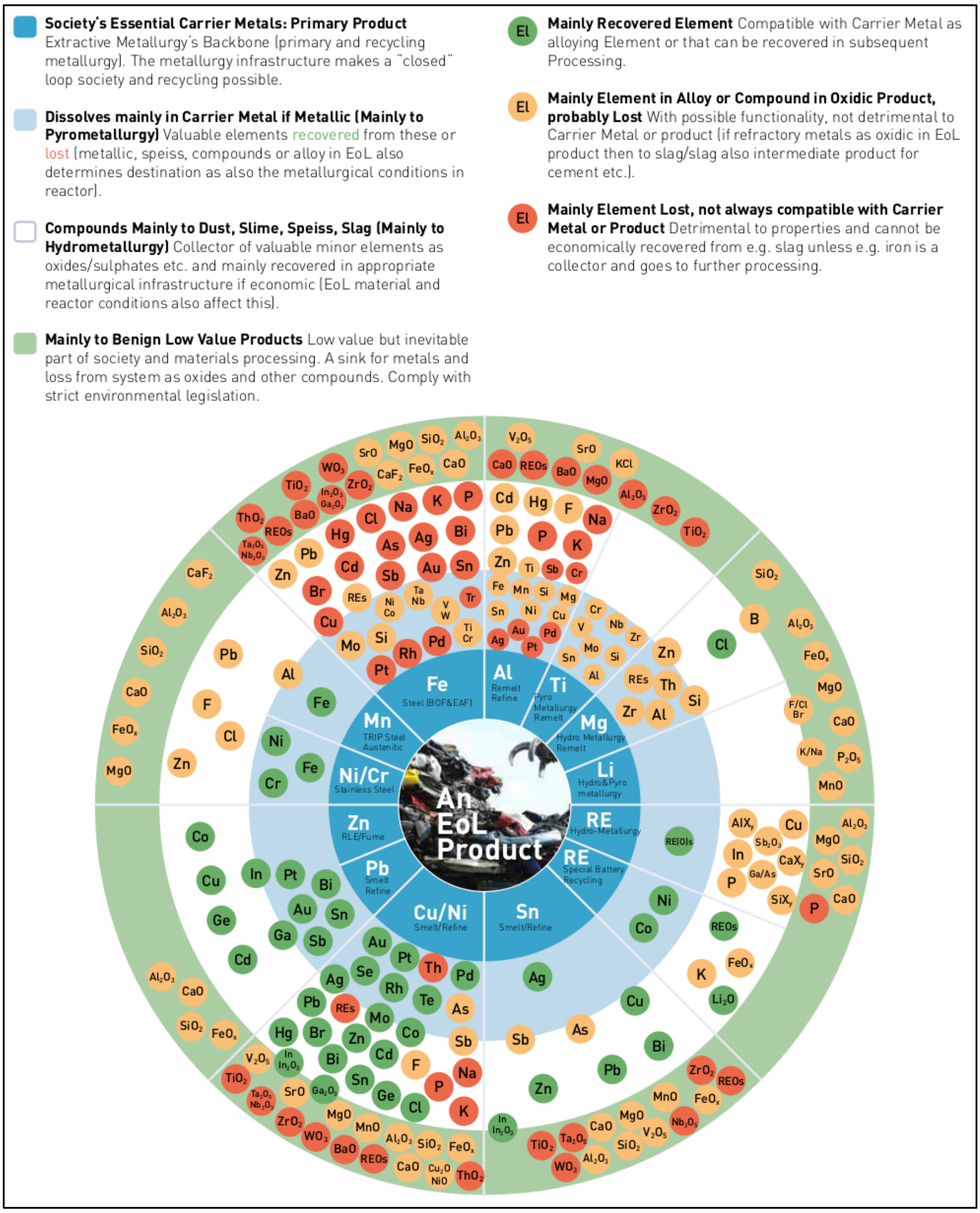

Figure 105: Metal wheel. The metal wheel shows which resources can be recovered by the different types of smelters.[315]

[315] http://wedocs.unep.org/handle/20.500.11822/8423

Table 87: Recycling compatibility of different types of plastic. 1= Compatible, 2 = Compatible with limitations, 3 = Compatible only in small amounts, 4 = Not compatible[316]

Important Plastics	PE	PVC	PS	PC	PP	PA	POM	SAN	ABS	PBTP	PETP	PMMA
PE	1	4	4	4	1	4	4	4	4	4	4	4
PVC	4	1	4	4	4	4	4	1	2	4	4	1
PS	4	4	1	4	4	4	4	4	4	4	4	4
PC	4	3	4	1	4	4	4	1	1	1	1	1
PP	3	4	4	4	1	4	4	4	4	4	4	4
PA	4	4	3	4	4	1	4	4	4	3	3	4
POM	4	4	4	4	4	4	1	4	4	3	4	4
SAN	4	1	4	1	4	4	4	1	1	4	4	1
ABS	4	2	4	1	4	4	3	4	1	3	3	1
PBTP	4	4	4	1	4	3	4	4	3	1	4	4
PETP	4	4	3	1	4	3	4	4	3	4	1	4
PMMA	4	1	3	1	4	4	3	1	1	4	4	1

[316] Chiodo, J., 2005. Design for Disassembly Guidelines. Available at: http://www.activedisassembly.com/strategy/design-for-disassembly/.

IV. Annex IV: Method to calculate refrigerant's Global Warming Potential in EcoReport tool

In the EcoReport Tool inputs, the refrigerant weight is included in the category "various other materials". However, it cannot properly calculate the impacts of refrigerants (or the impacts of leaking). The impact of the refrigerant and leakage are then calculated separately in this review study. The yearly leakage is presented in Table 88.

Table 88: Calculated leakage of refrigerants per year

	Condenser – heat pump
Refrigerant charge	0.38 kg
Annual leakage rate	1 %[317]
GWP	R404 A (GWP 1430)
Average Leakage kg/year	0.0036 kg/year

The leakage of refrigerants during the lifetime of tumble drier is included directly in the EcoReport tool manually, as kg CO_2-eq in the use phase, in the result sheet under the "Life cycle Impact per product". This includes the impact of leakage in all of the results by the EcoReport tool.

Regarding the EU stock, as the leakage rate of older air conditioners in the stock are difficult to determine, the values presented in Table 88 are used for calculating the emission of CO_2-eq of stock as well.

Note that the leakage rate is based on the leakage rate for portable air conditioners. Portable air conditioners are hermetically sealed, which also is the case for tumble driers. The leakage includes use and End-Of-Life.

[317] Based on the leakage rate for portable air conditioners which also are hermetically sealed. Depending on the study, the leakage rate varies from almost zero to above 2%. Hence 1% in chosen for this study.

V. Annex V: Detailed environmental impacts reported by EcoReport tool

The tables below show the environmental impacts for each of the categories in the life cycle phase. The highest impact is highlighted in red. The leakage of refrigerants is not assumed to have any impacts on the energy consumption, but only on the emission of CO_2-eq for BC 1.

- Condensers: 61.7 kg CO_2-eq, responsible for 7 % of the emitted CO_2-eq

The leakage rate is included in all tables below.

Table 89: All impact categories for BC 1- Condensing drier with heating element. 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)	2,674	684	542	27,895	53	-501	31,348
of which, electricity (MJ)	841	409	1	27,877	0	-157	28,972
Water – process (litre)	277	6	0	3	0	-51	235
Water – cooling (litre)	771	191	0	1,246	0	-78	2,130
Waste, non-haz./landfill (g)	10,367	2,293	322	14,465	171	-3,674	23,945
Waste, hazardous/ incinerated (g)	109	0	6	441	0	-12	545
Emissions (Air)							
GWP100 (kg CO_2-eq)	136	38	36	1,191	0	-33	1,369
Acidification (g SO_2-eq.)	857	164	109	5,273	2	-227	6,179
VOC (g)	5	0	8	622	0	-2	634
Persistent Organic Pollutants (ng i-Teq)	195	11	2	67	0	-74	201
Heavy Metals (mg Ni eq.)	304	26	16	285	2	-86	547
PAHs (mg Ni eq.)	232	0	19	67	0	-83	235
Particulate Matter (g)	751	25	1,231	119	16	-225	1,918
Emissions (Water)							
Heavy Metals (mg Hg/20)	252	1	1	122	0	-85	292
Eutrophication (g PO_4)	5	0	0	5	0	-1	10

Table 90: All impact categories for BC 2- Condenser drier with heat pump. 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)	3,753	851	542	11,844	67	-828	16,230
of which, electricity (MJ)	1,075	507	1	11,818	0	-204	13,197
Water – process (litre)	340	7	0	3	0	-63	287
Water – cooling (litre)	928	233	0	534	0	-105	1,591
Waste, non-haz./landfill (g)	11,337	3,021	322	6,198	197	-3,977	17,097

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste							
Waste, hazardous/ incinerated (g)	136	0	6	188	0	-16	313
Emissions (Air)							
GWP100 (kg CO_2-eq)	193	48	36	555	0	-51	781
Acidification (g SO_2-eq.)	1,370	205	109	2,244	3	-397	3,534
VOC (g)	6	0	8	264	0	-2	276
Persistent Organic Pollutants (ng i-Teq)	232	27	2	30	0	-88	203
Heavy Metals (mg Ni eq.)	462	62	16	124	2	-138	529
PAHs (mg Ni eq.)	520	0	19	33	0	-193	379
Particulate Matter (g)	885	32	1,231	56	21	-259	1,966
Emissions (Water)							
Heavy Metals (mg Hg/20)	498	2	1	59	0	-173	384
Eutrophication (g PO_4)	7	0	0	2	1	-1	9

Table 91: All impact categories for BC 3 Air-vented with heating element. 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)	2,322	513	542	29,101	48	-459	32,068
of which, electricity (MJ)	819	307	1	29,086	0	-157	30,056
Water – process (litre)	258	5	0	3	0	-50	215
Water – cooling (litre)	661	143	0	1,299	0	-82	2,021
Waste, non-haz./ landfill (g)	8,709	1,706	322	15,072	149	-3,070	22,888
Waste, hazardous/ incinerated (g)	98	0	6	460	0	-12	551
Emissions (Air)							
GWP100 (kg CO_2-eq)	122	29	36	1,242	0	-30	1,399
Acidification (g SO_2-eq.)	740	123	109	5,500	2	-188	6,286
VOC (g)	5	0	8	649	0	-1	660
Persistent Organic Pollutants (ng i-Teq)	150	7	2	69	0	-57	172
Heavy Metals (mg Ni eq.)	248	17	16	296	2	-64	515
PAHs (mg Ni eq.)	221	0	19	70	0	-80	230
Particulate Matter (g)	677	19	1,231	123	16	-198	1,869
Emissions (Water)							
Heavy Metals (mg Hg/20)	205	1	1	127	0	-65	268
Eutrophication (g PO_4)	5	0	0	6	0	-1	10

Table 92: All impact categories for BC 4 Air-vented gas fired. 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)	2,322	513	542	7,141	48	-459	10,108
of which, electricity (MJ)	819	307	1	1,579	0	-157	2,549
Water – process (litre)	258	5	0	-76	0	-50	137

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste							
Water – cooling (litre)	661	143	0	76	0	-82	799
Waste, non-haz./ landfill (g)	8,709	1,706	322	897	149	-3,070	8,713
Waste, hazardous/ incinerated (g)	98	0	6	26	0	-12	117
Emissions (Air)							
GWP100 (kg CO_2-eq)	122	29	36	375	0	-30	532
Acidification (g SO_2-eq.)	740	123	109	393	2	-188	1,180
VOC (g)	5	0	8	39	0	-1	50
Persistent Organic Pollutants (ng i-Teq)	150	7	2	5	0	-57	108
Heavy Metals (mg Ni eq.)	248	17	16	18	2	-64	237
PAHs (mg Ni eq.)	221	0	19	6	0	-80	166
Particulate Matter (g)	677	19	1,231	15	16	-198	1,760
Emissions (Water)							
Heavy Metals (mg Hg/20)	205	1	1	9	0	-65	150
Eutrophication (g PO_4)	5	0	0	0	0	-1	5

VI. Annex VI: Aggregated environmental impacts reported by EcoReport tool

Table 93: Environmental impacts during the entire lifetime of tumble driers sold in 2017

Materials	BC1	BC2	BC3	BC4	Total
Bulk Plastics (kt)	22.40	35.86	6.42	0.01	64.69
TecPlastics (kt)	1.19	3.10	0.62	0.00	4.91
Ferro (kt)	46.01	64.27	14.70	0.02	124.99
Non-ferro (kt)	7.32	25.57	1.90	0.00	34.79
Electronics (kt)	0.71	1.35	0.28	0.00	2.34
Misc. (kt)	82.52	148.47	25.84	0.04	256.87
Total weight (kt)	22.40	35.86	6.42	0.01	64.69
Other resources & waste					
Total Energy (PJ)	58.40	44.01	22.12	0.01	124.55
of which, electricity (PJ)	54.24	36.19	20.73	0.00	111.17
Water (process) (mln.m^3)	0.41	0.74	0.15	0.00	1.30
Water (cooling) (mln.m^3)	3.88	4.20	1.39	0.00	9.48
Waste, non-haz./ landfill* (kt)	43.73	45.21	15.79	0.01	104.74
Waste, hazardous/ incinerated* (kt)	1.01	0.84	0.38	0.00	2.23
Emissions (Air)					
GWP100 (mt CO_2-eq.)	2.55	2.11	0.97	0.00	5.62
Acidifying agents (AP) (kt SO_2-eq.)	11.48	9.52	4.34	0.00	25.34
Volatile Org. Compounds (kt)	1.19	0.76	0.46	0.00	2.40
Persistent Org. Pollutants (g i-Teq.)	0.36	0.53	0.12	0.00	1.01
Heavy Metals (ton Ni eq.)	0.99	1.39	0.36	0.00	2.73
PAHs (ton Ni eq.)	0.42	0.98	0.16	0.00	1.56
Particulate Matter (kt)	3.37	5.08	1.29	0.00	9.74
Emissions (Water)					
Heavy Metals (ton Hg/20)	0.53	1.00	0.19	0.00	1.71
Eutrophication (kt PO_4)	0.02	0.02	0.01	0.00	0.05

Table 94: Environmental impacts of tumble driers (EU-28 stock - 2016)

Materials	BC1	BC2	BC3	BC4	Total
Plastics (Mt)	22.40	35.86	6.42	0.01	64.69
Ferrous metals (Mt)	46.01	64.27	14.70	0.02	124.99
Non-ferrous metals (Mt)	7.32	25.57	1.90	0.00	34.79
Other resources & waste					
Total Energy (PJ)	81.09	32.14	36.82	0.01	150.05
of which, electricity (TWh)	76.41	22.90	35.25	0.00	134.56
Water (process)* (mln.m^3)	0.50	0.90	0.18	0.00	1.59
Waste, non-haz./ landfill* (Mt)	61.21	47.73	25.27	0.01	134.23
Waste, hazardous/ incinerated* (kton)	1.38	0.67	0.62	0.00	2.66
Emissions (Air)					
GWP100 (mt CO2-eq.)	3.54	1.59	1.60	0.00	6.73
Acidifying agents (AP) (kt SO2eq.)	16.01	7.92	7.19	0.00	31.12
Volatile Org. Compounds (kt)	1.68	0.46	0.78	0.00	2.91
Persistent Org. Pollutants (g i-Teq.)	0.54	0.72	0.19	0.00	1.45
Heavy Metals (ton Ni eq.)	1.36	1.59	0.55	0.00	3.50
PAHs (ton Ni eq.)	0.62	1.44	0.25	0.00	2.31
Particulate Matter (kt)	3.83	5.63	1.48	0.00	10.94
Emissions (Water)					
Heavy Metals (ton Hg/20)	0.77	1.38	0.29	0.00	0.77
Eutrophication (kt PO_4)	0.02	0.02	0.01	0.00	0.02

Table 95: Environmental impact share of EU total impacts (EU-27 stock)

Materials	BC1	BC2	BC3	BC4	Total
Plastics (Mt)	0.05%	0.08%	0.01%	0.00%	0.15%
Ferrous metals (Mt)	0.02%	0.03%	0.01%	0.00%	0.06%
Non-ferrous metals (Mt)	0.04%	0.13%	0.01%	0.00%	0.18%
Other resources & waste					
Total Energy (PJ)	0.11%	0.04%	0.05%	0.00%	0.20%
of which, electricity (TWh)	0.30%	0.09%	0.14%	0.00%	0.53%
Water (process)* (mln.m^3)	0.00%	0.00%	0.00%	0.00%	0.00%
Waste, non-haz./ landfill* (Mt)	0.00%	0.00%	0.00%	0.00%	0.00%
Waste, hazardous/ incinerated* (kton)	0.00%	0.00%	0.00%	0.00%	0.00%
Emissions (Air)					
GWP100 (mt CO_2-eq.)	0.07%	0.03%	0.03%	0.00%	0.13%
Acidifying agents (AP) (kt SO_2-eq.)	0.07%	0.04%	0.03%	0.00%	0.14%
Volatile Org. Compounds (kt)	0.02%	0.01%	0.01%	0.00%	0.03%
Persistent Org. Pollutants (g i-Teq.)	0.02%	0.03%	0.01%	0.00%	0.07%
Heavy Metals (ton Ni eq.)	0.02%	0.03%	0.01%	0.00%	0.06%
PAHs (ton Ni eq.)	0.05%	0.11%	0.02%	0.00%	0.17%
Particulate Matter (kt)	0.11%	0.16%	0.04%	0.00%	0.31%
Emissions (Water)					
Heavy Metals (ton Hg/20)	0.01%	0.01%	0.00%	0.00%	0.02%
Eutrophication (kt PO_4)	0.00%	0.00%	0.00%	0.00%	0.01%

VII. Annex VII: Stakeholders comments after first stakeholders meeting on draft interim report

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		31	Air vented tumble drier	Modification of the sentence needed for clarification: **Air-vented tumble drier** means a tumble drier that draws in fresh air, passes it over the textiles and vents the resulting moist air into the room or outside.	**Air-vented tumble drier** means a tumble drier that draws in fresh air, heats it up and passes it over the textiles and vents the resulting moist air into the room or outside.	Changed in report
	1	32	Left-on mode	Definitions are partly conflicting. We would like to ask that a clear definition of left on mode is provided, it should be corrected in order to be in line with other requirements.	Use the same definition as for WM but take into account the dewrinkling phase of TD. The left on mode starts after completion of any option that has been selected by the consumer.	Definitions in task 1 are those presented in the regulations. Definitions are proposed to be aligned with Washing Machines Working Documents. This has been briefly touched in task 7.
	1	General	Standby requirements	For WM, DW and WD, some of the standby requirements are in the vertical regulation. As the standby regulation is being revised, what will be the approach for TD? Will they be excluded from the horizontal regulation to be dealt with vertically?	Standby horizontal regulation is valid only for the current regulation on TD. If there is a new horizontal standby regulation, TD should be excluded from the horizontal standby regulation as DW and WM as soon as the new TD regulation enters into force.	These requirements are proposed to be aligned with Washing Machines', which are not less ambitious than those in the Standby Regulation. See section 7.2.3.
	1	39	Calculation method for energy consumption	"…where there are three different tumble driers labels for air-vented, condenser and gas-fired household tumble driers respectively and there is a different calculation methodology for energy consumption of each types."	**"…**where there are three different tumble driers labels for air-vented, condenser and gas-fired household tumble driers respectively and there is a	Changed in report

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					different calculation methodology for energy efficiency of each types."	
	1	40	Review of relevant legislation - EU Directive 2009/125/EC – Ecodesign for Energy-Related Products	- From 1 November 2013, for all household tumble driers: o The energy efficiency index (EEI) shall be < 85 - From 1 November 2015, for condenser household tumble driers: o The energy efficiency index (EEI) shall be < 76 o The weighted condensation efficiency shall be ≥ 70 %	- From 1 November 2013, for all household tumble driers: o The energy efficiency index (EEI) shall be < 85 o The weighted condensation efficiency shall be ≥ 60 % - From 1 November 2015, for condenser household tumble driers: o The energy efficiency index (EEI) shall be < 76 o The weighted condensation efficiency shall be ≥ 70 %	Changed in report
	1	40	Review of relevant legislation - EU Directive 2009/125/EC – Ecodesign for Energy-Related Products	"This cycle shall be clearly identifiable on the programme selecting device as the "Standard cotton programme" (Can be done with a symbol, or a combination hereof)."	"This cycle shall be clearly identifiable on the programme selecting device as the "Standard cotton programme" (Can be done with a symbol, or a combination hereof).*add reference to the publication in OJEU*"	Not clear. To be clarified with stakeholder.
	1	42	Reference to motors inside TD	In general, double regulation should be avoided. We should avoid regulation on components of products already regulated.	The TD regulation should indicate that motors that are part of TD should be excluded from the scope of the motor regulation if	The study team does not agree with this statement. Motor technologies in TDs vary, and

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					they are not already excluded in the motor regulation itself.	motor regulation covers the motor, tumble drier regulation the entire product. Risk of loop hole if motors in TD are excluded from motor regulation.
	1	53	Nordic Ecolabelling of White Goods	We do not know much about the Nordic Ecolabelling of White Goods	Could you please add the reference?	To be done in next version of report
	1	56	Measurement and performance standards EN 61121:2013 Tumble Driers for household use – methods for measuring the performance (Modified from IEC 61121:2012)	"The more recent AEc calculation method, in comparison to what defined in the Ecodesign and Energy Labelling Regulations for tumble driers, results in lower AEc for driers with power management systems that automatically switches the tumble drier to off-mode post cycle." The formula given in the standard results in higher energy consumption than the formulas given in the regulation.	"The more recent AEc calculation method, in comparison to what defined in the Ecodesign and Energy Labelling Regulations for tumble driers, results in higher AEc for driers with power management systems that automatically switches the tumble drier to off-mode post cycle."	Deleted as it was not relevant.
	1	57	Measurement and performance standards EN 61121:2013 Tumble Driers for household use – methods for	"The testing sequence is generally very thorough, and the overall procedure is to run a drying sequence until 5 valid runs are achieved. The mean value of these runs is then used as the final figure. The validity of the sequence is based on the final moisture content in laundry. The laundry used is cotton with 60% humidity, and the final moisture	CENELEC will provide a proposal for a correct reformulation.	To follow-up with CENELEC

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			measuring the performance (Modified from IEC 61121:2012)	level is either 0% (bone dry), 12% (iron ready), or 2% (Synthetic/blends textiles). The programme used is determined before the test series. The selected programme is used for all 5 testing runs." This wording is not correct		
	1	58	Measurement and performance standards EN 61121:2013 Tumble Driers for household use – methods for measuring the performance (Modified from IEC 61121:2012)	"The manufacturers can hence optimize their units for reference water properties, without considering the effect on the "real" water quality throughout the EU." APPLiA does not agree with that statement, manufacturers try to satisfy the need of their consumers, therefore, the appliances offer the possibility to adjust the settings to the local needs.	We propose to delete that statement.	We have altered the statement, but not remove it, as it is an important factor.
	1	70	Standard ONR 192102	"Standard ONR 192102 is an Austrian standard that establishes a label for electronic products designed for easy repair."	See APPLiA's position paper on the Analysis and development of a scoring system on reparability. 2018-05-07 APPLiA comments on Scorin	Comments considered in task 7
	2	73	Sales split and market shares, Table 8: Household tumble drier sales	It is mentioned that "The total sales increased on average 1.6% per year from 2013 to 2016…"	Please double check the calculations	The 1.6% increase is on average from 2007 to 2016, not 2013 to 2016. A decrease in 2008/2009 results in a low overall average.

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			in Europe 2013-2016, source: GfK (adjusted to EU28)	Data in table 8 shows that such increase is not correct and is underestimated. This should be corrected.		We have updated the report with the correct values.
	2	73	Sales split and market shares, Table 8: Household tumble drier sales in Europe 2013-2016, source: GfK (adjusted to EU28)	"The data shows that the heat pump technology during the four years has become the prevalent in the EU with the market share increasing from 31% in 2013 to 51% 2016. This has been at the expense of the electric heat element tumble driers, both the condenser and the air-vented type." This statement is not fully correct, we see that the heat pump market share has indeed increased but so has the market. It is therefore not correct to mention that it is at the expense of condenser and vented drier as the absolute numbers of sales have not much decreased.		The penetration rate shows the market hasn't grown much. The overall sales have increased, but so have the number of households throughout EU28. It thus may be a combination. Also, people might be more prone to replacing their old drier because of the heat pump technology. As the HP market have increased, and the others have decreased, is still considered a fair assumption.
	2	74	Sales split and market shares, Table 10: Derived tumble drier sales from 1990 to 2030	Table 10: Data for 1990, 1995 and 2000 are not correct. In the text, the assumption is made that the market share should be the same as in 2005. However, the data in the table are not in line with this assumption. This leads to calculations errors in the following analysis.	Please double check the calculations	The text is wrong – calculations are based on available data from the prep. Study /IA. We have changed text in report.
	2	74	Sales split and market shares, Table 9: Market shares of the four	Table 9 does not provide the full picture due to the years taken into account. In reality, the increase of heat pump market share really started in 2008/2009, not in 2005.		Table is not wrong, just with a low temporal resolution due to space considerations.

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			main tumble drier technologies			
	2	Generic		PRODCOM data do not differentiate between WM and TD as from 2010. Therefore, we do not believe that it is useful to use them in the context of this report.	We suggest not to use PRODCOM data for this report.	We have only used PRODCOM data from before 2000, as no other data was available. It has however not been used to draw any conclusions.
	2	76	Tumble drier stock, table 14, Stock of tumble driers in EU from 2000 to 2030	Table 14: Stock of tumble driers in EU from 2000 to 2030: numbers cannot be correct as they have been calculated with wrong numbers from table 10.		See comments to previous questions regarding stock calculations.
	2	79	Product trends, Figure 10: Energy class distribution and development for heat element air-vented tumble driers, 2013-2016	Figure 10: Energy class distribution and development for heat element air-vented tumble driers, 2013-2016 We question the data for that table. Indeed, it should be checked whether market share for B class heat element air vented are not overestimated. Also, it seems overestimated that market share for D class is 7% as this class has been phased out since 2013.		The study team have doublechecked the data, and the figure is correct and only visualising GfK data. The D class might be due to old stock, or inaccurate data. B class seems reasonable, as several driers exist on the market with a B class energy label.
		80, 81, 82	Product trends, Figures 11, 12 and 13	Could you please specify the rated capacity and take that differentiation into account in the graphs? Otherwise, there is a risk that the graphs are misleading the analysis. Could you please specify the sources for these data?	Please update the graphs taking into account the rated capacity of the appliances, and to revise the related findings.	The data from GfK cannot be disaggregated in terms of capacity and energy consumption, and the correlations can thus not be made. The raw data would be needed in order to do this

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						calculation, which GfK is not able to present. A specific AEc based on APPLiA model database can be seen in Task 4.
	2	81	Product trends, Figure 12: Distribution of annual energy consumption for heat element condenser tumble driers from 2013 to 2016	There is no technology with conventional heating element able to reach class A. Condensing drier have a minimum energy consumption of 400 KWh. According to the APPLiA database, there is no model with a rated capacity of below 6kg on the market.	Please check the correctness of the data, charts and associated calculations.	The figure is only presenting values from GfK without modifications. It might be due to manufacturers not a member of APPLiA being able to produce these machines.
	2	82	Product trends	"Even though both tumble drier types equipped with heating elements showed an increase in annual energy consumption, it might not be because of a general reduction in energy efficiencies. The annual energy efficiency is calculated based on the rated capacity (see section 3.1 for details on calculating the AEc), which on average is increasing (cf. Figure 22) and is thus influencing the depicted AEc distributions. Figure 8, Figure 9, and Figure 10 show that all drier types have improved in energy efficiency from 2013 to 2016, so the increase in AEc thus originates from the increase in capacity, which is larger than the increase in energy efficiency."	This paragraph should highlight that the current label is somehow misleading on the annual energy consumption.	AEc is also important since it shows the calculated absolute energy consumption, disregard less of their energy efficiency, which is also important. We can't conclude the label is misleading in task 2, as this is due to the consumer behaviour, and not product trends.

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				This paragraph shows that the display of the annual energy consumption currently on the label is misleading due to the fact that the relation to the rated capacity is missing.		
	2	83	Product trends	"Both technologies have a high market share of products for which the condensation efficiency is not declared according to GfK data", this is probably due to the collection of GFK data. The condensation efficiency is very likely declared correctly.	Please check the correctness of the data, charts and associated calculations.	The study team is only presenting the available GfK data, which unfortunately is incomplete. We cannot fix this, as more data are not available.
	2	89-90	Product trends, figure 23 to 26	Figure 23 to figure 26: same comment as above. The number of "non-declared" appliances is extremely high. Such proportion of not declared does not seem realistic to us. Could you please explain the reason why or correct the data?	Please check the correctness of the data, charts and associated calculations.	The study team is only presenting the available GfK data, which unfortunately is incomplete. We cannot fix this, as the data is not available.
	2	89	Product trends, figure 23 to 26	Figures 23 to 26 related to the cycle time should here again take into account the rated capacity in order to be relevant.	Please consider adding the relation with rated capacity for figure 23 to 26	We do not have access to this level of data.
	2	91-93	Product trends, Figure 27-30	Figure 27-30: the share of appliances having noise above 66db seems extremely high, according to APPLiA database, (e.g. only 17 models out of 105 air vented driers show a sound power level above 66db..)	Please double check these data.	Figure is correct and only displaying available data. Note data is from 2013-2016, and not only from 2016/2017.
	2	91-93	Product trends, Figure 27-30	Figure 27 to 30: Similar comment to the one above concerning the percentage of non-declared values. The number of "non-declared" appliances is extremely high. Such proportion of not declared	Please check the correctness of the data, charts and associated calculations.	The study team is only presenting the available GfK data, which unfortunately is lacking in quality. We cannot fix this, as the data is not available.

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				does not seem realistic to us. Could you please explain the reason why or correct the data?		
	2	94	Product trends, Figure 31	Figure 31 – the graph needs to be corrected since it is based on wrong sales and stock numbers (cf. comment above)	Please check the correctness of the data, charts and associated calculations.	Figure is correct. Stock from pre-2002 is not used due to a 12-year lifetime either way.
	2	94	Market channels and production structure	"The market for household tumble driers is characterised by a large number of manufacturers. Major players include, but is not limited to, BSH, Miele, LG Electronics, Samsung, Whirlpool, AEG, Electrolux, Candy, Gorenje, Vestel, and Whiteknight." Arçelik should also be mentioned as a major market player. AEG should also be removed as it is a brand part of Electrolux.	"The market for household tumble driers is characterised by a large number of manufacturers. Major players include, but is not limited to, Arçelik, BSH, Miele, LG Electronics, Samsung, Whirlpool, ~~AEG~~, Electrolux, Candy, Gorenje, Vestel, and Whiteknight."	Changed in report
	2	95	Consumer purchase price, table 15	Table 15: Could you please verify the values of that table? Could Gfk please also mention the source of where these prices were taken from?		GfK provide total market value (actual purchase price) across Europe. The EU coverage is 85%.
	2	97	Electricity and gas prices, table 17	Could you please specify the geographical scope of these average numbers? Could you explain why do you not use the weighted average based on country population? Why do you not use the specific values per country as part of the analysis?		We follow the MEErP and use average values. Specific values would be to comprehensive in task 5, task 6 and task 7 and different LLCC options may appear.

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	2	97	Electricity and gas prices, table 17	Is the linear extrapolation to determine future prices (and other future parameters) defined by the Meerp methodology or does it come from a motivated choice? If it is the latter, could you please provide the rationale behind?		The commission have discussed how to apply more realistic projections of the electricity prices. The commission have decided to use data from PRIMES. The PRIMES data has a lower annual increase in electricity costs and it includes future projections.
	2	98	Repair and maintenance costs, Table 18: Average total labour costs for repair services in EUR per hour	The net labour cost is not the only cost factor influencing the consumer willingness to repair. It includes also overhead costs, transport costs, etc. The consumer is in fine charged with a much higher value than what is presented in table 18.		Corrected in report
	3	109	Loading of the drier	"The real drying average load is hence assumed to be somewhere between 3.2kg - 5.3kg, based on the P&G and APPLiA study respectively, as they consist of the newest available data." P&G study does not provide any data on the drying average, as far as we are aware, this study was only related to WM. Concerning the APPLiA study, the average load seems indeed quite high. Among the reasons that could explain such high number is the fact that the		The difference in household size between washing machines studies[318] and the APPLiA survey is 0.1 persons/households and is thus not considered significant. The laundry behaviour is thus considered to be somewhat alike. 4.4kg is used throughout the other task of the study, as this is the load one gets when using cycles/week, total households,

[318] Kruschwitz, A.; Karle, A.; Schmitz, A. & Stamminger, R. (2014). Consumer laundry practices in Germany. International Journal of Consumer Studies, 38(3), pp. 265–277.

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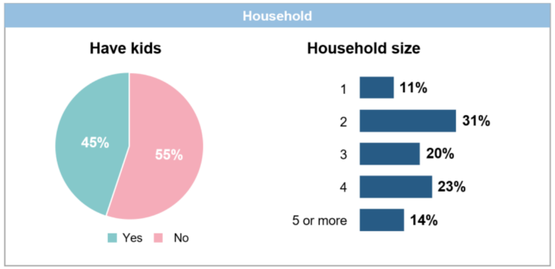
				study was conducted only on households owning a TD: Households owning a tumble drier are on average larger than households owning only a washing machine. This could explain why the respondents of the tumble drier study fill their TD significantly more. The study indeed shows that the size of the households was significantly higher for the TD study (Figure 1) than for the consumer study conducted for WM (Figure 2). Figure 1 – Household repartition for TD study  Figure 2 – Households repartition for WM study:		and average capacity to calculate the load.
	3	111	Conclusion	"The current testing procedures at full and half load conditions can hence be used as a comparative tool between products but is unlikely to represent the real annual energy consumption for the average user, and less so in the future with		Currently, based on the APPLiA study, the loading is about 62% (Based on a 4.4kg average load – which might be too high – and 7.1kg rated capacity), while the

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				foreseen increasingly large capacity driers on the market.” The present test conditions very well represent the consumer load. Indeed, the average rated capacity found by Insites Consulting study is 7,1Kg. The average consumer load found in this same study is between 4.0Kg and 4.9Kg which is in line with the weighted test load of 5Kg defined by the regulation for a 7kg machine.		loading from the regulation is about 71%. The washing machine studies showed no correlation between the rated capacity and loading %. As the machines is getting larger, the loading % is thus expected to fall and deviate more-and-more from the current regulation testing method.
	3	112	Conclusion	“Using the average number of drying cycles/week/household of 1.7 / 2.4 for summer and winter times respectively, this gives an average of 107 cycles/year.” Since the regulation requires to calculate the annual energy consumption based on 160 cycles, the results are overestimating the real annual energy consumption by above 50%. The real annual energy consumption will therefore likely be lower on average than indicated on the label.		We agree – the calculation is made exactly to prove this point.
	3	112	Impacts of tumble driers on secondary energy systems	“Driers with heating elements have generally lower condensation efficiency compared to driers with heat pumps: 91% of heat pump driers sold in 2016 had condensation efficiency labels B or better, while only 47.2% of driers with heating elements achieved this.”	Please check again the data and related calculations	Added note that the data might be inaccurate. 47.2% is based on the available data. Datapoints with condensation efficiency listed as “unreported” is thus not taken into account here.

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				This last number (47,2%) does not seem realistic. This is due to the incomplete collection of market data made by Gfk (cf. comment above).		
	3	115	Condensing driers with heating element	"The ambient temperature affects the energy consumption of the drier, with a high ambient temperature increasing the energy consumption of the drier due to the dew point being directly related to the temperature." This statement is not correct for condensing drier with heating element; due to higher ambient temperature, the heating element is switching on and off and therefore does not affect the total energy consumption. Only the drying duration is increased.		Longer cycle times means more energy is used in the fan/drum motor (as this is on the whole duration). Furthermore, longer cycle times result in more heat loss to the ambient, and lower condensation efficiency as it results in more time for the moist air to escape. The added energy consumption this might be small, but it is not zero.
	3	118	Durability and lifetime	Table 25: "The term "lifetime" used in the current study must be understood as the period (i.e. the number of years) during which the appliance is used and consumes electricity ("actual time to disposal"). Therefore, it is a value included between the social lifetime and the design lifetime." APPLiA disagrees with that approach. In our opinion, the concept of social lifetime does not apply to tumble driers as it is a rather stable		We are aiming at the actual life time at consumers which are a little longer than the design lifetime. No change

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				product not that much subject to fashion. Therefore, the concept of lifetime should be at minimum referring to the design lifetime or longer.		
	3	119	Durability and lifetime	"Based on the German study the share of people exchanging a functional machine with a new model is increasing from 12 % in 2004 to 19 % in 2012. This tendency may be due to increased efficiency of tumble driers or new functions such as network capabilities (controlled by e.g. a smartphone) or the purchase of combined washer/driers" It is not possible that **network capabilities** influenced the purchase of TD back in 2012 as this function hardly existed at that time.		Corrected in report
	3	119	Durability and lifetime	"For all large household appliances, it should also be noted that the proportion of appliances that were replaced in less than 5 years due to a defect increased from 3.5% to 8.3% between 2004 and 2012." Could you please indicate the source for this statement?		Source added in the report - Umwelt Bundesamt
	3	120	Durability and lifetime, figure 41	Figure 41: age of TD vs "The experienced lifetime of tumble driers are investigated by APPLiA and the results of the survey are presented in" The figure shows the current age of TD. However, it does not allow to draw conclusions on the lifetime of the appliances, especially not for heat		Corrected in report

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				pump tumble driers as this technology has been introduced only over the last few years.		
	3	128	Best practice in sustainable use	"As discussed previously, it is important to purchase a properly sized tumble drier and not buying it oversized. This may result in operation at part load, which increases the specific energy consumption (see section 3.1.1). According to presented data in this section, consumers load the machines similarly regardless of the capacity. Consumers may buy large appliances for the convenience if they want to dry large blankets resulting in operation with a low load most of the year. It is also important to spin the clothes properly in the washing machine as it is less energy intensive to spin the clothes in the washing machine than to dry it in the tumble drier." This statement is not correct. Based on APPLiA model database, the energy consumption for a household load of 4.00Kg is rather stable independently from the rated capacity of the machine.		We can only estimate efficiency based on partial loads (which is always 50% of rated capacity in this case), not specific loads. We hence can't compare machines at different rated capacities at a specific load (e.g. 4kg) from the model database. The APPLiA model database hence can't be used to evaluate this.
	3	128	Best practice in sustainable use	"Use a lower heat setting than, e.g. cupboard dry, if the clothes have anyway to be ironed afterwards."	"Use a lower dryness level than, e.g. cupboard dry, if the clothes have anyway to be ironed afterwards."	Corrected in report

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	3	128	Best practice in sustainable use	"Use the moisture sensor if it is available to avoid over drying."	"Use the moisture sensor ~~if it is available~~ to avoid over drying." Automatic sensor is available in most cases.	It is available in most cases, but not all. Driers exist on the market without moisture sensors.
	3	131	Local infrastructure Electricity	"In 2015 the share of renewable energy was almost 17%" This does not seem correct compared to the figure below that indicates "Almost half of the electricity generation still originates from combustible fuels (such as natural gas, coal and oil) and renewable energy sources only constitutes about 25 % of the electricity generation in 2015." This should be clarified.		In 2015 the share of renewable energy was almost 17% regarding gross final energy consumption. The figure below presents the electricity mix
	3	136	Verification tolerances	"*The study team is waiting for a round-robin test to be finished by March/April.*" Unfortunately, the results of the RRT is being delayed due to unforeseen issues with the transportation and test timing. The results will likely be available in August 2018.		The study team has not yet received the final report from APPLiA on this matter.
	4	137	Technologies	"No major technical improvements at product level have emerged on the market for tumble driers since the preparatory study."		Sentence modified

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				We tend to disagree with that statement; indeed, since the last preparatory study, heat pump driers' energy efficiency has increased by 25%.		
	4	140	Controller for all drier types	"Eco-mode programs are available on some driers, where an increased cycle time can result in lower energy consumptions. This is advantageous if the cycle time is unimportant for the customer. The increased cycle time is done by lowering the drying temperature by throttling the heat pump unit or the heating element." This statement is not correct, according to the Ecodesign regulation 932/2012, the standard cotton programme needs to be the most efficient programme available on the machine. Having such eco mode programme is not possible.		Deleted from report
	4	142	Filters for all drier types	"Filters for all drier types The lint filters act as a protective screen against lint-build up in the machine. Clogged filters reduce the process air flow, which reduces the drying efficiency. This effect is present as soon as the cycle starts, and thus marginally increases energy consumption during the cycle147. Designing filters less prone to clogging, or simply with better flow characteristics, reduces this effect and is thus advantageous to the energy efficiency."		This has been investigated further based on input provided by different stakeholders. See section 4.1.1 for conclusions.

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				This statement is not correct for conventional condenser drier where the efficiency is affected only on a very low level.		

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		16	BAT: Eco mode program	Corresponding to the EC directive 932/2012 the standard cotton program shall be the most efficient program to dry standard cotton load. Thus an 'eco mode program' cannot be more efficient and this BAT option is not given.	Delete 'Eco mode program' from BAT	Deleted
		33/34	Footnotes 33/34	The copies of the footnotes are not complete as given in EN61121:2013. They are part of the standard, thus should not be implemented as footnote into the report but as citation into the text.	Copy the notes of the standard as complete text into the text body of the report.	Section deleted
	1	40	If the drier is automatic, this this cycle should be used automatic	"If the drier is automatic, this this cycle should be used automatic " That is not clear, as there are automatic controlled driers that do not preselect the cycle at switch on.	"If the program is selected automatically with switching on the drier, then the standard cotton cycle shall be preselected at switch on automatically."	Changed
	1	41	Tolerances accepted	"The tolerance-levels determined in Regulation 932/2012 for the purpose of verification of compliance, are set to 6% for all parameters listed in the Regulation."		Corrected

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				For left-on-mode and off mode power consumption below 1W the tolerances are set to 0.1 W		
	1	57	Test runs	"The testing sequence is generally very thorough, and the overall procedure is to run a drying sequence until 5 valid runs are achieved. The mean value of these runs is then used as the final figure. The validity of the sequence is based on the final moisture content in laundry. The laundry used is cotton with 60% humidity, and the final moisture level is either 0% (bone dry), 12% (iron ready), or 2% (Synthetic/blends textiles). The programme used is determined before the test series. The selected programme is used for all 5 testing runs." The testing sequence for energy label concentrates on the cotton <u>regular</u> dry (0%) program with 7 test runs representing 5 times the full load.	Rephrase the whole clause: "The testing sequence EN 61121:2013 is based on that one given in the standard IEC 61121:2012 but modified with respect to reflecting the requirements of the European regulations EC 392/2012 on energy labelling of household tumble driers and EC 932/2012 on ecodesign requirements of household tumble driers. The testing sequence according IEC 61121:2012 is generally very thorough, and the overall procedure is to run a drying sequence until 5 valid runs are achieved. The mean value of these runs is then used as the final figure. The validity of the sequence is based on the final moisture content in laundry. The laundry used is cotton with 60% initial humidity or synthetics with	Replaced

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					50% initial moisture, and the final moisture level is either 0% (cupboard dry), 12% (iron ready), or 2% (Synthetic/blends textiles). The programme used is determined before the test series. The selected programme is used for all 5 testing runs. The modifications of EN61121:2013 in comparison to IEC 61121:2012 are as follows: The program defined for the energy label testing procedure is selected to cotton cupboard dry, a program that must be able to dry a standard cotton load from an initial moisture content of 60% to a final moisture content of 0%. This program is used with the treatments 'full', which is run 3 times with rated cotton capacity, and the treatment 'half', which is run 4 times with halt the rated cotton capacity. In addition, the power consumption is measured in the 'left-on-mode' as well as in the 'off-mode'."	

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	1	58	pH value	"This is because the sensors used to measure the moisture content in the laundry are dependent on the conductivity of the fabric, which can be influenced by the water hardness, alkalinity, and pH level." The most important water characteristic is the conductivity. pH Level has only very small impact to the moisture sensing system.	Replace "pH value" by "conductivity"	But it has an impact, so it has not been deleted
	1	58	Recent developments of standardisation work by TC59X/SWG1.9 on EN 61121:2013	Currently the main task within the standardization work on EN61121:2013 in the implementation of an amendment to eliminate the conflict on the noise standard.	The ongoing standardisation work proposes numerous changes to the standard with varying extend. The major changes proposed by the working group as of November 2017 includes: - An amendment excluding the reference to the standard EN 60704-3 considering the declaration and verification of noise values. This part 3 of the standard is in conflict with the publication of harmonized standards in the official journal of the EC. This amendment includes also a revision of Annex ZB as well as Annex ZZ. - Other improvements of the measurements and evaluation methods for the performance of household tumble driers as: ○ Definition of "combined test	To follow-up with CENELEC, although noise is not a priority in this review study

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					series" to be added. ○ A revised calculation method for condensation efficiency. Currently measurement over-represents partial load and under-represents full loads. From weighted average, to a summation of whole test series	
	1	58	1458-2:2012	"The electrical energy consumption is measured in accordance with EN 61121." The standard 1458-2:2012 - besides the reference to the EN 61121 testing method - provides how to evaluate the gas related energy consumption.		It has now been included
	1	59	EN60704	"Defines methods of determination of airborne acoustical noise. Part 1 states general requirements, Part 2-6 specifies particular requirements for tumble driers, Part 3 defines the procedure for determining and verifying declared noise emission values." The reference to part 3 of the standard is explicitly excluded by the OJ.	Add information that this part is not used for EU energy label of tumble driers.	Please provide exact reference to OJ in order to correct in report
	1	67/68	prEN45555	Two times same number of standard (EN 45555) is named but with different content.	Correct the corresponding names of the standards.	Corrected

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1	1	3	Scope	*"Gas-fired technologies represent a small share of the market which is expected to vanish by 2030, and according to information from industry, no major improvements are expected to happen in the future. Limited data available on energy efficiency and consumption confirm this, but it shall be discussed further at the stakeholders meeting. Therefore, it is questionable whether these should remain in scope of the Regulations."*	We believe that in no case a technology should fall out of the scope of the regulation and that gas-fired technologies need to remain in the scope to avoid any loopholes and non-regulated products taking over the market again. In addition, as suggested by the UK at the 1st stakeholder meeting, we invite the study team to assess the combustion emissions to allow informed decisions later in the process. In the absence of data, we call on the study team to carry on the work based on their own assumptions in order not to miss this opportunity.	Currently, we have no plans to exclude gas fired dries from the scope. Combustion emissions are not part of the items to review in this study. Please present evidence that shows this is of concern in order to start an assessment.
2	1	All	Scope	The study does not make any mention of professional and semi-professional tumble driers. 1. Even though **professional tumble driers** are covered in Lot 24 (which has not moved forward), their status and description is not mentioned. 2. Today **semi-professional tumble driers** (used in multi-family houses) are classified as household tumble driers. This is however a grey area because the current regulation and the preparatory study state that the scope applies only to tumble driers for households and they are not directly mentioned in	The review study on Lot 16 household tumble driers should be taken as a golden opportunity to move forward on Lot 24 and to unlock the savings potential derived from regulating professional wash appliances. We would like for semi-professional tumble driers to continue to be treated as household tumble driers. To avoid any future ambiguity, the preparatory study should include a definition of these products in order to specifically add them to the scope.	This is a comment to the commission, and not the study team.

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				neither. This could be seen as a loophole because semi-professional tumble driers are not placed in the household!		
3	1	67-68	Standards on material efficiency	Correct the references to the standards: *prEN 4555~~4~~* *This European Standard is currently under development and deals with the assessment regarding the ability to remanufacture energy related products. The aim is to ensure a general method for assessing the ability to remanufacture energy related products.* *prEN 4555~~5~~* *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.*	prEN 45553 General method for the assessment of the ability to re-manufacture energy-related products prEN 45554 General method for the assessment of the ability to repair, reuse and upgrade energy-related products	Corrected
4	3	110	Larger capacities	*"If the average load at 3.2kg of laundry is used, then driers with a capacity of 7kg or more (which is >98% of all sold condensing driers and >70% of air-vented driers in 2016, see Task 2) is on average running below even the partial loading capacity (i.e., half load) used in Regulation 392/2012. The driers are hence labelled at running conditions which they seldom, if ever, operate in. The introduction of driers with a capacity of 10kg seems especially disproportionate."*	We welcome the reflection on the trend towards increasingly larger capacities and it being identified as a major drawback to the impact of the Ecodesign and Energy Labelling Regulations. This is indeed a problem that has also been identified in other product categories and which undermines the energy savings linked to the Ecodesign and Energy Label measures. We call on the study team to propose more stringent requirements as the capacity increases. We recommend that the study team assesses options such as the use of moisture	Most of the TDs on the market have already moisture sensors. We have addressed this problem different to what proposed here.

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				"Users are heavily influenced by the energy efficiency when buying new tumble driers, but as the efficiency of the driers are generally higher at larger capacities (especially heat pump driers due to compressor efficiencies in general), users could be biased towards buying driers with higher capacities which are labelled as more energy efficient, although they in real life conditions – due to part load operations – may not be. The current testing procedures at full and half load conditions can hence be used as a comparative tool between products but is unlikely to represent the real annual energy consumption for the average user, and less so in the future with foreseen increasingly large capacity driers on the market. Changing the testing procedure to reflect the real use, could potentially reverse the trend of manufacturers producing unnecessary large units, and emphasize the importance of having driers which can differentiate between being fully loaded and being almost empty."	sensors - which would automatically stop the machine when a certain level of dryness is reached, in order to mitigate the risk of higher consumption for larger capacity appliances when not fully loaded. In the case of washing machines, larger capacities issue has eaten up a large part of the expected energy and water savings, and the current EEI formula is one of the causes of this unfortunate situation. An analysis by Topten Europe has shown that currently good efficiency levels are mainly reached by adding capacity and not reducing energy consumption[319]. This is because the capacity is often more significant for determining a machine's energy efficiency class than the energy consumption. We invite the study team to draw inspiration from the new proposals on washing machines, fridges and displays, where it was attempted to tackle this issue. The washing machine draft proposes to have a quarter, half and full load test to avoid machines getting bigger. We, however, believe that a fixed small load would be more effective because the consumer's average load does not change in function to the size of the tumble drier they own.	Please see our proposal in task 7.

[319] Anette Michel, Sophie Attali, Eric Bush. Topten 2016. Energy efficiency of White Goods in Europe: monitoring the market with sales data – Final report. ADEME, 72 pages.

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					At the same time, we are of the opinion that the test method should be closer to real life use in order to provide consumers with useful and reliable information. Also, we believe that the capacity of tumble driers should be in line with the capacity of the washing machines (or it should be even smaller). Therefore, the formula should not favour tumble driers which are bigger than washing machines.	
5	3	120	Durability test	*"According to manufacturers tumble driers are tested with a durability test which ensures a lifetime that fits with the brand of the tumble drier."*	We encourage the study team to provide further details on the durability tests manufacturers perform as these could serve as an inspiration for the work to come on tumble drier material efficiency requirements.	Manufacturers have their own individual durability test, which they currently not wish to share.
6	3	124	Durability	Measures that can facilitate repair	Further possibilities of measures that can facilitate repair to be looked at within the study: ▪ Spare part availability One of the major factors causing unsuccessful repair of products is the availability of spare parts in terms of: • being able to find spare parts for purchase (17% of those trying in a recent survey[320] could not find suppliers for the necessary parts) and/or • the prohibitive cost of spare parts (18% of those trying to carry out repair found the parts too expensive).	Updated based on inputs and the study teams agree that spare part availability is a keystone.

[320] https://www.ellenmacarthurfoundation.org/assets/downloads/ce100/Empowering-Repair-Final-Public.pdf

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					Therefore, the availability of spare parts is a key material efficiency consideration that requires policy attention. ▪ Durability requirements on early breaking parts ▪ Access to key components for dismantling ▪ Spare part maximum delivery time to a fixed number of years that is representative of the expected lifetime of the product ▪ Spare part maximum delivery time ▪ Unrestricted independent operator access to information on repair ▪ Requirements for dismantling instead of for "disassembly" to go beyond material recovery and recycling, and to also facilitate repair ▪ Restrictions on the use of plastics/polymers that impede adequate recycling, such as non-compatible for recycling polymer blends, incompatible coatings, very dark plastics that have no recycling routes, etc. ▪ Marking of plastics and additives according to the relevant ISO standards, particularly marking content including flame retardants The study team could also mention the study on the repair index and discuss the usefulness of implementing it for tumble driers.	
7	3	136	Tolerance	*"As the standardisation group has created very thorough testing procedures and continuously works to refine them, no reasons to increase the tolerances have been found."*	Art. 7 of the regulation indicates "assessing verification tolerances set out in the regulations" as one of the objectives of the review, while the study concludes that there is no reason to increase the verification tolerances. Assuming that the quality of test methods improves, we invite the study team to also assess the option of decreasing the tolerances.	We are waiting for the EU results of a Round Robin Test performed by APPLiA which we will use to assess this item.

Organization: ECOS-EEB-Coolproducts				Name: Nerea Ruiz Fuente	Date: 20/07/2018	
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8	1	43	Low power modes	The study mentions that there are only 2 low-power modes for tumble driers (off-mode and left-on mode). *"Tumble driers do in some models offer "delayed start" options. These modes are not covered in the standby Regulation, as this mode does not last for an indefinite time. Similarly, tumble driers have a left-on mode, after operation. This mode is also not covered in the Regulation, as the mandatory power management system turns the appliance off after a set amount of time. Furthermore, left-on mode requires no further user intervention by the end-user, which happens when appliances are on standby, due to reactivation.* *The study also does not investigate the networked standby function.* *Left-on mode and off mode are indirectly regulated in the ecodesign and energy labelling Regulations of tumble driers are they are included in the EEI calculation. If the tumble drier regulation were to align with the regulation for washing machines, the low power modes will fall out of the EEI equation which means that they will not be reflected anymore."*	As it is the intention of the Commission to take a vertical approach in regulating standby consumption, the study should investigate the low power modes further, and notably envisage decreasing the thresholds to at least the levels discussed as part of the draft horizontal regulations on standby and network standby.	Based on the APPLiA Model database, the average tumble drier is currently below the proposed change in off-mode consumption limit of 0.3W, and we see no need to further investigate this, as this has been done in similar studies for similar appliances. We have no market share data on tumble driers equipped with networked standby, but we expect it to be very low.

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Number	**Task**	**Page #**	**Topic**	**Comment**	**Proposed change**	**Reply study team**
9	4	142	Refrigerants	It has been established by the study that the heat pump technology is taking over the market. This will lead to a large quantity of refrigerants with high GWPs to be put on the market. The study does not reflect however on the impact of the refrigerants that are in the heat pumps. A report from the Energy Efficiency Task Force of the Montreal Protocol[321] states that the choice of the refrigerant only impacts the energy efficiency of the product by maximum 5-10%. This is considered to be insignificant and is compensated by the CO_2eq. avoided by a low GWP refrigerant. **The F-gas regulation does not explicitly mention tumble driers in its scope.** The refrigerant charge being small, this does not represent a large security issue if the product contains more flammable refrigerants.	Based on the overall increase of heat pump technology within the tumble driers market, we invite the study team to further assess the existing options and low GWP units, and even to explore a bonus system as it was the case with AC units using low GWP refrigerants – or a malus system for those appliances with high GWP. The study should include broken down data per type of refrigerant to identify the best technology available in terms of refrigerant use.	We have received more data indicating no effect on energy consumption. Thus, we propose this as a design option and part of all the policy options.
10	1	45	Condensation efficiency	The threshold for a Class A condensation efficiency is 90%. Classes D to G have already been removed from the market. Technological improvement has also taken place for this function which is important because it puts less burden on the secondary energy system of the room where the tumble drier is located. Today there are already models that reach a 95% condensation efficiency (e.g. Miele).	A re-scaling of the condensation efficiencies is most likely needed since from the A-G scale only classes A, B and C can be put on the market. This does not fully exploit the A-G scale. We recommend performing an assessment of what the best condensation efficiencies are, and to gather some data on this aspect.	This is considered for task 7. The study team are aware of the problems regarding a wide A-C interval.

[321] http://conf.montreal-protocol.org/meeting/oewg/oewg-40/presession/Background-Documents/TEAP_DecisionXXIX-10_Task_Force_EE_May2018.pdf

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Number	**Task**	**Page #**	**Topic**	**Comment**	**Proposed change**	**Reply study team**
11	3	100	Consumption denominator	For washing machines and dishwashers there are similar discussions to change the denominator from an annual to a cycle-based consumption which removes the assumption on the amount of cycles per year.	Annual or cycle consumption. The denominators for tumble driers should be adapted to the outcome of the discussions on washing machines (and washer driers) to allow for comparability and understanding from the consumer.	We agree, but as the drying behaviour is not identical to the washing behaviour, a differentiation might still be required.
12		All		We believe that the preparatory study should present the technical basis to define future ecodesign and energy labelling requirements based on the existing Regulation (EU) 932/2012 and 392/2012 while avoid taking strong position unless substantiated.	We encourage the study team to use a more balanced approach throughout the assessment in order to avoid making decisions at this stage of the process. Some examples: "*it is clear that existing market forces are regulating the market towards using condenser driers instead of air-vented. <u>This might nullify the effects of new ecodesign Regulations</u> on these types of driers, as they are gradually being removed from the market on a voluntary basis.*" "*<u>The low collection rate of tumble driers can challenge the improvement potential</u> of any suggestions regarding resource efficiency since many products do not reach the desired recycling facility.*" "*<u>Some requirements may be difficult to address from a market surveillance perspective</u> because the requirements are difficult to control such as requirements of ease of dismantling.*"	No decisions are made in task 1 to task 4. These statements are only observations. The report is updated with the work on the Scoring System on Reparability

Organization: ECOS-EEB-Coolproducts				Name: Nerea Ruiz Fuente	Date: 20/07/2018	
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					In this sense, several of the above-mentioned statements can already be challenged. For instance, note the proposed requirements on dismantling and disassembly for washing machines and dishwashers. While the verification of requirements for ease of dismantling are already being implemented in IEEE standards based on documentation, we could also imagine establishing a simple test procedure to be carried out by independent laboratories. We therefore invite the study team to focus more on the opportunities that resource efficiency parameters may offer, rather than highlight the challenges, responding to the clear political guidelines foreseen in the Ecodesign Working Plan 2016-2019.	
13	3	117	Resource efficiency	The preparatory study concluded that the technological improvement of tumble driers will take place through an improvement of its main components. Resource efficiency should be treated similarly, and the resource efficiency potential should be assessed on the basis of its components – identifying the key components and the ones that are the most subject to fail. The durability of the machine is strongly correlated with how the consumer uses the machine.	The study should investigate resource efficiency aspects on the basis of the components. It should also take into account the user's behaviour that could negatively affect the durability of the machine (benefits of self-cleaning filter for users that do not properly clean their device).	It is difficult to obtain the needed data to assess the resource efficiency on a component level. Also, any result will be connected with a high uncertainty. However, the

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						report already pinpoints critical components.
14	3	126	Repairability & Critical components	Through the NGO network working on repair, we acquired the following information corresponding to the largest retailer of EEE in France. ▪ Lifetime of a tumble drier: o median lifetime: 8 years ▪ Reasons for replacement of tumble driers and failure rate: o 87.5% of the tumble driers were replaced because of a failure, and o 12.5% while they were still working. o The failure rate before the legal warranty period (in France 2 years) is 3.6% (a stable figure from 2015 to 2017) ▪ Ranking of replaced spare parts (very often the tension idler will be replaced alongside the strap/belt) o For the least reliable product: Pump 41,70% Strap/belt 28,41% Resistance 15,87% Tension idler 6,27% Drum 3,32% Turbine 1,85% Thermostat 1,48% Bearing block 1,11% o For the most sold model (with a failure-rate slightly better than the average): Resistance 42,19% Pump 18,75% Strap/belt 14,06% Turbine 13,28% Drum 9,38% Tension idler 2,34%		Report updated based on falling parts

Organization: ECOS-EEB-Coolproducts				Name: Nerea Ruiz Fuente		Date: 20/07/2018
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				In view of this retailer's experience, top 3 failing spare parts would be: Pumps, Resistance and belts although the order may vary. ▪ Spare parts average price depends on brands but indicative prices: 25€ et 50€ for pumps10€ et 15€ for belts/straps 10€ et 30€ for tension idler 40€ et 80€ for resistances 100€ et 180€ for drums 15€ et 40€ for turbines 10€ et 30€ for thermostats 15€ et 60€ for bearing blocks		

Organization: BSH Hausgeräte GmbH				Name: Ulrich Nehring		Date: 22.06.2018
Number	**Task**	**Page #**	**Topic**	**Comment**	**Proposed change**	**Reply study team**
	4	142	Efficiency of propane HP	"No "Best available" refrigerant is thus available, however, organic refrigerants are preferred from a global warming potential perspective, although they may not necessarily be the optimal for increasing the efficiency of the whole heat pump circuit."		Corrected. Latest evidence shows no impact on energy efficiency of the heat pump circuit.

Organization: BSH Hausgeräte GmbH				**Name:** **Ulrich Nehring**		**Date:** **22.06.2018**
Number	**Task**	**Page #**	**Topic**	**Comment**	**Proposed change**	**Reply study team**
				HP driers using organic refrigerants are available in the highest efficiency class A+++ and in parallel belong also to the fastest HP driers in the market.		
	4	143	Self-cleaning condensers	This is a competitive issue and should not be part of the study - there is no evidence on this hypothesis		Correct. Deleted.
	4	144	Table 37	BLDC compressor drive is relevant for BAT HP TD. It is precondition for VSD.	Set corresponding cross in the table.	Corrected

Organization: **Samsung Electronics**				**Name:** **Hartmut Kraus**		**Date:** **05.07.2018**
Number	**Task**	**Page #**	**Topic**	**Comment**	**Proposed change**	**Reply study team**
1	3 34	110 128 143	Increase of energy consumption during lifetime / self-cleaning heat exchangers	So far there is not much knowledge about the increase of energy consumption of heat-pump driers over time. Therefore, used driers have been purchased from consumers after several years of usage and tested for their energy consumption	Include the findings from this investigation into your study as appropriate: 2018-07-12 Increase of energy consumptic	This has been included as part of the assessment of the report. However, lack of data from this and other test results provides prevents from drawing any final conclusion on the effect of not cleaning filters on energy consumption.

VIII. Annex VIII: Energy label distributions used for scenario analyses in task 7

Following is the energy label distributions used for calculating key parameters in Task 7. Note that PO1 & PO2 are using the new EEI calculation methods after year 2021, and that BAU is using the old throughout the period. Since PO3 and PO4 follow the BAU energy distribution, they are not shown.

BAU								
		2015	2020	2021	2025	2030	2035	2040
Heat pump condenser	A+++	8%	25%	26%	28%	30%	30%	30%
	A++	59%	65%	65%	65%	65%	65%	65%
	A+	31%	10%	10%	8%	5%	5%	5%
	A	2%	0%	0%	0%	0%	0%	0%
	B	0%	0%	0%	0%	0%	0%	0%
	C	0%	0%	0%	0%	0%	0%	0%
	D	0%	0%	0%	0%	0%	0%	0%
		2015	2020	2021	2025	2030	2035	2040
Heating element condenser	A+++	0%	0%	0%	0%	0%	0%	0%
	A++	0%	0%	0%	0%	0%	0%	0%
	A+	0%	0%	0%	0%	0%	0%	0%
	A	0%	0%	0%	0%	0%	0%	0%
	B	81%	100%	100%	100%	100%	100%	100%
	C	19%	0%	0%	0%	0%	0%	0%
	D	0%	0%	0%	0%	0%	0%	0%
		2015	2020	2021	2025	2030	2035	2040
Heating element air vented	A+++	0%	0%	0%	0%	0%	0%	0%
	A++	0%	0%	0%	0%	0%	0%	0%
	A+	0%	0%	0%	0%	0%	0%	0%
	A	0%	0%	0%	0%	0%	0%	0%
	B	15%	100%	100%	100%	100%	100%	100%
	C	80%	0%	0%	0%	0%	0%	0%
	D	5%	0%	0%	0%	0%	0%	0%

PO1		2015	2020	2021	2025	2030	2035	2040
Heat pump condenser	A	8%	30%	0%	13%	30%	30%	30%
	B	59%	70%	35%	39%	45%	45%	45%
	C	31%	0%	60%	44%	25%	25%	25%
	D	2%	0%	5%	3%	0%	0%	0%
	E	0%	0%	0%	0%	0%	0%	0%
	F	0%	0%	0%	0%	0%	0%	0%
	G	0%	0%	0%	0%	0%	0%	0%
		2015	2020	2021	2025	2030	2035	2040
Heating element condenser	A	0%	0%	0%	0%	0%	0%	0%
	B	0%	0%	0%	0%	0%	0%	0%
	C	0%	0%	0%	0%	0%	0%	0%
	D	0%	0%	0%	0%	0%	0%	0%
	E	81%	100%	0%	0%	0%	0%	0%
	F	19%	0%	100%	100%	100%	100%	100%
	G	0%	0%	0%	0%	0%	0%	0%
		2015	2020	2021	2025	2030	2035	2040
Heating element air vented	A	0%	0%	0%	0%	0%	0%	0%
	B	0%	0%	0%	0%	0%	0%	0%
	C	0%	0%	0%	0%	0%	0%	0%
	D	0%	0%	0%	0%	0%	0%	0%
	E	15%	100%	0%	0%	0%	0%	0%
	F	80%	0%	100%	100%	100%	100%	100%
	G	5%	0%	0%	0%	0%	0%	0%

PO2		2015	2020	2021	2025	2030	2035	2040
Heat pump condenser	A	8%	30%	0%	13%	30%	30%	30%
	B	59%	70%	35%	39%	45%	45%	45%
	C	31%	0%	60%	44%	25%	25%	25%
	D	2%	0%	5%	3%	0%	0%	0%
	E	0%	0%	0%	0%	0%	0%	0%
	F	0%	0%	0%	0%	0%	0%	0%
	G	0%	0%	0%	0%	0%	0%	0%
		2015	2020	2021	2025	2030	2035	2040
Heating element condenser	A	0%	0%	0%	0%	0%	0%	0%
	B	0%	0%	0%	0%	0%	0%	0%
	C	0%	0%	0%	0%	0%	0%	0%
	D	0%	0%	0%	0%	0%	0%	0%
	E	81%	100%	0%	0%	0%	0%	0%
	F	19%	0%	100%	100%	100%	100%	100%
	G	0%	0%	0%	0%	0%	0%	0%
		2015	2020	2021	2025	2030	2035	2040
Heating element air vented	A	0%	0%	0%	0%	0%	0%	0%
	B	0%	0%	0%	0%	0%	0%	0%
	C	0%	0%	0%	0%	0%	0%	0%
	D	0%	0%	0%	0%	0%	0%	0%
	E	15%	100%	0%	0%	0%	0%	0%
	F	80%	0%	100%	100%	100%	100%	100%
	G	5%	0%	0%	0%	0%	0%	0%

IX. Annex IX: Sensitivity analysis detailed results

The detailed results of the sensitivity analyses are shown in the next pages, where the effect of each parameter assessed is shown for relevant indicators, following the analyses described in section 7.4. Note that the PO4 added repair cost are evaluated for 2040 as well.

Sensitivity plots

Figure 106 and Figure 107 show the sensitivity of the different parameters for the *average* variation across the effected policy options, e.g. when varying the escalation, the effect on the indicators vary across the policy option. The shown effect in % is the average for all the effected policy options. This means that for the PO4 repair cost, only the effect from PO4 is shown. For the BAU scenario A+++ heat pump market share, only the BAU scenario is shown. For the PO1a/PO1b/PO2 A-class drier market share, the effect is evaluated for PO2 as it is most significant. For the programme's correction factor on Figure 106 and Figure 107, a 100% increase in this parameter is indicated as a change in the correction factor from 0% to 1%, a 200% increase from 0% to 2% and so on.

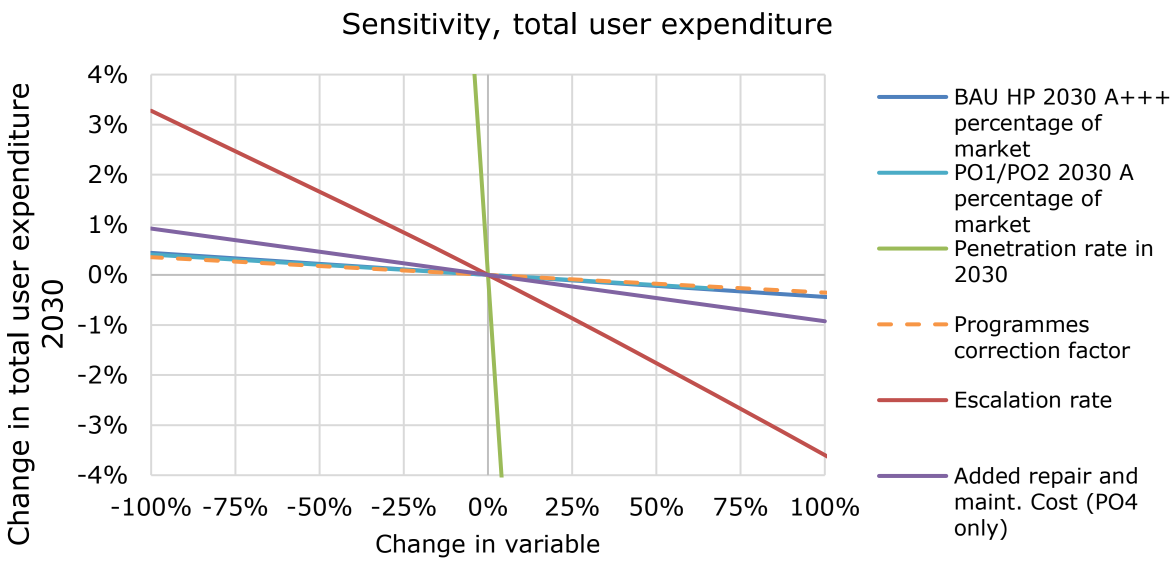

Figure 106: Sensitivity of the six parameters evaluated by the change in total user expenditure in 2030

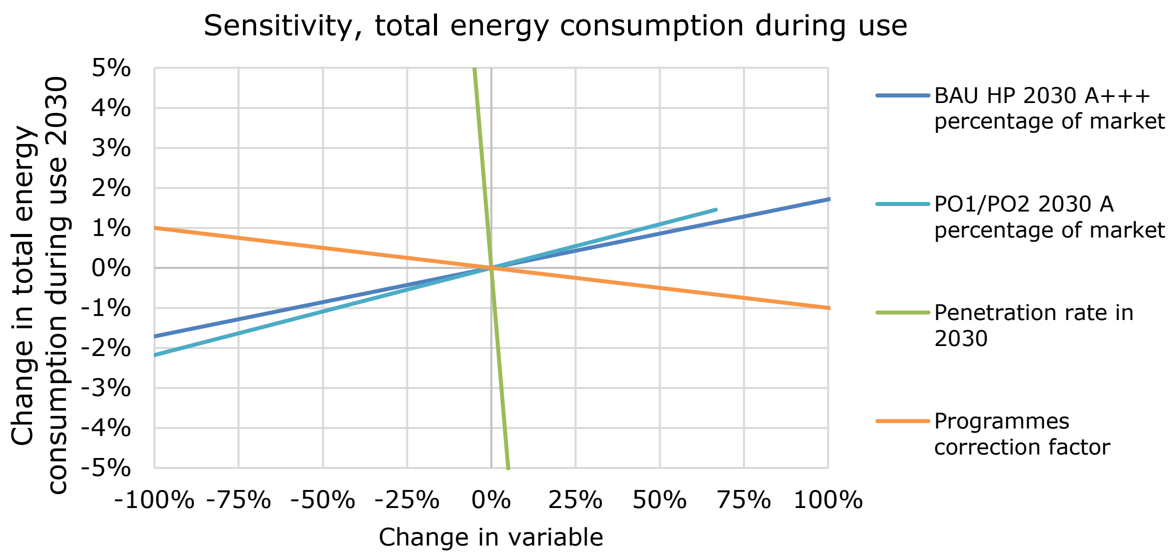

Figure 107: Sensitivity of four parameters evaluated by the change in energy consumption during use in 2030

Market share of A+++ heat pump driers in 2030 for the BAU scenario

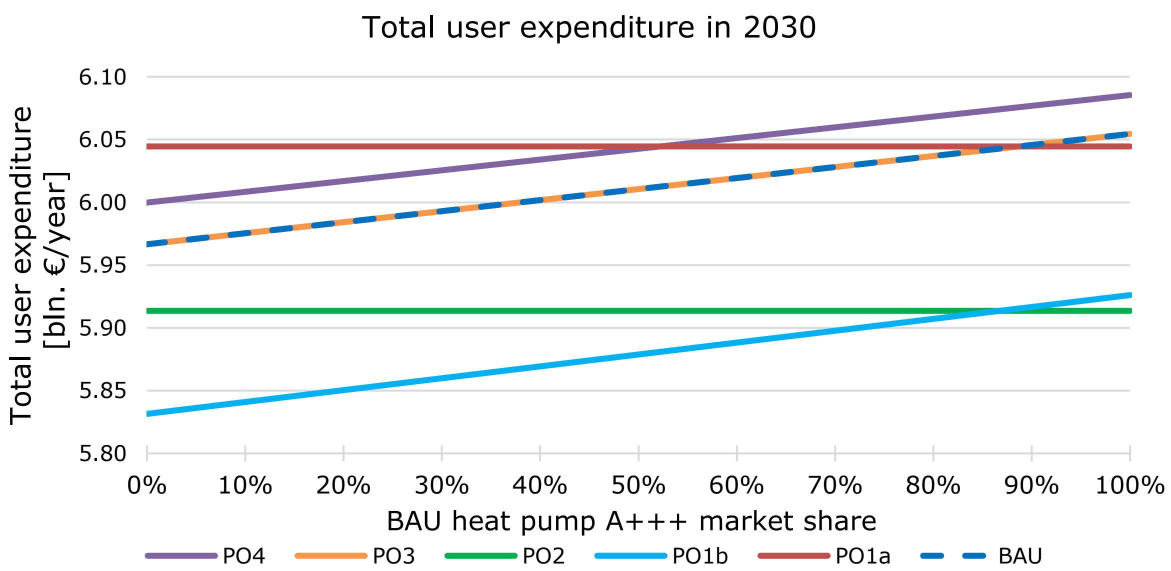

Figure 108: Total user expenditure in 2030 as a function of the A+++ heat pump market share in the BAU scenario

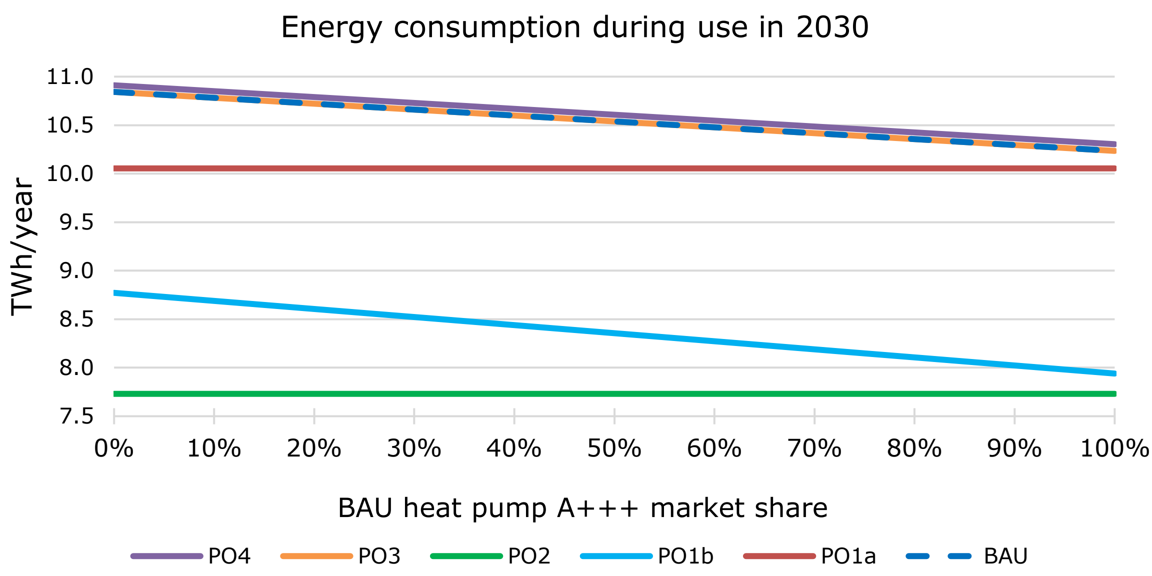

Figure 109: Energy consumption during use in 2030 as a function of the A+++ heat pump market share in the BAU scenario

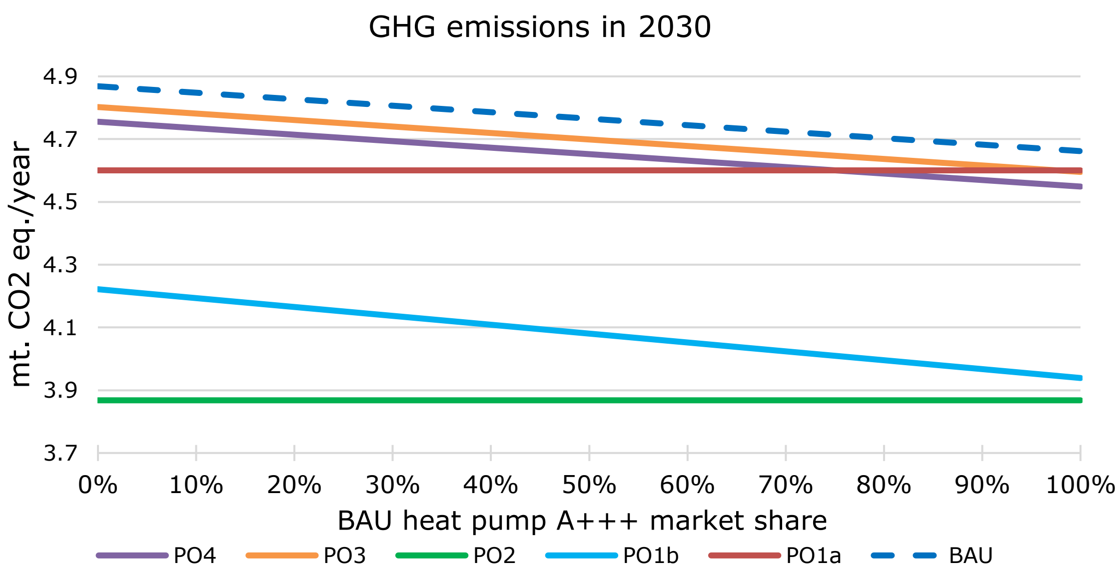

Figure 110: GHG emissions in 2030 as a function of the A+++ heat pump market share in the BAU scenario

Market share of A-label drier in 2030 for PO1a/PO2 scenarios

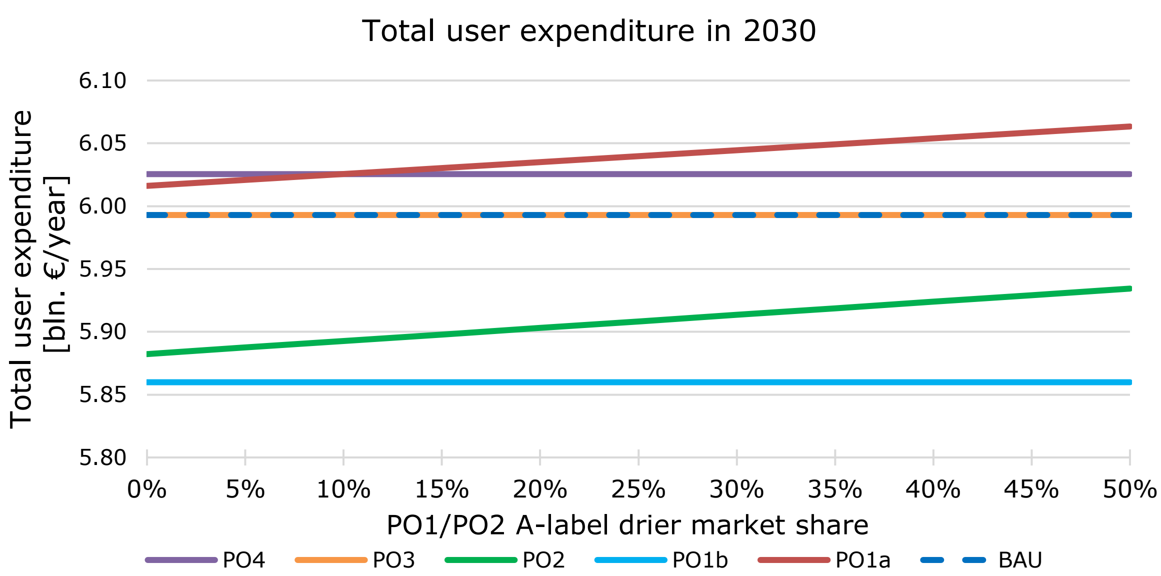

Figure 111: Total user expenditure in 2030 as a function of the A-label drier market share in PO1/PO2

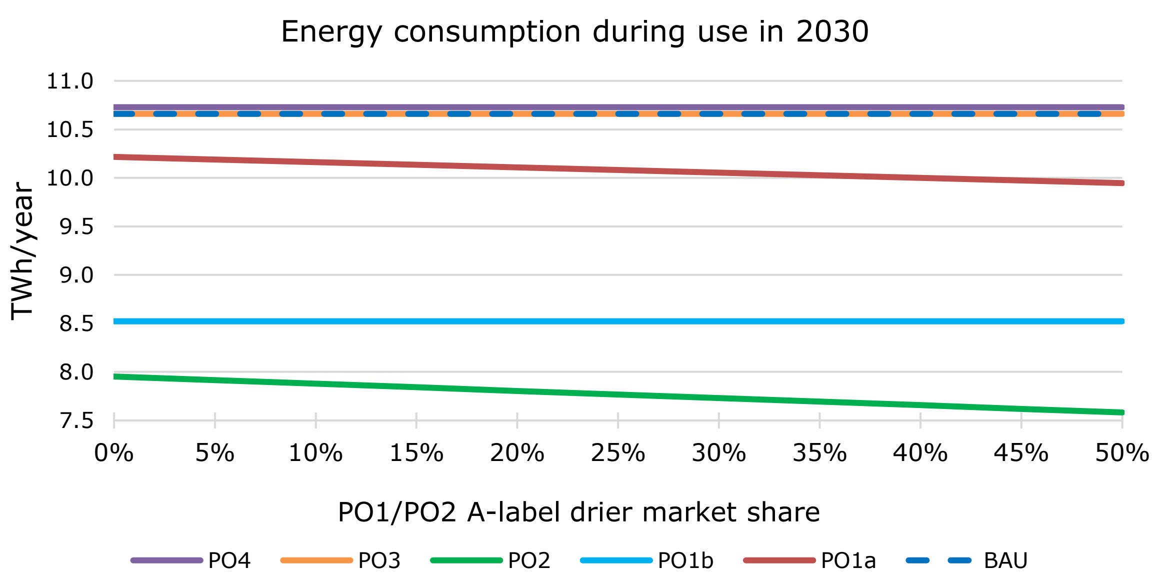

Figure 112: Energy consumption during use in 2030 as a function of the A-label drier market share in PO1/PO2

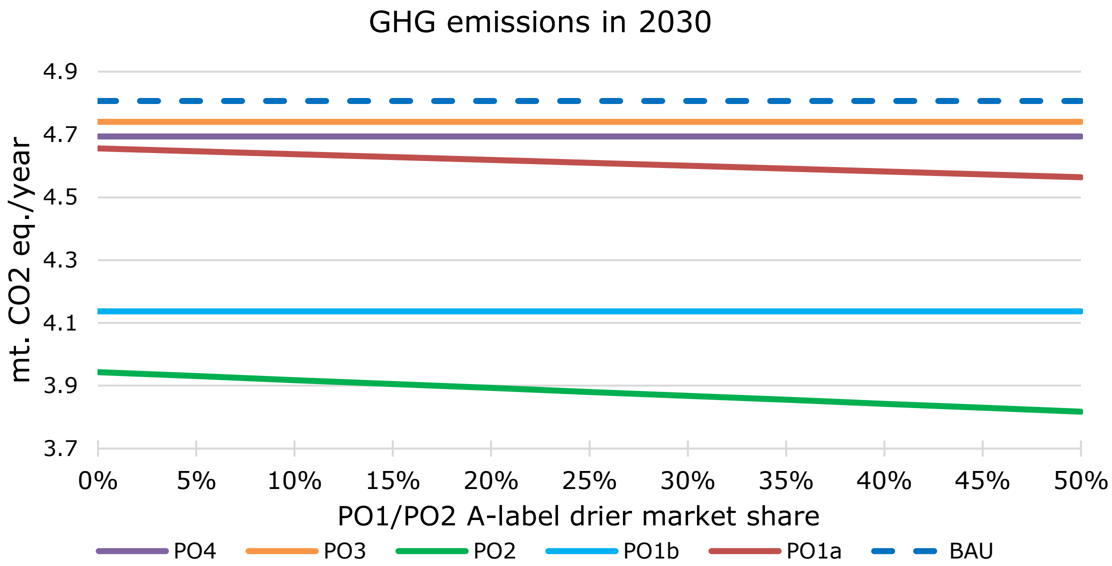

Figure 113: Total GHG emissions in 2030 as a function of the A-label drier market share in PO1/PO2

Penetration rate in 2030

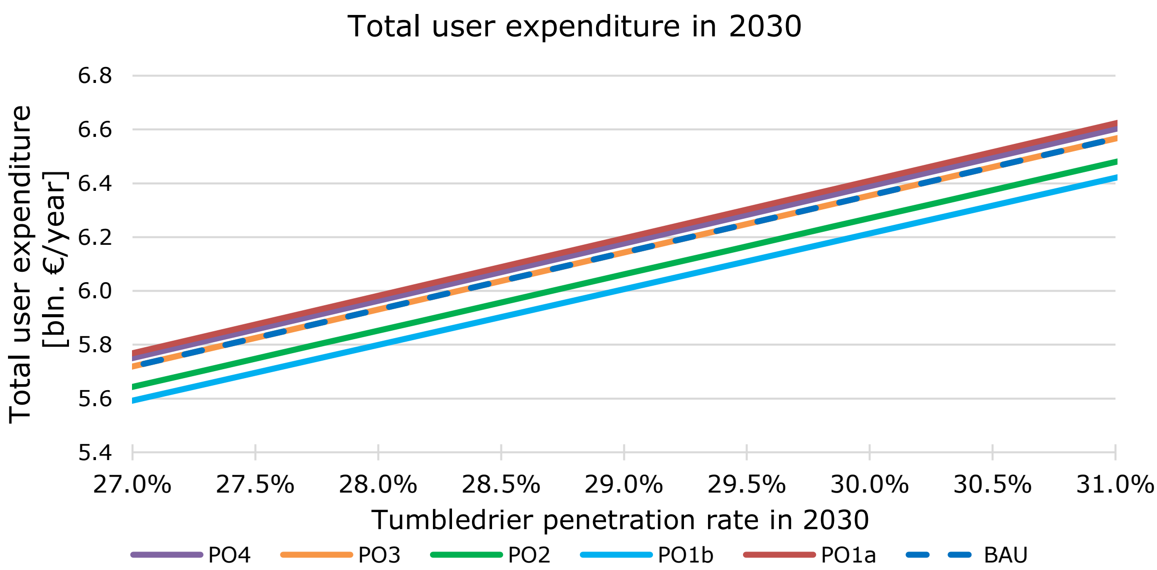

Figure 114: Total user expenditures in 2030 as a function of the tumble drier penetration rate

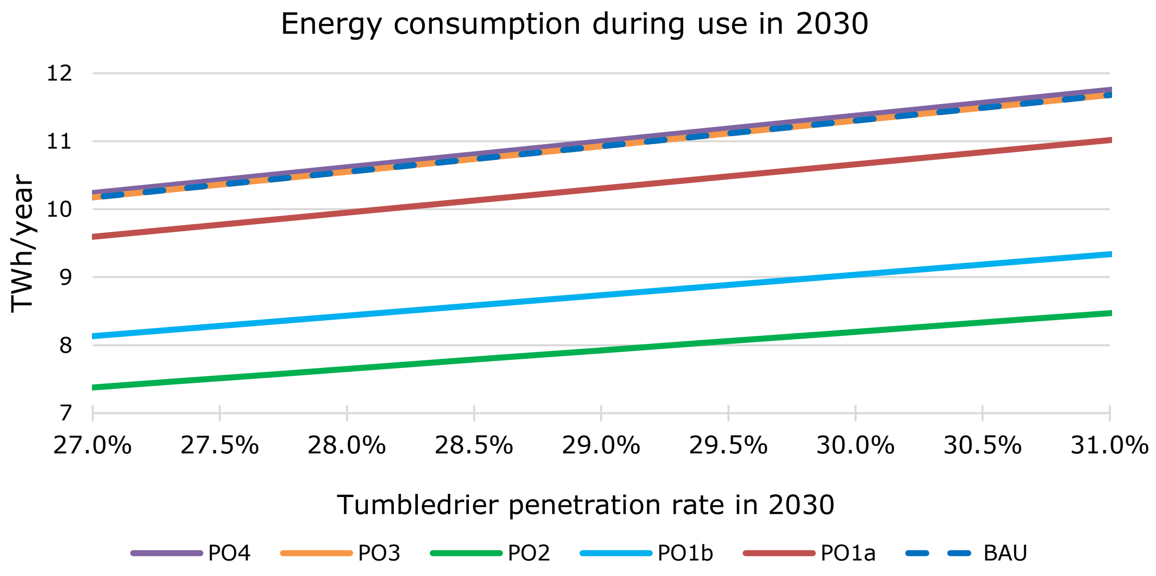

Figure 115: Energy consumption during use in 2030 as a function of the tumble drier penetration rate

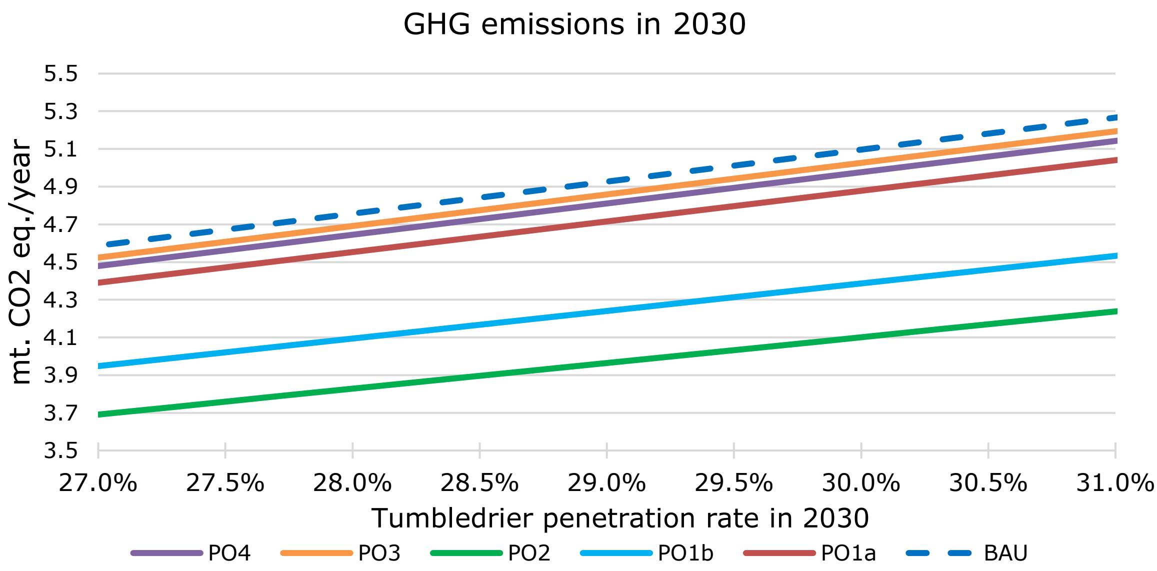

Figure 116: Total GHG emissions in 2030 as a function of the tumble drier penetration rate

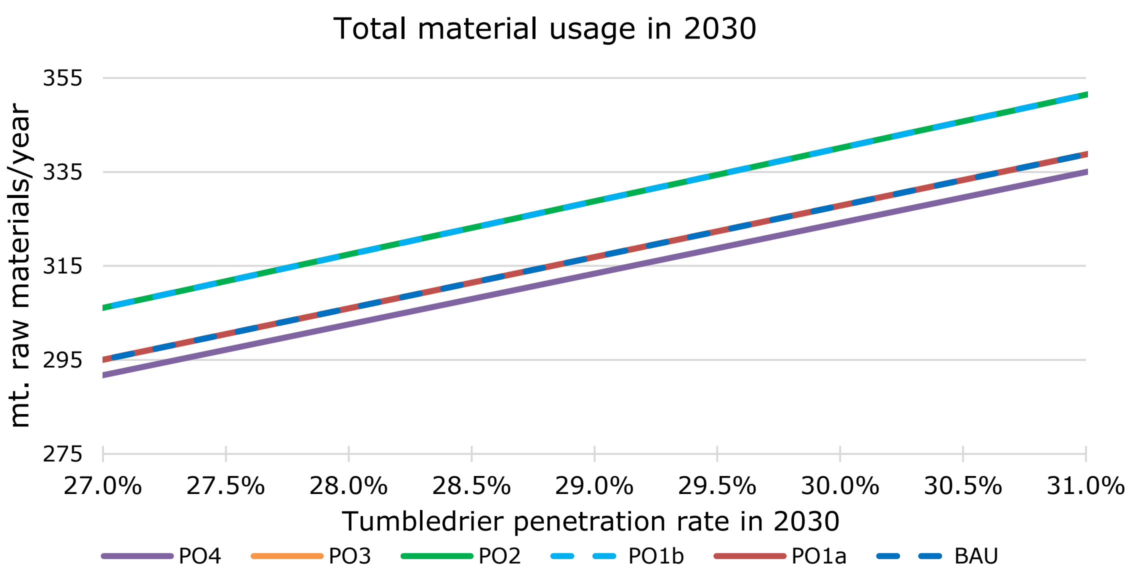

Figure 117: Total material consumption in 2030 as a function of the tumble drier penetration rate

Escalation rate

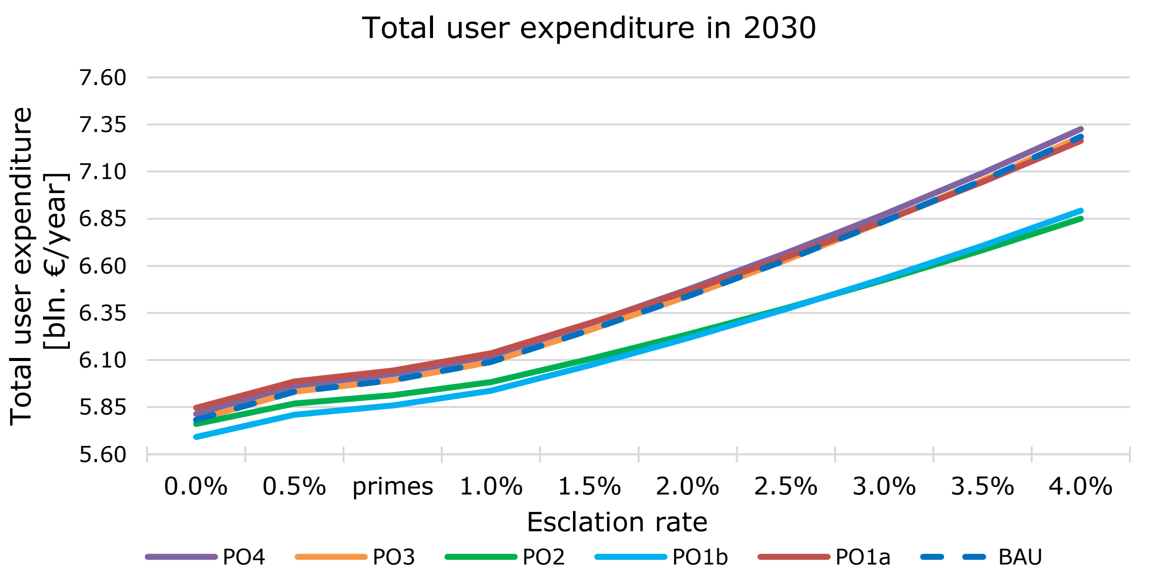

Figure 118: Total user expenditures in 2030 as a function of the escalation rate of electricity

PO4 added repair and maintenance cost

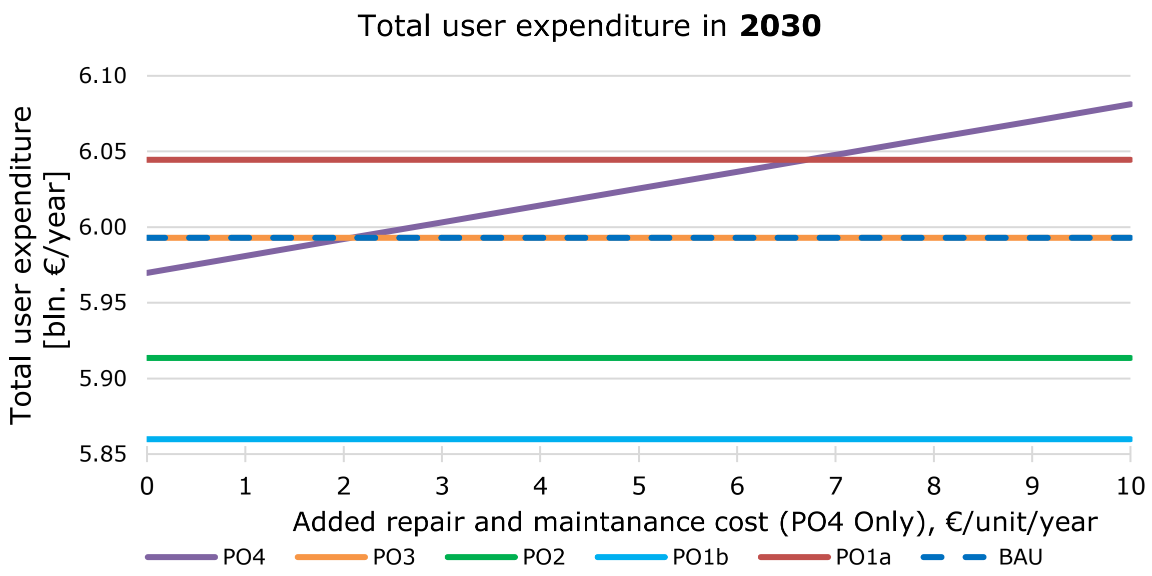

Figure 119: Total user expenditures in 2030 as a function of added repair and maintenance cost for PO4

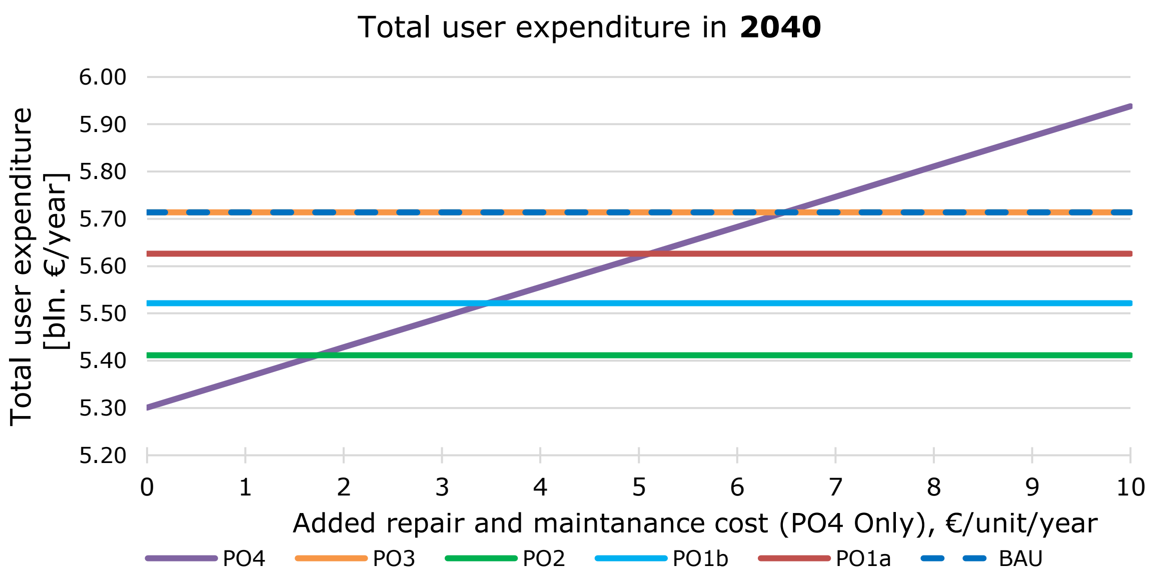

Figure 120: Total user expenditures in 2040 as a function of added repair and maintenance cost for PO4

Change in energy consumption due to programmes usage.

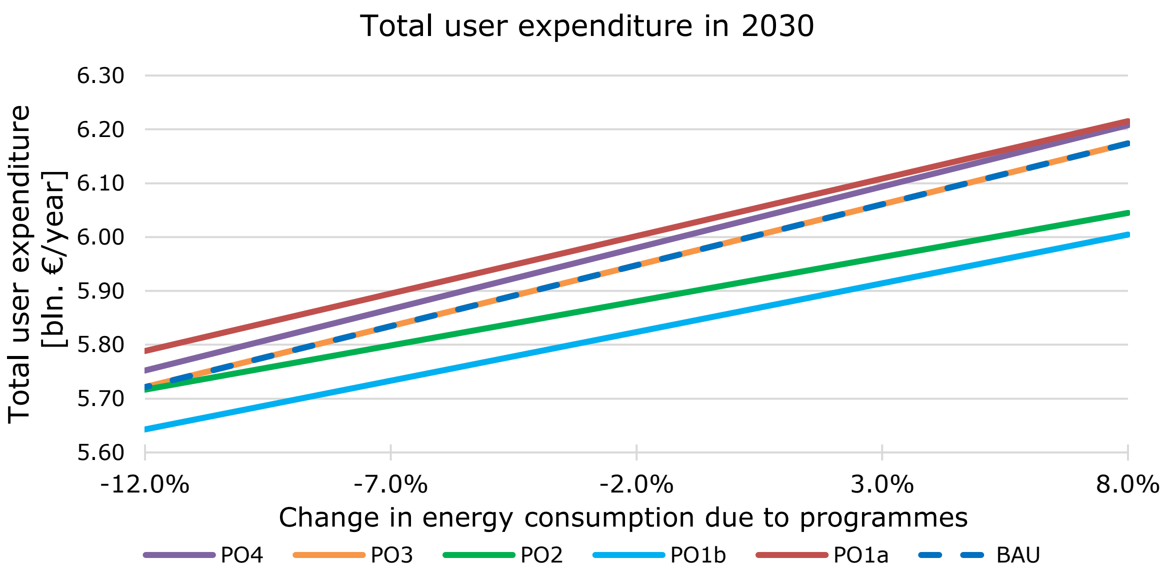

Figure 121: Total user expenditures in 2030 as a function of change in energy consumption due to using different programmes than the standard cotton cycle.

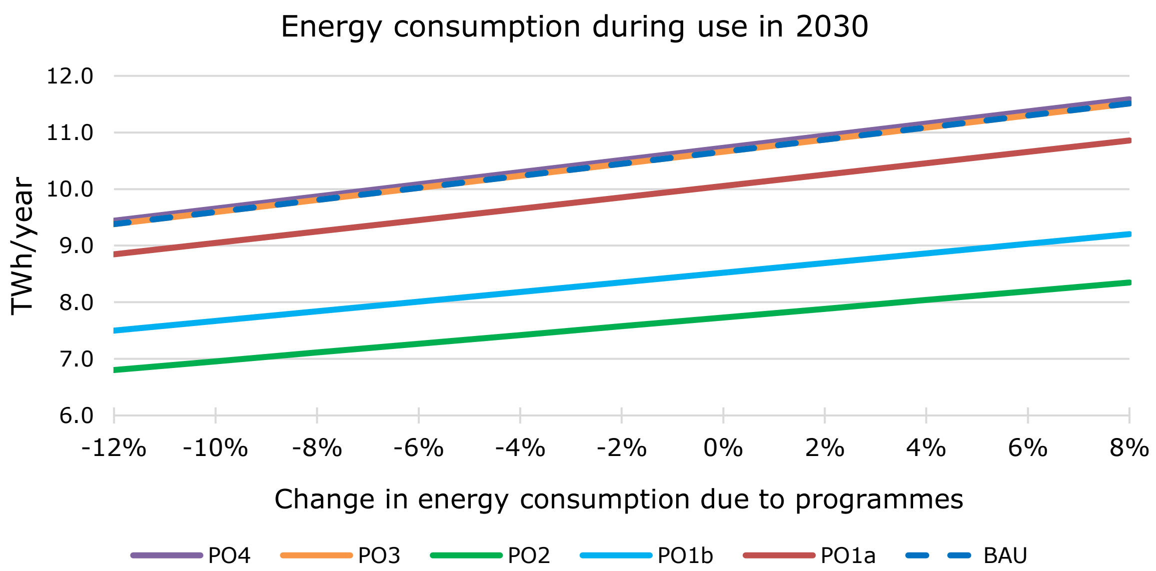

Figure 122: Energy consumption during use in 2030 as a function of change in energy consumption due to using different programmes than the standard cotton cycle.

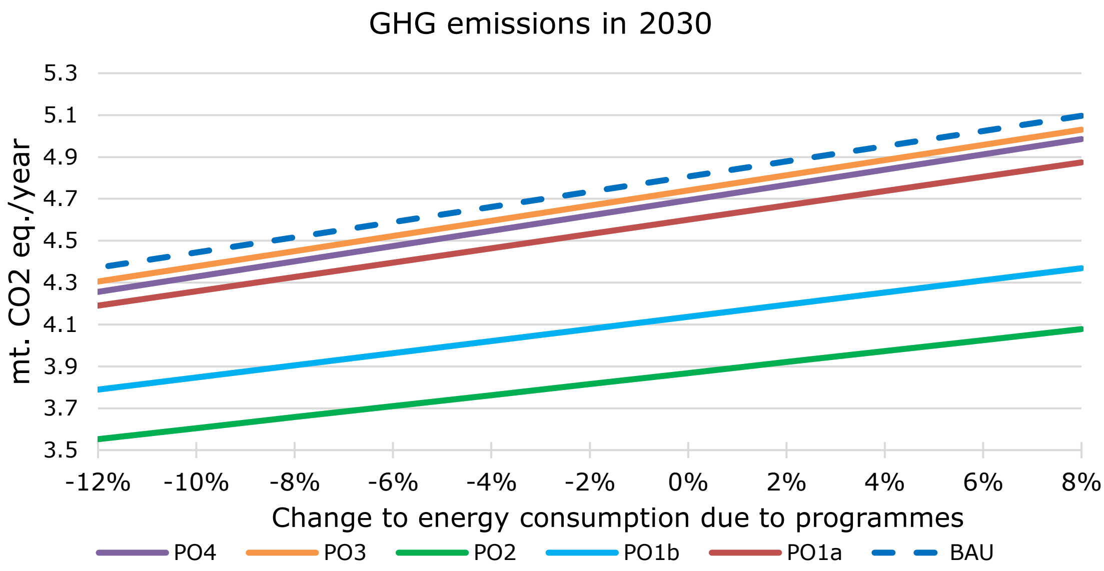

Figure 123: GHG emissions in 2030 as a function of change in energy consumption due to using different programmes than the standard cotton cycle.

X. Annex X: Stakeholders comments after second stakeholders meeting on draft final report

Organization: APPLiA				Name: Giulia Zilla		Date: 04.01.2019
Number	**Task**	**Page #**	**Topic**	**Comment**	**Proposed change**	**Reply study team**
1			General Comment to the Summary	The summary opens a lot of questions which are not clarified in the summary itself, but later on in the Report. The summary cannot be understood as such.	We recommend making the summary clearer.	We have updated the summary, so it adds more value to the report.
2	5	37	Figure vi	In the table vi, the LCC estimated is too low. We believe that the LCC for BC1 is not appropriate, we invite the Consultant to redo the calculation.	We recommend splitting in in two base cases. See comments 30-31, to use the calculation for the LCC that has been done for Dishwashers. APPLiA proposes a different calculation for the LLCC (similar to the one used for the Dishwashers). Please, consider our proposal attached here.  2019-01-04 LLCC from a market	The base cases will be split into four cases: 1. Condenser with heating element 2. Condenser with heat pump 3. Air vented with heating element 4. Air vented with gas burner The LCC values for previous BC1 are now split and allocated to BC1 and BC2. The LCC calculation method used in this study follows the MEErP methodology. This includes discounting and escalation rates, repair, and EoL expenditures which are not included in the proposed LLCC methodology. Thus, the method has not been changed.
3	7	40	Rescaling Condensation efficiency	Is there a real benefit in changing the condensation efficiency classes with respect to the environmental aspects? What is the justification behind the choice to increase the number of classes which would imply a higher use of energy to comply with it?	We recommend adding the justification considering also the disadvantages.	96% of the current market have condensation efficiencies better than 80%. The justification for setting ecodesign requirements at 80% is thus that the current market supports this very well. The rescaling should not have any major impact of the average condensation

Organization: APPLiA				Name: Giulia Zilla		Date: 04.01.2019
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						efficiency but will enable users to better differentiate between the different driers.
4	7	41	Figure xi - PO1b – Energy and load average of market	Currently no technology available. This causes extra effort for control panels: rises costs of appliances, simple controls are not allowed any more.	We recommend deleting this policy option (PO1b). Four reasons: 1. Storage and accumulation of wet laundry is not recommended. 2. There is no possibility to differentiate the amount of dry load from the water load 3. There is no technology available to estimate the weight of the dry load based on the weight of the wet load. 4. Such ecodesign requirement would imply that all the appliances should be equipped with a display as control panel. This would increase the cost of the appliance and would have a strong impact on the resource efficiency.	The study team has chosen to remove the PO1b and PO2b from Task 7 and Task 6. The four reasons listed are true, but it might be technological possible to integrate such a system on a lower level. For instance, instead of integrating a status display, a LED could change colour from Red/Yellow/Green depending on the selected programme and weight of the laundry (based on an average wetness).
5	7	41	Figure xi - PO2b – Energy and load BAT	Currently no technology available. This causes extra effort for control panels: rises costs of appliances, simple controls are not allowed any more.	We recommend deleting this policy option (PO2b). Four reasons: 1. Storage and accumulation of wet laundry is not recommended. 2. There is no possibility to differentiate the amount of dry load from the water load 3. There is no technology available to estimate the weight of the dry load based on the weight of the wet load.	Same comment as above.

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					4. Such ecodesign requirement would imply that all the appliances should be equipped with a display as control panel. This would increase the cost of the appliance and would have a strong impact on the resource efficiency.	
6	7	42	PO3 – Dismantling and Recycling	Such information not part of energy label – it changes the intention of the label	We recommend **to not** include this information on the energy label. This would mislead the main intention of the energy label. Moreover, this could lead to a large number of obstacles and numerous difficulties for industries that need to be taken in consideration. Please find in the file attached below, valid argumentations on why we ask to not include this information on the energy label. 2019-01-04 Recycled plastic	Label information requirement has been deleted due to small potential savings identified in Task 6
7	7	42	PO4 – Reparability and durability	Not in the manual of the product, this would cause repairs by non-professionals, with the risk of serious damage or injuries.	We recommend allowing information only on the webpage for professional repairers.	It should be in a place where all professionals can access to, not only those accredited by OEMs. A possibility is the manual, with a caution sign for consumers in case of warranty claims.

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8	7	42	Figure ix - Energy consumption during use for the different POs PO1B value	The effect of 20% for the measure of displaying the load size is much too high.	We recommend deleting this point which is in line with our request to eliminate the PO1b and PO2b.	This is maximum potential based on values from GfK and the APPLiA model database. However, PO1b/2b will be removed.
9	7	42	Figure ix – Energy consumption during use for the different POs BAU value	Why is there such a big difference between BAT and current market (30%)? This seems unrealistic. Current market is oriented to the BAT.	We recommend to re-calculate the BAU with the assumption that percentage of heat pump driers increases between 2020 and 2040. We ask using the base case 1 that we recommended to split in two, also in this calculation.	PO2 is not necessarily 100% BAT. There are heat pump condenser driers that are superior to average levels calculated for PO2. Sales and stock of BAU, PO1, PO2, and PO3 are the same. Sales average growth rate for BC2 (HP-C) over 2020-2030 is 4%. For 2030-2040, no change in sales are assumed. The reason for the differences between BAU and the POs is that BAU assumes there is no development in the energy class distribution in tumble drier sales from 2021 onwards (we have assessed this in the sensitivity analysis).
10	7	43	*“The difference between PO1a and PO1b, and PO2a and PO2b, shows the large increased energy consumption*	The effect is much smaller. Consumers will continue to dry only partial load as they cannot wait for two or the washing loads to be collected for one drying load. This behaviour is not realistic, but only theoretically given.	We recommend deleting this policy option PO1b and PO2b. Three reasons: 1. Storage and accumulation of wet laundry is not recommended.	Same reply as to question 4.

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			due to part load operations, which further reduces the energy consumption with about 30%."		2. There is no possibility to differentiate the amount of dry load from the water load 3. There is no technology available to estimate the weight of the dry load based on the weight of the wet load. 4. Such ecodesign requirement would imply that all the appliances should be equipped with a display as control panel. This would increase the cost of the appliance and would have a strong impact on the resource efficiency.	
11		45	*Rescale the condensation efficiency classifications*	See comment above on rescaling condensation efficiency: Is there a real benefit in changing the condensation efficiency classes with respect to the environmental aspects? What is the justification behind the choice to increase the number of classes which would imply a higher use of energy to comply with it?	We recommend adding the justification taking in consideration also the disadvantages.	Same reply as to question 3
12		45	*"If equipped with a status display, the limit shall be 0.8W"*	Please align it with the Washing Machine and Washers driers	APPLiA supports the alignment with the value established in the current revision of Washing Machine and Washers-driers Regulation.	Changed from 0.8W to 1W according to the current standby regulation and washing machines voted regulation.

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13		45	*Include a pictogram on the energy label, showing the content of recycled plastic in the plastic parts of the product*	This information should not be part of the energy label because it changes the mislead the intention of the label.	We recommend **to not** include this information on the energy label. This would mislead the main intention of the energy label. Moreover, this could lead to a large number of obstacles and numerous difficulties for industries that need to be taken in consideration. Please find in the file attached below, valid argumentations on why we ask to not include this information on the energy label. 2019-01-04 Recycled plastic	Same reply as to question 6
14		45	*Technical information on how to disassembly (for repair) and dismantle (for endof-life) for critical components should be available in booklet/technical documentation*	This information should be made available only to educated professionals. It must not be part of the booklet / user manual due to misuse by non-educated consumers.	We recommend allowing information only on the webpage for professional repairers.	Same reply as to question 7. In the case of dismantling, this requirement has been changed since it doesn't make sense to make end-of-life information available on the product manual. Critical parts are only relevant for repairing activities.

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15	3	129	Cleaning frequency of filters-	3 different sources depicted with 112, 113 and 114 reference number in this sequence. We need to see details of these sources; how could we acquire these sources?	Please provide the source/report with these data.	The sources are given in the report. More details cannot be disclosed due to confidentiality issues.
16	5	178	*Base cases (first paragraph)*	Characteristics of heat pump and electrically heated condenser dryer are too different to be combined in one base case.	Please differentiate or make two base cases for condenser dryer in order to appropriately calculating benefits and costs for each policy options.	The study team agrees. Base case 1 have been split based on heat source.
17	5	178	Table 43: Key performance parameters for the three selected – Base case 1: Condenser A+	It is useless to say that the average EEC is A+ for condensing dryers when HP dryers have in average A++ and heater condensing dryers have B. Please see comment above	Please differentiate or make two base cases for condenser dryer in order to appropriately calculating benefits and costs for each policy options.	Same reply as above
18	5	179	*The largest difference is the fact that heat pump condensing driers are now listed as a base case.*	This is not true, when HP and heater condensing dryers are put together into BC1	Split in two base cases (see comment above)	Same reply as above
19	5	180	*Thus, the material composition of Base Case 1 (condensers) will be based on a weighted average 186 of heat pump - condenser and heat element –*	These are significantly different technologies -can easily be seen in the mass of the dryers - about 40 kg for heater condensing but 55kg for HP. This cannot been put into the same pot.	Split in two base cases (see comment above)	Same reply as above

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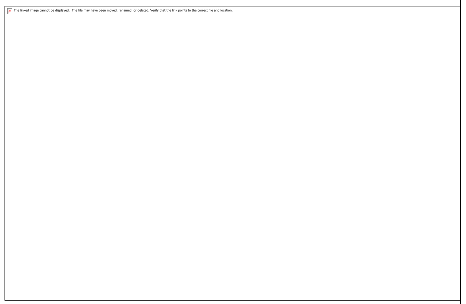
			condenser			
20	5	183 – Paragraph 5	Definition of Loading input is incomplete	What is about the initial moisture content of the base load? Shouldn't it be re-evaluated? According to APPLiA survey the spin speed has increased to 1150 rpm (compared to 1000 rpm assumed for current regulation)	Please analyse APPLiA consumer survey to find the correct IMC in households.	We have included an evaluation of the IMC in the report, based on the APPLiA consumer study. As we do not want to change testing procedures and lack solid data, we will not evaluate the IMC in our calculations in Task 6 and 7.
21	5	184	*Larger machines and a constant load means that the loading percentage will decrease, and thus the energy consumption per kg laundry will increase*	Where is the evidence for this assumption? Machines with larger capacities do not necessarily be less efficient at average load. They may only be even more efficient at the higher full load.	Please revise this statement. Specific energy consumption to dry partial load (i.e. 3 or 3,5 Kg) is the same independently on the rated capacity of the dryer (i.e. 7, 8 or 9 kg).	The correlation between rated capacity and energy consumption at 4.4kg differs based on the energy label of the drier. For A+ driers, a higher rated capacity increases the energy consumption at 4.4kg, where as a A+++ dryer reduces the energy consumption compared to a similar dryer with a lower rated capacity. See figure based on the 2017 APPLiA model database: 

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						Previously, a linear regression between the specific energy consumption (kWh/kg) at 100% load and 50% load was made, and the rated capacity of each dryer was divided with the average load of 4.4kg to find the loading factor. This regression was then used to find the energy consumption at 4.4kg, and to "penalize" machines at higher rated capacity (as the loading % was lower). The difference between the two calculation methods are negligible, but the study team has chosen to remove this penalization factor (it was only 1.5% at the maximum effect) to increase the transparency of the calculations.
22	5	184	*This effect is quantified based on the increase in energy consumption for part load operations shown in Figure 33, which shows that at 50% loading, the driers use ~12% more energy compared*	But partial load does not necessarily mean 50% of the rated capacity. As given in the base case a constant average load of 4.4 kg is considered. The described effect of increasing energy consumption of partial load with increasing rated capacity is only related to the higher absolute load at 50% capacity (e.g. at 7kg rated cap. The 50%partial load is 3.5 kg which has logically lower energy consumption than 50% partial load of 9kg rated capacity of 4.5 kg, but with both rated	Please re-do the calculations. We recommend using APPLiA data to review this calculation.	According to Ecodesign Regulation, the partial load is 50% of the rated capacity. However, 4.4 kg is also a partial load. We will reformulate text. For other comment, see answer to question 21.

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			to a cycle loaded 100%. A linear correlation between the energy consumption for 100% loading ("0% more energy"), and 50% loading is established and then used to calculate the effect of the increased nominal capacity of driers.	capacities the energy consumption is the same at 4.4kg)		
23	5	184	*This above described increase effect per kg laundry is the only thing that is assumed to change regarding the efficiency of the tumble driers after year 2016. The average EEI levels of sold tumble driers from 2016 is thus assumed to be constant.*	To be honest this assumption seems to be wrong! Evidence can be done by calculating the energy consumption for a fixed load of 4.4 kg using a linear interpolation between the declared values for full and half load of all models given in the APPLiA model data base.	Please re-do the calculations. We recommend using APPLiA data to review this calculation.	See answer to question 21.

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24	5	184	Table 46: Electric consumption an hours in different operation modes	Why have air vented dryers less duration in left on-mode than condenser dryers? Cycle times for air vented dryers are shorter than for condenser dryers. So, there should be more hours in off-mode.	Recalculate with appropriate timings also for other tables in the document. We recommend reviewing all table 46.	Table have been updated with new base cases, and updated values based on a combination of GfK data and the APPLiA 2017 model database. Air vented driers have more off-mode hours than condenser driers.
25	5	184	Table 46 Row4	According to 392/2012 the left-on-mode duration in cases of dryers without power management system is the time of the year minus the operating time for 160 cycles divided by 2. An average duration of 41 h per year would assume that all dryers have an average left-on-mode duration of 15 min per cycle. That is not true.	Please re-calculate the duration considering the right assumptions	Same comment as above
26	5	184	Table 46 row 6	This would mean the dryer is only running for 4h per year (total hours in a year = 365 * 24 = 8760h) This cannot be true	Please recalculate it.	Same comment as above
27	5	185	*Conversion factor*	This factor has been established in about 2010. Is this still true? It should have changed within the last 8 years significantly with the introduction of renewable energy sources.	We recommend taking in consideration the current factor in calculations.	The factor used is in correspondence to factor used in other studies.
28	5	191	*Content of copper for BC1*	This high amount is only valid for HP dryers. heater-element dryers are much closer to vented dryers.	Please separate BC1 into two cases for each HP dryers and heater condensing dryers.	Base cases will be split and values for each updated.
29	5	191	Table 50	The missing differentiation between HP and Heat-element condensation dryers give the wrong figures.	Please separate BC1 into two cases.	Same comment as above.

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30	5	188, 191	Table 49: Input economic data for Ecoreport tool; Table 50: LCC of the three base cases	Why are there no installation costs for gas-fired dryers in table 49?	We recommend including installation costs for gas-fired dryers in table 49 as in table 50	An installation cost has been added equal to which was stated previously in the report.
31	5	192	*while BC 2 has the lowest LCC.*	According to Table 50 BC3 has the lowest LCC	Please align table 50.	Table and conclusions have been updated following the new base cases
32	5	192	*Main conclusions*	Why does lower energy consumption results in higher CO2 emissions (compared to first bullet point)?	Please, explain on which bases this assumption is made.	
33	5	192	*2nd bullet point of conclusions*	How are the savings of TD versus drying the laundry in heated rooms considered?	Please consider the benefit of drying in TD versus drying on the line in heated rooms.	We are not comparing drying methods but only establishing the life cycle environmental impacts and costs of the driers.
34	6	195	Table 52, point 3: List of design options with descriptions and input parameters – *Multi-motor setup*	A setup with additional motors will also consume additional material.	We recommend including under “other potential effects” material for additional motor.	No significant impact on materials consumption. Two smaller motors might have larger material consumption compared to one large, but this would not always be the case. Increase considered negligible.
35	6	195	Table 52, point 4: List of design options with descriptions and input parameters - *Longer cycle time with lower drying temperatures*	-5.0% for base case 1 and 2 is a wrong assumption.	We ask to provide physical and thermo-dynamic argumentations for justification of this assumption.	The efficiency/COP of a heat pump circuit is proportional to the difference between the evaporation and condensation temperature/pressure – a higher pressure means the compressor needs to do more work, and thus lowers the COP. It is also described in section 6.1.4. See

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						https://en.wikipedia.org/wiki/Coefficient_of_performance#Derivation Assuming a refrigerant evaporation temperature of 10C, and a condensation at 65C, reducing the drying temperature to 50C will increase the efficiency of the heat pump circuit by ~31%, but reduce the heating power by ~23%. Assuming this corresponds to a 23% longer cycle time with 200Wmotor, the combined effect is a savings of 4-5% electricity. For non-heat pump driers, a lower drying temperature would reduce the heat loss (which is proportional to the temperature difference between the ambient and the drier). This effect is much lower and is thus considered negligible compared to the increase in electric consumption on the fan/drum motor.
36	6	195	Table 52, point 9: List of design options with descriptions and input parameters – *Load sensors*	A new sensor and the related electronics will consume additional material. The load sensor cannot be considered as a design option (please refer to our comment at row 4 and 5 of this table).	We recommend including under “other potential effects” material for new sensor and related electronics.	Design option removed.

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				The assumption that the introduction of a display of the actual load has no impact to the material is not true. The sensors needed are not yet available, must be added to the dryers in addition, dryers without display would be eliminated. Costs of the dryers will significantly rise with such a system		
37	6	196	Table 52, point 7	Where is the evidence for this assumption? See also comment on efficiency of dryers with different capacities at partial load in clause 5.1.3	Re-evaluate the effect as mentioned in the comment 23	Design option removed. By removing the penalisation factor of 1.5% extra energy consumption mostly for HP TDs, the effect of this option is negligible.
38	6	196	Table 52, point 8	The effect of exchanging heater condensing by HP is factor 50% minimum. The wrong estimation is due to wrong assumptions of base case (HP and heater condensing in one case)	Divide the base cases of HP and heater condensing dryer and recalculate.	Base cases have been split and table updated.
39	6	199	6.1.1 replacing asynchronous induction motor with permanent magnet synchronous motors	The additional cost is mainly due to the more expensive electronics needed to control the motor. This cannot be scaled down to the motor size	An improvement cost should be much higher than 10 € (depending on the technology).	This cost is based on available information (Washing Machine's preparatory study, page 427, Table 6.4). Considering APPLiA's input to Design Option 2 (below), and that we see larger price differences between a++ and a+++ models on the market (130 EUR), costs have been modified to 16 EUR/unit, which gives and increased observed retail price of ca.45 EUR/unit.
40	6	199	6.1.2	The costs difference of 5€ assumed are not correct (too low).	An improvement cost closer to 45 € (depending on the technology) is more representative.	Same reply as above. We have changed improvement cost to 16 EUR/unit.

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41	6	200	6.1.4 Longer cycle time with lower drying temperatures	Changing the temperature in a heat-pump dryer is quite complex (requiring to either use a variable speed compressor or to change the complete heat-pump setup). How did they calculate the optimum cycle time for such a change	Please explain calculation in more detail. We ask to provide physical and thermo-dynamic argumentations as justification of this assumption.	Same reply as to question 35
42	6	205	6.1.12 Spare parts availability	We see no reason why spare part prices will decrease in medium/long term. On the contrary, they will increase due to higher storage facility and logistics costs	We recommend including higher spare part costs in the assessment.	We have removed any assumption on purchase price increase and have only included increase of repair costs for consumer in LLCC analysis, to avoid subjective judgments. The study team has requested APPLiA to provide specific input, but only generic comments have been provided.
43	7	224, 225	7.1.2 Effectiveness of the regulations	We have the impression, that the effect of the present energy labelling regulation on sales and prices of heat-pump dryers is overestimated. Heat pump technology was just not mature enough to be manufactured on large scale before 2013. On the other side, other comparison possibilities for consumers (e.g. consumer organization test results) are underestimated by the study.	In general, we recommend including in the analysis all the factors which play a role in this field (such as consumer organization test results, technology, etc.)	We agree that consumer organization tests and economic incentives in some MS also have contributed to the development. However, these factors have not been included in the analyses and we consider the effect minor compared to the effect of the energy labelling regulation. We have mentioned other factors in the text.
44	7	228, 231	7.1.3 Efficiency *Evaluation question 1* *Evaluation question 4*	Manufacturer turnover should not be mixed with manufacturer profit. The higher cost of heat pump tumble dryers is not only due to R&D expenses, but also due to a much higher cost of a heat pump system as compared to a heating element.	We recommend reviewing this evaluation by including also other factors (such as the higher cost of heat pump system).	This section does not consider the profit of the manufacturers but only the turnover. The content about innovation costs is of more general nature. Innovation costs could include both R&D and higher costs for heat pump systems.

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						The last section in 7.1.3 is dealing with administrative costs. However, the word administrative was missing. It has now been added. Some minor changes of the text have been made to reflect this comment.
45	7	232	7.1.3 Efficiency *Evaluation question 6*	Why should the product database reduce regulatory costs? It requires additional bureaucratic effort and thus increases costs for manufacturers. Also, for member states the costs are increasing, because they have to check the correctness of the data in the database in addition to the compliance testing	Point out in the report, that checking correctness of the data in the database does not replace compliance testing, on the contrary it has to be done in addition.	We have deleted the section about the product registration database, because this measure will probably require a revision of the Ecodesign Directive. Therefore, it is not relevant in this context.
46	7	233	7.1.4 Relevance	We doubt, that without an energy label there is no incentives for the manufacturers to make further improvements. There will always be competition on the energy efficiency, like "most efficient ...". This does not require an energy label.	The energy label is a strong incentive, but it is not only one. Please, take in consideration also other factors (i.e. competitiveness, consumers organisation testing etc.).	Agree. Text has been changed. The new text mention that the incentives for the manufacturers will be reduced without the energy label.
47	7	240	*The new SEc will be based on the heat pump driers only*	It is assumed that declared values represent the real consumption well. This is not true as manufacturers use various strategies for declaration based on the measured values (within the rules of the elabel).	For the definition of the SEc consider that in the declaration values given in the APPLiA model database some uncertainties are included which are not physically based.	The study team will take this into consideration – but as it is currently the only data source available, we still need to use it as a basis for estimating the effect on a new SEc. The uncertainty linked to these parameters have resulted in the SEc line being modified from the first draft.
48	7	240	*Figure 70*	The slope of the trend-line in this graph is highly dependent on the numbers of the models considered (for 10 kg very low, for lower capacities much higher).	Consider the uncertainty of the graph. We recommend following the recommendation given at the stakeholder meeting (keep it as it is with the exponent 0.8).	A new slope is made based on the average value for each capacity and energy label, which is assumed to be a better fit for the current market compared to the old 0.8 factor.

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7.2.3 49	7	240	Proposed policy options incl. barriers and opportunities-	New EEI calculation method contains Etc and SEc. Further calculations show only weighted average energy consumption (Et) and weighted average cycle time (Tt) and Sec for both vented and condenser dryers. Etc calculation is not explicitly given.	Editorial remark: Et should be Etc. Please correct the typo.	Corrected.
50	7	240	EEI Formula – $\text{EEI} = \frac{Etc}{SEc}$	The multiplication (x 100) is missing. Please add it.	Please re-write the formula as follow: $\text{EEI} = \frac{Etc}{SEc} \times 100$	Corrected
51	7	241	EEI - Description	The description of EEI has no unit [kWh].	Please remove the unit kWh.	Corrected
52	7	241	SEc formula	This approach means that versus the current regulation the dryers with higher load will be panelised even more. Considering the 7kg rated capacity dryer as base case with new formula 9kg dryer has a penalty by 8.4% where it has been 6.3% before.	Please justify the additional penalty of large rated capacity dryers.	The new standard energy consumption is changed to reflect the current market as good as possible, and not to penalize dryers with higher rated capacity. The adjustment is the result of the old SEc being outdated and only valid for a market that does not currently exist.
53	7	242	Calculation Ct	What about Ct? The same structure of formulas as for energy and time should be used. A better approach would be: calculate the sum of water evaporated and the sum of water collected through all test runs and calculate quotient out of this.	Please consider a modified calculation of the weighted condensation efficiency.	Added.
54	7	244	7.2.3. Table 59 *PO1a - Barriers*	If tumble dryer sales are reduced this implies higher rate of laundry drying in heated rooms, which would increase overall energy consumption	This effect should be mentioned in barriers as well.	There is no evidence showing this will happen.

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7.2.2 55	7	244	Proposed policy options incl. barriers and opportunities - *all heating element equipped driers from the market, significantly reducing the overall energy consumption and GHG emissions.*	APPLiA suggest to better rephrase as suggested on the side.	Please rephrase this "*all heating element equipped driers from the market"*, with: *(…) Dryers with electrical heating element as a main source (…)*	Corrected.
7.3.3 56	7	254	Description of policy options for energy and performance-	In order to see energy class distribution, Et value is taken as Etc. A++ and A+ products are going to C class when we take Et in EEI calculation.	Please replace A+++ (+10%) with A+++ (-10%) The new scheme should reflect the different technology used in the heat pump and in conventional dryers. Please check the calculation and the definition of the class limits.	Corrected A+++ label. New class intervals have been made.
57	7	255	Table 63: New proposed condensation efficiency class intervals	The calculation method on how they calculate the condensation efficiency class intervals is missing.	Please clarify the calculation used.	Added in section 7.2.3
			Questions presented during the Stk meeting			

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	6		Design options	a. Do you agree with the design options presented? Are they relevant? b. Do you agree with the potential environmental improvemen identified? And with the LCCs? c. Do you agree with the applicability of the design options for each base case? d. Do you agree with the clustering of the design options? The were used as starting point for defining policy options e. Other questions/comments on task 6?	Answers: b. It is highly recommended to look at heat pump dryers as a separate base case. This would allow to identify the relevant improvement potentials for heat pump dryers, which are covered by the replacement of electric heaters with heat pumps in the combined base case.	The base cases have been split by heat source.

	7		Scenarios	• Low power modes: comments about the proposed removal of low pov modes in the energy consumption calculations?
				• Comments/questions about the proposed horizontal amendments?
				  • Any input to the calculation of SEc?
				• Comments/questions about the proposed Policy Options?
				• Comments/questions about 'a' and 'b' POs?
				• Comments/questions about the rescaling of energy classes?
				• Comments/questions about scenarios for energy and resources?
				• Comments/questions about the main conclusions and recommendatic
				  • What is the increased loading you would expect from a consumer feedback system? Do you think 10EUR/unit is a realistic additional cost? If not, why?
				  • Do you think that a period of 5 years for making spare parts available is eno Or do you think they should be available for longer?
					Answers:
					a. We agree
					b.
					b.1 we recommend to keep 0.8 as exponent (see comment 48 above)
					c. we strongly disagree with POs b, as it is not feasible (see our comments 4-5 and explanations above)
					(…)
					h.
					h.1 no increase of loading expected as proposal not feasible – much higher additional costs expected (see our comment 39 and explanations above)
					h.2
						Actions already cited in previous questions' replies

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<tr><td>1</td><td>3</td><td>130-131</td><td>Larger capacities</td><td>We welcome the reflection on the trend towards increasingly larger capacities and it being identified as a major drawback to the impact of the Ecodesign and Energy Labelling Regulations. This is indeed a problem that has also been identified in other product categories and which undermines the energy savings linked to the Ecodesign and Energy Label measures.

We think the study team's suggestion to base the standard energy consumption (SEc) on the "best fit" line for heat pump tumble driers is a step in the right direction, as this effectively makes the energy efficiency index (EEI) slightly less dependent on the rated capacity of the products. This is however not enough to address the issue of growing capacities of tumble driers, which is happening despite household size steadily decreasing in all EU countries[322], and which might be neglecting some of the savings associated to increased efficiency.

In the case of washing machines, larger capacities issue has eaten up a large part of the expected energy and water savings, and the current EEI formula is one of the causes of this unfortunate</td><td>We suggest the study team looks into these design/policy options:
• We invite the study team to draw inspiration from the new provisions discussed in the washing machines, fridges and displays files in 2018.
For washing machines for example, it was discussed having a quarter, half and full load test to avoid machines getting bigger. This can improve the consumption adaptation to small loads for the label programmes. Small loads (such as only white underwear) are a reality in washing machines and tumble driers and the consumer's average load does not change in function to the size of the tumble drier they own.
• Introducing a digressive/asymptotic SEc formula, which would provide virtually no additional benefit for larger capacity tumble driers beyond a certain capacity.
• Options to encourage tumble driers to be used as close to full capacity as possible. Indeed, aiming at a better adaptation to underloading as suggested by the study team will not be enough to stop the trend to larger machines, because there is no guarantee that the adaptation will happen for loads and programmes others than those required for testing by the regulation.</td><td>• A quarter loads are not as relevant for tumble driers (only 3% according to APPLiA's survey). Not all washed clothes are dried in the drier. We have adjusted the Etc formula to reflect lower loads without having to modify test method which we think still reflects current loading.
• The study team have investigated different ways to do the SEc formula (incl. asymptotic) but have ultimately decided on a variation of the presented fit. This difference between all the investigated options are minor. This limits the amount of subjective assumptions and bases the new calculation method solely on the available data. Compared to the old SAEc calculation method, this reduces the energy label incentive of producing larger machines because the correlation between SEc and the rated capacity will be much lower.
•</td></tr>
</table>

322 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Average_household_size,_2007_and_2017_(average_number_of_persons_in_private_households)_new.png

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				situation. A study[323] by Coolproducts campaign and an analysis by Topten Europe have shown that currently good efficiency levels are mainly reached by adding capacity and not reducing energy consumption [324]. This is because the capacity is often more significant for determining a machine's energy efficiency class than the energy consumption. We believe that the capacity of tumble driers should be in line with the capacity of the washing machines (or it should be even smaller). Therefore, the EEI formula should not favour tumble driers which are bigger than washing machines.		
2	3	156	Tolerance	Art. 7 of the regulation indicates "assessing verification tolerances set out in the regulations" as one of the objectives of the review, while the study concludes that there is no reason to increase the verification tolerances although no result for the EU RRT performed by APPLiA has been presented yet.	Assuming that the quality of test methods improves, we invite the study team to also assess the option of decreasing the tolerances.	The study team is waiting on the RRT results. The conclusions about not changing the tolerances might be revised at a later stage in the study when the results are available.
3	5	178	Base Cases	BC1 (condenser tumble driers) includes both heating element and heat pump tumble driers. In order to better analyse design and policy options, it might be better to split this base case into two.	Split BC1 into two separate base cases and adapt the subsequent analysis accordingly.	Base case 1 will be split according to heat source, thus making 4 base cases in total.
4	6-7	196	Table 52	At the second stakeholder meeting on 4/12/2018 stakeholders found design Option 9 "Decreased specific electricity consumption and increased average load by displaying the actual load with weight sensors (i.e. consumer feedback systems)" not adequate based on the following reasoning: • Load of the drier depends almost exclusively on load of the washing machine	• Remove design option 9 in table 52 and elsewhere in Task 6. • Remove policy options PO1b and PO2b in Task 7.	PO1b and PO2b have been removed as design options and policy options.

[323] https://www.coolproducts.eu/policy/white-goods-spin
[324] Anette Michel, Sophie Attali, Eric Bush. Topten 2016. Energy efficiency of White Goods in Europe: monitoring the market with sales data – Final report. ADEME, 72 pages.

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				• Weight of wet clothes will depend on the moisture content of clothes, and therefore any displayed load might be misleading i.e. because optimised drying efficiency would also consider the function of the spin cycle of washing machine used. Hence, it makes no sense to have sensors on tumble driers, but they should rather be a requirement for washing machines and washer-driers.		
5	7	233-234	Relevance of current regulations	The report mentions: *"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 27% improvement in energy efficiency)"* Note that the energy efficiency objective has recently been updated to 32.5% by 2030 (see here).	Revise the text to reflect the new energy efficiency objectives. **More importantly, the analysis of design and policy options needs to take into consideration the considerably increased energy efficiency target, by suggesting more ambitious Ecodesign/Energy labelling measures for Tumble driers. For example, by introducing new Ecodesign requirements to enter into force in 2021.**	The new target has been added to the text. The analyses of new design and policy options is not part of the evaluation of the current regulation in this section.
6	7	235	Relevance of current regulations	The report states: "*The ecodesign regulation is probably less relevant to the citizens, but that is linked to the nature of ecodesign regulations in general*." The Ecodesign regulation might be less "visible", but not less "relevant" in our opinion.	Delete the sentence, or alternatively include the following: *"The Ecodesign regulation provides consumers better performing products and saves them money by ensuring that products that are too costly to run are not allowed in the EU. It also requires for relevant information (e.g. programme time and energy consumption of the most common programmes; energy consumption in off-mode and left-on modes) to be included in the instruction booklet for users."*	Agree. Text has been revised. Proposed text used.
7	7	236	Stakeholders consultation	*"A first stakeholders meeting was held on the 26th of June where representatives from Member States, testing facilities, consumer organisations and manufacturers provided input to the first four tasks"*	Correct accordingly: *"A first stakeholders meeting was held on the 26th of June where representatives from Member States, testing facilities, consumer and **environmental organisations** and manufacturers provided input to the first four tasks".*	Added.
8	7	240-241	EEI Formula	The Energy Efficiency Index is described as:	Correct: *EEI = Etc/SEc *100*	Corrected

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				EEI = Etc/SEc Which means that a "standard" tumble drier would have an EEI of 1.		
9		242		'Delay start" mode has not been included.	The "delay start" mode has not been included in the report and hence, proper justification for this should be provided or the definition and proposed requirements for that mode should be included.	It has been included and aligned with the ED WMs requirements on low power modes
10	7	244-245	Policy Option 2a	The study team mentions as a barrier that *"Removing all heating elements driers from the market might reduce the total sales and thus industry turnover, as the average price per product would increase."* The experience from previous Ecodesign and Energy Labelling measures from tumble driers, which the study team very well describes in the earlier parts of chapter 7, shows that the fact of selling more expensive products more than compensates any loss in revenues from lower sales.	Rewrite the sentence: *"Removing all heating elements driers from the market might reduce the total sales of products. However previous experience shows that any lost revenues would likely be compensated by the increase in the average price per product"*	Corrected
11	7	244-246		There is discrepancy between the suggested dates of entry into force of Ecodesign and Energy Labelling requirements. There is also discrepancy between the resource efficiency options under Ecodesign (PO3 and PO4) and the energy requirements. We do not think there are reasons for delaying the entry into force of Ecodesign requirements on energy efficiency to 2023, particularly in view of the increased EU targets on EE (see our comment #7	Assess a policy option where all requirements (energy labelling and resource and energy requirements for Ecodesign) enter into force in 2021 - also aligning with the entry into force of other white goods revised measures in 2021.	See answer to question 5. This is to ensure a transition period where manufacturers get familiar with the new rescaling and energy efficiency methods, which are quite different to current scaling and methods. Also, this will facilitate the verification process, since Ecodesign proposed energy requirements will be linked to specific

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				above) and the urgency to act on climate change recently highlighted by the Intergovernmental Panel on Climate Change[325].		class interval limits. This transition period is not deemed necessary for the Ecodesign proposed resource efficiency requirements
12	7	246 & 269	Availability of critical spare parts	*"Ensure that critical spare parts are available for at least 5 years after the production of a model ceases, to promote a* longer *average lifetime of the product."*	All spare parts should be available during at least the average product lifetime.	A differentiation should be made between critical and other spare parts. It is mostly critical parts that make a difference in terms of availability. The availability period has been harmonised with the Washing Machines (10 years).
13	7	251	Figure 72	Graph is incomplete/wrong when compared to the energy label classes thresholds in Annex 6, Table 1 of Regulation (EU) No 392/12	Please add a "C" line at EEI level 85 and remove the "D" line currently at EEI level 100	Added
14	7	253-254	Figure 74, Tables 60-62.	We welcome the suggested rescaling of the energy label and the fact that class A is left empty as requested by the Energy Labelling Framework regulation. We believe however that the classes should be aligned with the proposed PO2 and adapted accordingly. Also, the width of the proposed energy classes is too heterogenous and may not help the consumer differentiate based on energy efficiency. In addition, the fact that classes E and F would be left empty does not exploit the full potential of the rescaling.	Please revise the energy class thresholds so that they help the consumer differentiate based on energy efficiency. We suggest something along these lines: A ≤ 55 55 < B ≤ 64 64 < C ≤ 74 74 < D ≤ 86 86 < E ≤ 100 100 < F ≤ 116 116 < F ≤ 134	The initially suggested classes will be revised – the provided input will be considered when updating the classes.

[325] Https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/

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15	7	254-255	Condensation efficiency	The study team suggests 4 condensation classes (A-D) evenly distributed between 80 and 100. This has the problem of making the colour-code on the scale difficult. The study team also suggests no increase in condensation efficiency under the proposed policy options. Given that under the proposed energy efficiency requirements most heating elements driers will not be allowed on the market, and that the condensation efficiency of condensation driers is generally much higher, we believe an increased condensation efficiency requirement is feasible and necessary.	We recommend the study team to explore the benefits of this alternative solution: • Three condensation classes evenly distributed between 85 and 100. • An Ecodesign requirement for condensation efficiency of 85 (as of 2021).	The condensation efficiency is inversely linked to the energy consumption of the driers. Thus, setting a higher condensation efficiency ecodesign limit might increase the energy consumption in general. A minor adjustment from 70% to 80% is thus proposed. The added classes are made to better differentiate the different models, and not to majorly increase the average condensation efficiency due to the points described above.
16	7	42 & 246	PO4	The study suggests some measures to facilitate repair and increase durability. We welcome these but think these options can be considered more comprehensively.	The study should look into the following design/policy options: ▪ Duration: <u>all spare parts should be available during the average product lifetime</u>, i.e. 12 years after the last unit is supplied. ▪ Delivery: A <u>maximum delivery time of one week</u> for spare parts should also be specified. ▪ Audience: <u>spare parts access should not be restricted to professional repairers but should be open to all types of repairers</u>. We firmly believe that no restrictions should be put to the availability of spare parts, to facilitate the involvement of as many actors as possible. Spare parts have a cost, which will serve as a deterrent to unexperienced consumers. ▪ Ensure <u>unrestricted access to repair & maintenance information from date of placing on the market.</u> ▪ Other factors to consider include <u>disassembly requirements</u>, disassembly sequence, the cost of spare parts, the use of	• See answer to question 12 • In the WMs this is fifteen days, we see no reason to have only one week • Agree, should be available to all repairers but introduce a warning sign to consumers • Added in Table 60 • JRC work is not yet finalized and not yet mature to uptake. Moreover, introducing economic parameters as requirements would add high uncertainty due to large variation between countries.

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					commonly available tools, and software update availability. Reference to ongoing work by the JRC and the Benelux/KU Leuven[326] study could be used to support this section.	
17	7	42, 246 256	PO3	The study suggests some measures for dismantling and recycling. In principle, we welcome these but think these options can be considered more comprehensively.	The study should look into the following design/policy options: ▪ We encourage to replace the term "dismantling" with "disassembly" to go beyond material recovery and recycling, and to also facilitate repair ▪ Restrictions on the use of materials or chemicals which represent a hazard to the environment, consumers or workers (in the context of multiple cycles of materials in the circular economy), i.e. for SVHCs and POPs which will limit recycling pathways. ▪ Restrictions on the use of materials or chemicals which represent a barrier to dismantling and recycling, i.e.: ○ Additives or coatings which are difficult to manage in recycling systems (e.g. carbon black, or opacifiers) ○ Non-modular, multi-layer or multi-material designs which are difficult to separate. ▪ Marking of plastics and additives according to the relevant ISO standards, particularly marking content including flame retardants.	▪ Dismantling is for EoL, a definition has been included and referenced in the report ▪ There is much uncertainty on their identification and REACH/RoHS already takes care of restricting these substances, not included ▪ The study team does not have evidence that shows these materials and chemicals prevent dismantling and recycling of tumble driers, not included ▪ This will pose great verification issues, not included
18	7	264-266	Turnover and employment	Figures 80-82 and tables 73-75 fail to cover the increased revenues and employment in independent repairers, which results in Policy Options 3 and 4 looking less attractive than others. In addition, as the study team also highlighted "product service models" could also generate additional retail turnover and employment opportunities for manufacturers – if well designed these could be linked with repair. In general, the modelling of revenues and employment poorly accounts for or supports circular business models and how these can be resource and energy efficient. As both retail turn over and employment are used to inform the recommendations this is quite a big omission and works against the ambition to use eco-design as a lever for the circular economy.	Estimate as possible the benefits from increased repairing activities.	The repair and maintenance cost have now been added to the manufacture's revenue in the task 7 model. This might not be an accurate represented of a real scenario as repair shops other than those associated with OEM are also present. It does however give a rough estimate on the increase in jobs and revenue. The difference between the manufacture's revenue, and the [retail revenue]/2.8

[326] http://www.benelux.int/files/7915/2896/0920/FINAL_Report_Benelux.pdf

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				Some studies are already showing very clearly how diversified business models can support sustained revenues in a given sectors. e.g. for the automotive industry McKinsey show this for falling direct sales, substituted by a growing after-market (repair) and recurring (sharing) revenues. See page 6 https://www.mckinsey.com/~/media/mckinsey/industries/high%20tech/our%20insights/disruptive%20trends%20that%20will%20transform%20the%20auto%20industry/auto%202030%20report%20jan%202016.ashx Some other general studies also highlight employment benefits from the circular economy: Green Alliance/WRAP 2015 http://www.wrap.org.uk/sites/files/wrap/Employment%20and%20the%20circular%20economy%20summary.pdf Circle Economy 2017 https://www.circle-economy.com/wp-content/uploads/2017/03/goldschmeding-jobs-report-20170322-lite.pdf WRAP/BITC 2018 https://www.bitc.org.uk/sites/default/files/smart_growth_economic_case_circular_economy_may_2018.pdf Club of Rome https://circulareconomy.europa.eu/platform/sites/default/files/the-circular-economy-czech-republic-and-poland.pdf IISD 2018 https://www.iisd.org/sites/default/files/publications/employment-effects-circular-economy.pdf Coolproducts, 2018 (p9) http://ecostandard.org/wp-content/uploads/Briefing-on-Ecodesign-and-Energy-Labelling-for-a-circular-economy.pdf		(due to retail margins) is thus the added effect of the repair and maintenance services.
19	7	266	Conclusions and	The report states: *"All the various policy options are evaluated based on a number of indicators. PO2 seems the most ambitious in terms*	Change to: *"All the various policy options are evaluated based on a number of indicators. PO2 seems the most ambitious in terms of*	Added

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			recommendations	*of energy savings, but at the initial high cost of **consumers expenditure**.”* While the statement is generally correct, it is based on average prices and fails to acknowledge the diversity of consumers and products in the market. Consumers for which upfront cost is an important criterion are able to find products whose cost is below the average. For example, from a quick internet search in the UK, we find: • Condenser tumble driers at £189.99 (€210.12, compared to an average of €504) • Air-vented tumble driers at £139.99 (€154,95, compared to an average of €248) • Gas-fired tumble driers at £179.99 (€199,06, compared to an average of €374)	*energy savings, but at the initial high cost of **consumers’ average expenditure**.”*	
20	7			The report states: *“All the various policy options are evaluated based on a number of indicators. PO2 seems the most ambitious in terms of energy savings, but at the **initial high cost** of consumers expenditure.”* We recommend to include learning curves (mentioned in the Ecodesign methodology for new preparatory studies) to predict future cost benefits allowing to ‘account for price and efficiency effects of technological learning in the period between data recording and a regulation taking effect’ (Ecofys, 2014).	We invite the study team to apply this methodology and thereby reach cost estimations that are closer to reality and allows for more effective policy measures.	Added “initial” to the paragraph. The high initial expenditure is due a high amount of consumers being forced to buy heat pump driers instead of heating element driers. As an alternative, ecodesign limits could be introduced in tiers to even-out the initial high cost, however, this would reduce the effectiveness of the regulation.
21	6-7		Material efficiency	Use of recycled plastic has not been considered in design and policy options. This might be interesting as it could help bring the initial consumer expenditure down due to the use of more economic, recycled plastic.	Explore a design option which limits the amount of virgin plastic in TDs in Task 6, as has been suggested by the consultants under the preparatory study for vacuum cleaners.	All design options have been recalculated based on updated base cases splitting and the potential environmental savings for this design option in particular came too small for all base cases. Thus, it has

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						been removed from LLCC and Task 7 analysis.
22	6-7		Moisture sensors	As we understand it, moisture sensors have not been included in the design or policy options.	We recommend that the study team assesses the benefits (in terms of energy consumption) and drawbacks (in terms of additional materials needed) of an Ecodesign requirement for mandatory moisture sensors - which would automatically stop the machine when a certain level of dryness is reached.	Without moisture sensors, the driers will use considerably more energy during testing procedures, which has made manufacturers include them in all (>99%) of all available models on the market. It is thus assessed that there is no need for an ecodesign requirement related to moisture sensors, as the current regulation is enough to ensure that all driers are equipped with them.
23	6	197	Refrigerants	It has been established by the study that the heat pump technology is taking over the market and this will lead to a large quantity of refrigerants with high GWPs to be put on the market.	The study should include broken down data per type of refrigerant to identify the best technology available in terms of refrigerant use. Additionally, we invite the study team to take the opportunity of this review to further assess requirements to encourage a more widespread use of low-GWP refrigerants. Here some suggestions: 1. Efficiency bonus for appliances using GWP ≤ 4 or preferably natural alternatives; 2. Malus scheme to penalize on the energy efficiency requirements those appliances using refrigerants with the highest GWP allowed in the market; 3. The Energy Label to include a pictogram indicating if a product contains a natural refrigerant and/or lower-GWP or a higher-GWP refrigerant; 4. Restriction of use of HFO.	It is too early to introduce such requirements; the study team believes information on refrigerant use is the first step in order to get an overview about refrigerant used. Also, due to its low significance when quantifying GWP. We have therefore only introduced an information requirement in product manual.
24	5	178	Energy consumption	The study team states there is "no data for energy consumption in other programs than the standard cotton program", however, under	We invite the study team to further check the availability of energy consumption in other programs as the real consumption might be	The study team do not have access to this level of data. Even though that some

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				the current Regulation it is mandatory for manufacturers to provide indicative information on time and energy consumption of the main drying programmes.	higher than indicated in the base cases within Task 5. Other preparatory studies such as the ones for washing machines and dishwashers may serve as inspiration on how this information has been treated. In case of lack of information, we invite the team to work based on assumptions.	manufacturers report the energy consumption of multiple programmes in the product fiche, this data is not reported and collected on a widespread basis. A section has been added to discuss the effects of the tumble drier programmes used.

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1	5	3, meeting minutes	Second meeting minutes; "B"; base cases	"Current base cases show that gas driers have the lowest LCC due to mix of condensing driers and the primal to electric conversion factor. **This should not be the case**,"	I don't know which would be most economical; but the comparison should be made in the report. (and with reducing the number of cycles, Heat Pumps may not be economical). 'this should not be the case' imo should be altered. Also note I proposed making Condenser & Heat pump dryers into 'Base Case 1A' & 1B, with a time-variable ratio between them defining the global Base Case 1. As closing remark: some of the policy options, or materials (refrigerant, copper) only apply to 1 group.	Base cases have been split as BC1 and BC2 for simplicity reasons.

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2	6	na	Policy options: Making heat pumps more economically advantageous?	in terms of policy options: if Heat Pump dryers are the most expensive in LCC, but best option for GWP/energy usage, and best 'improvement path' perhaps policy options could include measures purely encouraging to lower the cost of HP dryers; e.g. lower VAT tariff in most direct example; although VAT is at national level; lowering repair costs on heat pump dryers (allowing other dryers to 'die off' faster).		Assessment of impacts, including monetary costs and not LCC, is part of a review study in Task 7 (see page 139 MEErP methodology, part 2). The other indicators proposed are outside the scope of a preparatory study.
3	6	200	6.1.4 Longer Cycle Time with lower drying temperatures	Cycle duration 'below 6 hours' will absolutely be an issue for many consumers. We actually tested once an 'A' label dryer, without heat pump: it took 8 hours to dry. That this is an option or may be an option in the future should be very clear to consumers purchasing a dryer. This is also relevant as for the Washing Machines, the 'eco' program will be the default. Including the energy label program time (cycle duration) on the label as information, would allow consumers to make an informed choice (even if cycle	* Consider (proposing to) including cycle duration on energy label. (*If not, how to prevent 'cold air' dryers from getting an incorrect label class, for a program that will rarely if ever be used? a max duration limit, some stipulation,..)	The cycle time is already shown on the label. Rest of the comment not clear.

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				time would have no effect on energy label class).		
4	7	Slide 42	New energy label	I fear many consumers may see a listed consumption per cycle on future energy label and assume that is the consumption value *for a full load.*	* Consider showing the separate values on energy label: consumption (& cycle duration) of full, and half load. (energy label class still based on weighted average; condensor efficiency imo doesn't need to be shown per load)	This might confuse consumers more, as the label will then include a lot of information. Surveys shows consumers already have a hard time understanding the current label. More information will make this worse.
5	7	Slide 51	RESCALING OF ENERGY LABEL CLASSES	General remark: the economical benefit of the classes will be quite limited. Currently, we estimate about 30-40€ annual electricity cost (Belgium) for heat pump dryers, with 3 cycles/week. With only 2 cycles, saving 10% electricity e.g., (by going up 1 class), would save. 2-3€ per year?	Should, for the consumer, selecting a dryer of a higher energy class, not result in higher savings, in energy cost? Should this be somewhat taken into account, probably resulting in energy classes with a bigger range? Should resulting financial savings be made more obvious?	The proposed classes will be modified to better reflect the energy savings between the different labels. Energy savings are part of the calculations of monetary savings.
6	6	Slide 29	Nr 8, Total Energy, vs GWP	Different numbers seem listed for task 8 on the slides, vs in the report. I also think, the GWP reduction is *due to* lower energy consumption. So is it still correct to sum these two on slide 33?		The stakeholders meeting presentation have the most recent and correct numbers, which will be subsequently included in the final report. The summation has been revised.