Circular economy principles – quantifying the additional greenhouse gas savings potential of products covered under ecodesign

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Keywords

resources, Ecodesign Directive (EuP/ErP), change of behaviour, emission reduction, durability, circularity

Abstract

In December 2015, the European Commission adopted an ambitious Circular Economy Package designed to accelerate Europe's transition towards a circular economy. The Commission expects this transition to boost global competitiveness, foster sustainable economic growth and create new jobs. In the context of these wider goals, the authors conducted a study to prepare a first-order estimate of the greenhouse gas emission savings that could be delivered by applying circular economy principles to all products covered by the ecodesign and energy labelling regulations.

The circular economy principles modelled in this analysis were: improved recyclability, extended service life, service economy approach (e.g., product leasing, pay-per-unit-of-service) and improved refurbishment. The potential impact of extended service life, service economy approach and improved refurbishment was estimated for each product group individually. For improved recyclability, product groups were divided into five categories – white goods, lighting, electronics, motors and motor systems, and heating and cooling products. A representative product was selected from each of these five categories for a product-specific analysis and the findings for improved recyclability were then extrapolated to the full product category.

This paper presents results for each of the five product categories. Consumer electronics were found to have the largest greenhouse gas savings potential, particularly for recyclability and extended service life. And, for service economy approach, the study also found the average efficiency of the leased products was the most critical parameter influencing emission savings.

Building on these findings, this paper offers suggestions for next steps – including developing product metrics, stimulating recycled materials markets and developing more detailed market feasibility studies.

European policy context and objective of the study

Starting four decades ago, leading researchers introduced the concept that our modern, open-ended economic system of consumption could not be sustainable forever, and proposed that markets should evolve towards a more circular economy. These ideas were put forward through the work of Walter R. Stahel [Stahel, 2010], Michael [McDonough & Braungart, 2013], William McDonough [McDonough & Braungart, 2002], David W. Pearce [Pearce & Turner, 1990], R. Kerry Turner [Turner *et al.*, 1994] and many others. Although the exact definition may vary between authors, the general principles remain the same and are summarised by this definition used by the Ellen MacArthur Foundation [MacArthur, 2017]:

> A circular economy is restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times.

The European Commission expressed its willingness to take a position of leadership on this issue, with the adoption in December 2015 of a Circular Economy Package designed to stimulate Europe's transition towards a circular economy [EC, 2015a]. The description of a circular economy made in the European Commission Communication: *Closing the loop – An EU action plan for the Circular Economy* is quite similar to the definition by the Ellen Mac Arthur Foundation and corresponds to the understanding that the current paper is based on:

> The transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised, is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy. Such transition is the opportunity to transform our economy and generate new and sustainable competitive advantages for Europe.

Some private sector companies experimented with the implementation of these concepts while others went so far as to make it their business model; however these companies have remained exceptions and outliers, and not all have been successful [Guardian, 2012; GreenBiz, 2016]. For circular economy principles to become a mainstream economic business model, the current legislative and cultural framework that strongly favours (profits from) the open-ended linear economic system needs to be re-designed.

The Commission anticipates that this transition would boost global competitiveness of European businesses, foster sustainable economic growth and create new jobs in Europe. Undoubtedly, an open-ended consumption system in a world with finite and increasingly scarce resources will see costs increase. An economy that is built to run and thrive without importing new resources would have a considerable competitive advantage. But changes like those required to move toward circularity are not likely to take place spontaneously in an economic system that favours open-ended, linear markets. [Milios, 2016] For this reason, the strong political leadership demonstrated by the Commission through the Circular Economy Package will be instrumental in shifting the European Union toward a stronger, more competitive and environmentally sustainable global position.

The Circular Economy Package contains many facets, including a legislative proposal to reduce waste and an Action Plan that specifically identifies the Ecodesign Directive [EC, 2009] as a tool through which policy-makers can start to apply the principles of a Circular Economy to products. In addition to the Circular Economy Package, in December 2015 the Commission also issued a mandate to CENELEC, the European standardisation organisation, to develop measurement standards on material efficiency aspects to further support the implementation of ecodesign. In turn, CENELEC established a Joint Working Group that is focusing on developing horizontal measurement methods and standards on material efficiency which would later be supplemented by product-specific standards. Through the Circular Economy Package and the standardisation mandate, the EU is creating a robust policy framework to push the Circular Economy agenda forward. However, defining resource efficiency requirements is only the beginning of a true shift to a Circular Economy, and implementing measures that are taking this first step have already encountered resistance from companies. [EC, 2017] For this resistance to be overcome, the economic, social and environmental benefits of a transition towards a Circular Economy need to be made clearly visible. Some think tanks, advocates and academics have published work on the opportunity and wider benefits of a circular economy [Bačová *et al.*, 2016; MacArthur, 2013] but no study has attempted to thoroughly quantify the impacts of such a shift for appliances.

To improve the general understanding of some of the environmental benefits of such a transition, the exploratory study presented in this paper provides a first-order estimate of the greenhouse gas emission reduction that could be expected from products covered by the ecodesign and energy labelling [EC, 2010] regulations. Looking at all stages of the product life cycle, this study assessed and quantified the additional greenhouse gas savings that would result by applying the following circular economy principles in Europe: improved recyclability, extended service life, service economy approach (e.g., product leasing, pay-per-unit-of-service) and improved refurbishment. These estimates are intended to provide guidance where policy action could yield the greatest impact on greenhouse gas emissions. There are, of course, many environmental benefits that would result from a transition to a circular economy beyond avoided greenhouse gas emissions, however quantifying those benefits was beyond the scope of the exploratory study.

Methodology

The authors' exploratory study is meant to provide first-order estimates of the potential greenhouse gas emission savings from applying circular economy principles to products covered by ecodesign and energy labelling. The methodology followed for this study required making certain simplifying assumptions concerning the scope and depth of analysis of the study. These included:

- Analytical boundaries – the whole life cycle of the products analysed was covered in this study, from extraction of materials through to disposal; however, impacts beyond the product boundary (e.g., factory retooling and exogenous infrastructure upgrades) were outside of scope. The main sources of product life cycle assessment information were the ecodesign preparatory studies which are generally easily available and have been reviewed by European stakeholders. That said, life cycle assessment is not the main focus of the preparatory studies and they use a simplified methodology;
- Environmental impacts assessed – only CO_2 emission impacts were analysed in this exploratory study, although other environmental impacts would deserve a similar analysis;
- Technological obsolescence – the "smartness" and rapid technological evolution of products is expected to impact energy in use as well as useful service life. However, this impact was considered outside of scope and not assessed in this study because forecasting the interplay between technology evolution and consumer demand would be complex and difficult to predict at this stage.
- Deep design re-think – strong policy and/or price incentives to extend the lifetime of products and/or make them easier to maintain, refurbish, dismantle or recycle could deeply impact product design. However, this impact was not assessed in this exploratory study because predicting product redesign in response to hypothetical price and policy measures is not possible at this stage.

This study quantified additional greenhouse gas emission savings from applying general circular economy principles described above, but did not detail the specific policy measures that would be necessary to achieve these savings. The calculations focused on the CO_2–equivalent impacts, using Commission data sources and studies, including ecodesign preparatory studies. This may mean that the impact on CO_2 emissions of material considerations may be under-represented in this analysis; however, a sensitivity analysis testing the impact of a 30 % higher impact on CO_2 emissions of the non-use stages showed that this did not significantly change the conclusions.

DATA SOURCES

Data for the representative products has been derived from a number of sources, including recent Life Cycle Assessment (LCA) studies as well as Ecodesign ErP Preparatory Studies (PS) and Ecodesign Impact Assessments. Important data sources that were utilised are listed in Table 1.

Several studies have shown that the environmental impacts of life cycle assessment stages other than the use phase may be underestimated in the ErP Preparatory Studies ([EEB, 2009], [Oko Institut, 2012]). Therefore, a sensitivity analysis was conducted evaluating the effect of a 30 % higher impact for all life cycle stages except the use phase. The conclusion of this additional analysis was that the impacts associated with the higher share of all life cycle stages other than the use phase did not affect the conclusions, neither in terms of magnitude of the potential nor in terms of prioritisation of the products or type of improvement to be stimulated. The main shift was that for some product groups (e.g., coffee machines and professional refrigeration equipment), extending the service life became marginally beneficial instead of marginally negative.

Sales data and efficiency projections rely on information from [VHK, 2014] and [EC, 2015b] for all products except mobile phones for which [BIO, 2014] was used. Information and projections from these studies were peer-reviewed and adjusted, if obsolete, based on expert knowledge.

SCOPE OF PRODUCTS ANALYSED IN THE STUDY

At the moment there are more than 30 product groups (also called product "Lots") which are regulated under the EU Ecodesign Directive and Energy Labelling Directive. The dozens of energy using products covered under the Ecodesign Directive and Energy Labelling Directive were divided into five product categories as described in Table 2.

APPROACHES AND SCENARIOS CONSIDERED

This study estimated potential CO_2-equivalent emissions reductions by product category that could be delivered through a range of circular economy scenarios, including:

- Improved recyclability;
- Extended service life;
- Service economy approach (product leasing, pay-per-unit-of-service, etc.); and
- Improved refurbishment (modelled as one of the scenarios under "service economy approach").

Improved recyclability represents the impact of increasing the proportion of materials recycled for the share of 2020 products that are expected to be recycled, holding product material composition constant. It was assessed on the basis of a literature review focusing on the representative product for each of the five product categories. The findings calculated for each representative product were then extrapolated to all the other products within the product category (or appropriate subcategory). The extrapolation involved expressing the impact of improved recyclability as a percentage of the impact of the production and end of life of the reference product group, and applying this percentage to the sum of the production and end of life impacts of each of the other products in the group to estimate the overall impact of improved recyclability for that product category.

Extended service life refers to extending the average lifetime of products. It was assessed by applying the durability methodology in "Integration of resource efficiency and waste man-

Table 1. Sources of data for the estimates by representative product type.

Product group	Representative product analysed	Data sources
White goods and related products	Dishwashers	Ecodesign Preparatory Study for each product lot in this group[CIRCABC, 2016], [JRC, 2015a], [JRC, 2012b], [Ricardo, 2015]
Consumer electronics and related products	Television and computer displays	Ecodesign Preparatory Study for each product lot in this group [CIRCABC, 2016], Analysis for the review of Ecodesign and Energy Labelling Regulations, [JRC, 2012b], [JRC, 2014], [JRC, 2015b], [Bhakar, 2015], [Oko Institut, 2012], Life Cycle Assessment studies
	Mobile phones	[BIO, 2014], Life Cycle Assessment studies: [Ercan, 2013], [Güvendik, 2014], [Zink, 2014]
	Printers, notebooks	Ecodesign Preparatory Study for each product lot in this group [CIRCABC, 2016], [JRC, 2012b], other LCA studies for verification
Lighting Products	Non directional Lamps	LED Lamp Life Cycle Assessment Study [US DOE, 2012]; Lighting Regulation Review Study [DG Energy, 2015]
Motors and Motor Systems	Electric Motors	Ecodesign Preparatory Study for each product lot in this group [CIRCABC, 2016], methodology from [JRC, 2012a], [JRC, 2012b], [JRC, 2012c]
Heating and Cooling Products	Room Air Conditioning	Ecodesign Preparatory Study for each product lot in this group [CIRCABC, 2016], methodology from [JRC, 2012a], [JRC, 2012b], [JRC, 2012c]

agement criteria in European product policies – Second phase – Report n° 1 Analysis of Durability" [JRC, 2012a].

Service economy approach refers to a market offering based on a new economic model that charges for the service provided by a product, rather than on ownership of physical product itself. It was assessed by modelling the impact of both a "limited adoption" and a "broad adoption" scenario, as described in Table 3. The default scenarios presented here were adapted for some products as suggested by the literature and by product experts who peer-reviewed the study.

The potential impact of *improved refurbishment* was modelled as an additional scenario in which a service economy would develop but without impacting the average energy efficiency of appliances.

In this study we consider the potential impact of applying the principles of a circular economy to the products sold in 2020. For each product, potential greenhouse gas emission reductions are calculated for the lifetime of the baseline functional unit.

Findings

OVERVIEW

The findings of the study, in terms of CO_2 savings estimates for each product group are shown in the bar chart presented in Figure 1. The five circular economy principles are shown on the X-axis, and the five product groups are visible along the Y. The Z-axis provides the greenhouse gas savings in terms of kilotonnes of CO_2-equivalent emissions. On the far right, the CO_2-equivalent savings associated with the existing ecodesign and energy labelling regulations is shown, in order to provide a relative scale for the savings potential of the circular economy principles considered.

Figure 1 shows that consumer electronics emerged as the product category with the highest potential for greenhouse gas savings, particularly for extended lifetime and improved recyclability. For many of the products analysed, the emission reductions associated with the development of a service economy were strongly linked to the assumption that product efficiency would be higher under this scenario. For consumer electronics, the service economy did not indicate significant savings potential although there are still efficiency gains to be made. Thus, it would seem that the use phase may no longer represent such a dominant source of greenhouse gas emission savings over the product life cycle.

In the modelled scenarios, the development of a service economy was linked to the assumption that procurers of leased products would specify products that are more efficient than the average (i.e., purchasing the better quality/performance products on the market). Although anecdotal evidence suggests this assumption reflects the current situation, there is no guarantee that this practice would continue if there were to be a widespread market shift toward a service-based economy.

Table 2. Product categories of products analysed, covered under the Ecodesign Directive and Energy Labelling Directive (reference products marked in bold)

Five product categories created for this study	Product "Lots" under ecodesign and energy labelling
White goods and related products	Commercial refrigerators and freezers Domestic refrigerators and freezers Domestic washing machines **Domestic dishwashers** Laundry driers Vacuum cleaners Kitchen appliances Professional wet appliances and dryers Non-tertiary coffee machines Refrigerating and freezing equipment
Lighting products	Tertiary Lighting **Domestic lighting (general lighting equipment)** Directional lighting
Consumer electronics and related products	PC:s and servers **Televisions** **Imaging equipment** Enterprise servers Complex set-top boxes Simple set-top boxes Sound and imaging equipment Smart Phones
Motors and motor systems	Distribution and power transformers Ventilation fans **Electric motors** Circulators in buildings Electric pumps
Heating and cooling products	**Room air conditioning appliances** Local room heating products Central heating products (other than CHP) Tertiary Air Conditioning

Table 3. Summary of default assumptions under each "service economy" scenario in 2020.

Factor	Limited Adoption Scenario (LA)	Broad Adoption Scenario (BA)	Improved refurbishment / Average efficiency Scenario (IR-BA)
Market adoption rate	10 %	50 %	
Impact of refurbishment and maintenance	One repair/refurbishing/upgrading transaction would take place every five (5) years during the life of the leased machine, each equivalent to 10 % of the kg CO2-equivalent impact of initial production.[1]		
Lifetime	The average lifetime of a leased product is assumed to be 1.5 times longer than the average non-leased product		
Efficiency	Leased products are assumed to be more efficient than the average non-leased product (varies by product)		Same efficiency as average non-leased product
Impact of a better design[2] for dismantling, repair and recycling (due to leasing influence)	0 %	A 20 % reduction in the impacts of the extraction of material and of the end-of-life for the base case (due to reduced time and energy required for part/material extraction, to higher recycling rates and even potential re-use of some components).	

[1] The impact of each transaction used to estimate the impact of extended service life is 10 % of the initial impact of production and end-of-life. This impact was made quite significant here to take into account some level of refurbishment to improve efficiency throughout the lifetime, and in the case of a change of use the impact of cosmetic changes and transport.

[2] Better design for dismantling may also result in increased recycling yields (more material recycled in general, and more recyclable materials present in the original design) but this has not been quantified because it would require changes to the underpinning LCA analyses used in this study and is not predictable. Thus, the estimates presented in this report may be underreporting the benefits.

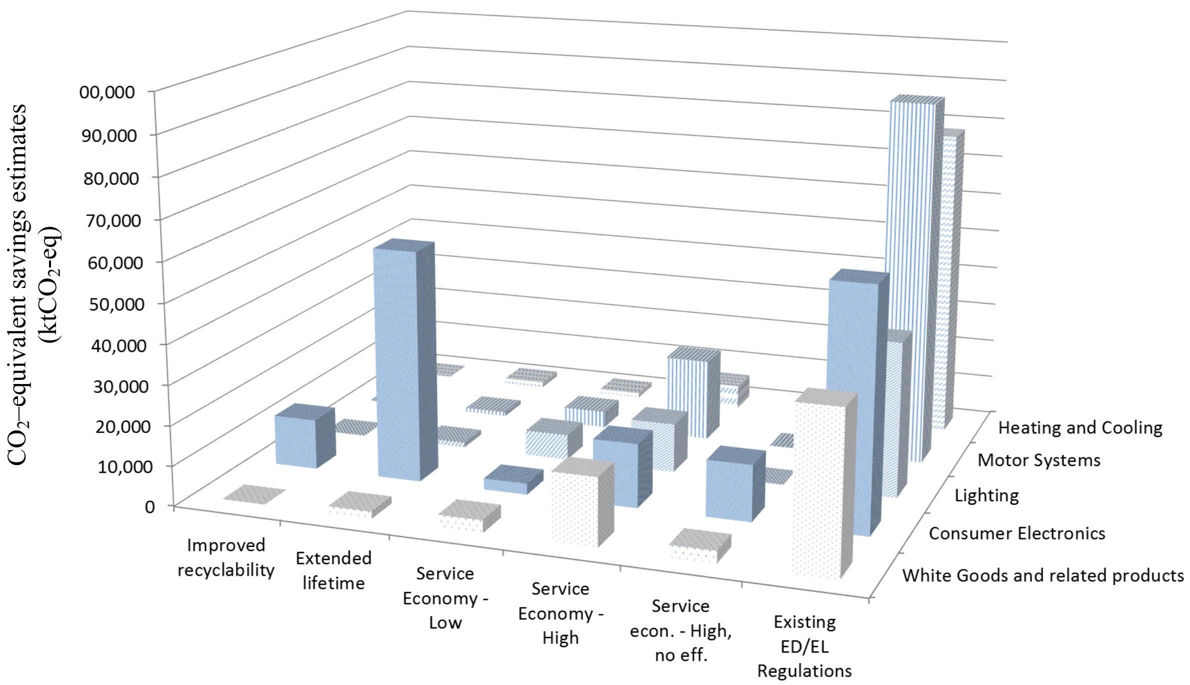

Figure 1. CO_2–equivalent savings estimates for each product category and each circular economy scenario.

Thus, promoting the service economy option, in the absence of policy measures to encourage more energy-efficient leased products, represents a risk that greenhouse gas emission savings related to leasing may not be realised, and leasing could even increase emissions if less efficient models were installed.

One option to address this issue would be to combine requirements on energy performance and extended life time (*e.g.,* via the ecodesign and energy labelling regulations), such that the more efficient a product is, the longer it will last. However, the fact that ecodesign and energy labelling requirements only apply to a product when it is first placed on the European market could be an issue. These directives may need to be revised if a service-based economy becomes main-stream and products are refurbished and placed for a second or third time on the market. Furthermore, product software and firmware may need to be updated, affecting product performance and efficiency; and the applicability of the regulatory framework is uncertain as this is not how the product was originally placed on the market. A second option to help ensure energy efficiency and long lifetime are promoted would be to make sure that the service economy offered to end-users includes both the appliance itself and personalised feedback on how to use the equipment more efficiently.

FINDINGS OF THE CIRCULAR ECONOMY IMPACTS FOR WHITE GOODS AND RELATED PRODUCTS

For white goods and related products, the development of a service economy approach offers the highest CO_2-equivalent reduction potential of the circular economy scenarios assessed for this group, with the modelled impacts of this approach (broad adoption) being approximately 17 Mt CO_2-equivalent savings for products sold in 2020. This corresponds to around 40-50% of the estimated impact of the ecodesign and energy labelling regulations for these products in 2020. The highest CO_2-equivalent emission reduction is achieved by combining the service economy approach with leased products that have a higher efficiency than the average products sold.

The impact of an extended service life varied significantly between the white goods products analysed. The variance depended on the proportion of CO_2-equivalent emissions attributable to the use phase and the expected efficiency improvement potential. Although this potential will reduce as new, more efficient products are introduced to the market, for most of the white goods and related products considered, the impact of an extended service life still tends to result in a slight increase in the total CO_2-equivalent emissions.

Based on currently available data, the impact of improved recyclability on the total CO_2-equivalent emissions for the white goods product category typically represents less than 1 % of the impact of the ecodesign and energy labelling implementing measures for those same products. Therefore, considering greenhouse gas emissions only, improved recyclability does not currently represent an interesting circular economy intervention mechanism – although it has other environmental benefits that were not analysed as part of this study.

FINDINGS OF THE CIRCULAR ECONOMY IMPACTS FOR LIGHTING PRODUCTS

For lighting products, the service economy approach offered the best option analysed in this study. Applying service economy principles to lighting products offers a reduction of between a 17 % (low adoption scenario) and 32 % (broad adoption scenario) of the CO_2-equivalent emissions reduction due to all the ecodesign implementing measures for lighting.

Extended service life did not yield significant savings largely because the lifetime of the baseline LED lamps is already long and balanced against the increasing efficiency of new lighting products entering the market, the CO_2-equivalent emissions impact of an extended service life would only yield a reduction of 1 to 3 %. And, a slight increase in the expected pace of efficiency improvement could cancel this potential reduction and even mean that extending the service life of light sources could result in slightly higher CO_2-equivalent emissions due to the dominance of the use phase.

The impact of improving the recyclability of LED lighting products is estimated to have a very slight increase in CO_2-equivalent emissions relative to the baseline due to the energy involved in recovering and recycling the materials embodied in the LED lighting products. Thus, from purely a greenhouse gas emissions perspective, recycling does not offer an attractive policy option, however it could become an appropriate option for CO_2-equivalent emission reductions in the future once the difference in efficiency between existing and new products starts to narrow.

FINDINGS OF THE CIRCULAR ECONOMY IMPACTS FOR CONSUMER ELECTRONICS AND RELATED PRODUCTS

For consumer electronics, our analysis found that extending the service life represents the most promising application of the circular economy principles. A clear case can be made for extending the lifetime, with our calculations finding a CO_2-equivalent emissions reduction potential for computers that would be one order of magnitude larger than the reduction estimated from its ecodesign regulation.

The development of a service economy and improved recyclability also represent interesting options to lower the total CO_2 emissions, although the modelled potential of increasing the lifetime appears to be one order of magnitude higher. For televisions, personal computers and imaging equipment, improved recyclability was found to represent a CO_2-equivalent emissions reduction of between 20 % and 50 % of the emissions savings estimated by their respective ecodesign and energy labelling regulations.

FINDINGS OF THE CIRCULAR ECONOMY IMPACTS FOR MOTORS AND MOTOR SYSTEMS

Even with the energy efficiency improvements achieved for these products over the years, the use phase still dominates the life cycle CO_2-equivalent impacts of motors and motor systems. With the exception of the service economy approach, circular economy options that would only affect the production and end-of-life phases would have a very limited impact on the greenhouse gas emissions associated with these products.

The only circular economy option considered in this study that would deliver significant CO_2-eq. emission reduction for motors and motor systems is the service economy approach. Following this approach, businesses would contract motor services from ESCOs, motor manufacturers or other market players that would optimise the management of motors and motor systems. Our analysis estimates CO_2-equivalent emissions savings of between 5 % and 25 % of the impact derived from the current ecodesign and energy labelling measures.

In stark contrast to this level of savings, the impact of extended service life and recyclability on the total CO_2-equivalent emissions each represents less than 2 % of the impact of ecodesign and energy labelling measures, therefore these options do not appear to be strongly justified from an emissions point of view.

FINDINGS OF THE CIRCULAR ECONOMY IMPACTS FOR HEATING AND COOLING PRODUCTS

The results showed that adopting a service economy approach could be effective for reducing greenhouse gas emissions from room air-conditioners (RAC). The efficiency of the leased product is by far the parameter that has the most significant impact on greenhouse gas emissions across all the options analysed. The service economy related savings potential for central heating products could also be attractive, but is strongly dependent on the energy efficiency improvement, suggesting that the type of contract proposed by an ESCO or other service provider will be important.

RAC is the only product in this category for which the potential impact of extended service life is large enough to be considered interesting in terms of CO_2-equivalent emissions. The potential was found to be approximately half of the size of the impact of the ecodesign and energy labelling regulations.

The estimated potential reduction of improved recyclability, although not negligible in absolute terms, is found to be one order of magnitude lower than the potential impact of extending the lifetime. Following the policy action already taken to significantly reduce the impact of refrigerant gases, improving recyclability of heating and cooling products no longer appears as a priority to reduce the CO_2-equivalent emissions associated with this product category.

Table 4 gives an overview of estimated potential additional CO_2-equivalent emissions reduction for each type of improvement and product group.

Potential next steps

This study found that the estimated magnitude of the emissions reduction potential associated with the application of circular economy principles in some product groups is even higher than the emissions reduction from the ecodesign and energy labelling measures for those same products. This study is, however, only a first order estimate of the emissions reduction opportunity and is intended to support the planning and consideration of potential policy actions. It is also intended to help guide future areas of research around principles of a circular economy, which could include more product-specific analyses.

Additionally, in consultation with our peer-review group and other experts, the study presents a several areas of work, some of which have been initiated already, which would contribute to accelerating the adoption of a circular economy in Europe:

- Economic assessment – an evaluation of the economic requirements and potential impacts of applying the principles of a circular economy considered in this paper across Europe, including e.g., a cost-benefit analysis, return on investment, financing needed, etc.;
- Accounting standards – the development of new financial and accounting standards and metrics that capture the full benefits of energy-efficiency and the circular economy;
- Product metrics – the development and improvement of metrics to assess whether a product is eco-effective and eco-efficient or not; enabling companies, governments and consumers to identify eco-efficient products;
- Plastics recycling industry – conduct market research and develop policy measures designed to stimulate and support the development of a larger and more robust plastics recycling industry in Europe;
- Best opportunity focus: products – conduct a more in depth analysis to explore the improvement potential for specific products which offer the greatest greenhouse gas saving potential, and contribution to the ecodesign work plan;
- Best opportunity focus: improvements – conduct a more in depth analysis of the improvement potential for those options which were found to offer the greatest greenhouse gas saving potential. This could cover a product by product analysis of what lifetime extension would be realistic; investigate the upgrading potential of some products, and their modularity. These options are believed to have very significant potential for consumer electronics in particular;
- Policy measure study – a research study on potential and appropriate policy mechanisms to encourage a market transition to a circular economy, looking at incentives as well as voluntary and regulatory policy measures;
- Focus on energy-related products – a scoping study for products that are related to energy use (e.g., windows or insulation – non-energy using products); and
- Shared resources – an evaluation of the potential savings that could be achieved via policy incentives toward a sharing economy in relation to certain ecodesign products (e.g., super-efficient washing machines and tumble driers, game consoles, printers). The scenarios developed for leasing in this study result in saving estimates that are comparable to what could happen when sharing resources (potentially more efficient products, less production and end-of-life impacts for a same provision of services). Sharing would however not be possible for all products (e.g., not for lighting or for commercial refrigeration equipment). Moreover, very little literature could be found about the potential level of adoption of sharing as opposed to owning, or how many potential owners would share the equipment at the same time. Any estimates developed would have to be product specific.

In the coming years, the community of stakeholders working on circular economy will continue its work to establish and implement a policy framework that supports the redesign of appliances and promotes the uptake of new business models that capture the full decarbonisation and circularity potential of appliances. On-going research, exchanges with experts and engagement with industry will all help to support the overall objective of establishing a sustainable and robust circular economy in Europe.

Table 4. Estimated additional CO_2-equivalent emissions reduction for each product group in 2020 by circular economy scenario*.

Impact on CO_2-equivalent emissions for 2020 sales	Improved recyclability	Extended lifetime	Service economy – Low	Service economy – High	Service economy – High, no efficiency impact	Existing ED/EL Regulations
Units	*(kilotonnes CO_2-equivalent)*					
Dishwasher	3	0	227	1,225	123	1,600
Tumble drier	2	0	165	858	71	2,000
Washing machine	15	0	257	1,525	327	2,300
Domestic refrigerators and freezers	12	0	750	3,921	144	4,100
Vacuum cleaners	11	1,762	308	1,766	1,014	8,000
Kitchen appliances	8	0	425	2,277	116	2,000
Non-tertiary coffee machines	2	0	94	502	147	1,000
Professional wet appliances and dryers	2	0	296	1,504	65	4,000
Professional refrigerating equipment	10	0	340	1,948	634	7,000
Commercial refrigerators and freezers	6	0	275	1,487	382	7,600
Televisions	6,316	23,518	812	5,241	5,740	33,000
Computer Screens	623	1,808	121	719	565	0
Simple set-top boxes	0	0	0	0	0	3,000
Complex set-top boxes	330	1,180	117	686	511	TBC
Video	136	897	28	179	190	0
Game consoles	149	1,495	1	55	209	0
Computer Servers	279	0	476	2,490	437	16,000
Personal Computers	3,437	20,202	857	4,864	4,571	7,000
Smart Phone	942	4,887	228	1,204	1,263	0
Imaging Equipment	419	4,003	148	588	628	1,000
Industrial Fans	27	814	1,713	8,566	-132	18,200
Electric Motors	89	0	2,392	11,962	-300	57,000
Electric pumps	3	140	851	4,253	-10	1,000
Distribution and power transformers	81	0	0	0	0	5,000
Circulators in buildings	7	75	35	184	1	10,000
Residential ventilation	0	0	0	0	0	0
Chillers	9	0	12	72	-2	0
Tertiary Air Conditioning	2	10	0	1	-5	61,000
Central heating products (other than CHP)	4	0	403	2,014	-9	3,700
Local room heating products	27	0	514	2,613	115	8,400
Room air conditioning appliances	147	1,330	218	1,369	601	5,000

** For Ecodesign the estimated impacts are given for the stock of products in 2020. The estimates shown here for each of the five product categories do not take into account the impact of extended service life for product categories where the impact was found to increase CO_2-eq. emissions.*

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Acknowledgements

The authors wish to thank colleagues at the European Climate Foundation (ECF) for supporting this study and helping to guide the work through reviews and comments along the way. In particular, we would like to thank Renée Bruel and Francisco Zuloaga of ECF. The authors would also like to thank the following technical experts who provided detailed comments on the report[1] on which this paper is based: Conrad U. Brunner, Impact Energy, Switzerland; Kim Christiansen, Kimconsult, Denmark; Carl Dalhammar, Lund University, Sweden; Catriona McAlister, Sea Green Tree, United Kingdom; Leena Tähkämö, Aalto University, Finland; Edouard Toulouse, independent consultant, France; Carsten Wachholz, European Environmental Bureau, Belgium; Rita Werle, Impact Energy, Switzerland.

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