The circular economy as a key instrument for reducing climate change

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1 Summary: What are the potential greenhouse gas savings of moving to a more circular economy?

"A circular economy will bring benefits for society, benefits for climate and greater benefits for business." – Karmenu Vella, European Commissioner for the Environment

Global climate change is high on the political agenda. During the climate negotiations in Paris in December 2016, countries all over the world pledged to keep global temperature rise below 2ºC and if possible to 1.5ºC.

The cause of climate change is the emission of greenhouse gases additional to natural greenhouse gas emissions. In 2013 mankind emitted a total of 39.6 Gt of CO_2 (1), with the European Union emitting 4.5 Gt (2). To keep global temperature rise below 2ºC, emissions will need to minimised to net zero before 2100 (3).

The European Commission has recognised the potential of the circular economy model to maintain or improve the European Union's competitiveness as an economic entity and at the same time reduce its CO_2 emissions (4). However, in the climate policies of the EU as well most member states no reference is made to circular economy policies as a means of reducing European greenhouse gas emissions. At present, climate policies are focused on energy and transport; potential climate benefits of policies on the circular economy are generally being overlooked.

Table 1 Reduction of greenhouse gases due to increased recycling of 2/3 of Municipal Solid Waste

			
Already achieved	6.7%	5.0%	1.8%
Remaining potential	0.5%	4.1%	5.9%
TOTAL	7.2%	9.0%	7.7%

Summary of Table 3. Municipal Solid Waste makes up 10% of all waste generated. It does not include industrial waste or construction and demolition waste. Because of rounding, totals may not add up.

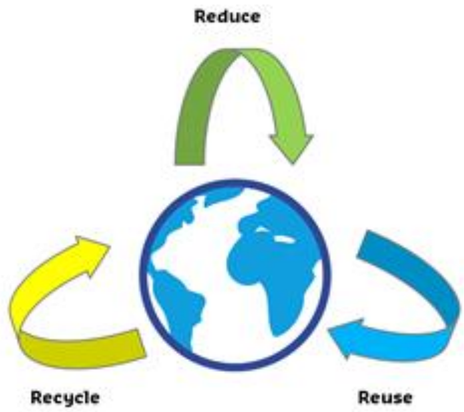
Moving up the 'waste hierarchy' from landfilling towards increased recycling of a handful of waste streams can significantly reduce annual greenhouse gas emissions. The reduction in greenhouse gases shown in Table 1 would be considerably higher if the other 33% of municipal waste and other waste fractions, such as industrial and building and construction waste, were also factored in.

It can be concluded that reduced materials use, increased recycling and resource optimisation can and should be seen as effective strategies to reduce greenhouse gas emissions.

Box 1: The circular economy

The current economic model is a 'take, make, dispose' model (33) in which resources are extracted, products made and products disposed of. For each new product, new raw materials are extracted. We live in a mainly linear economy.

The opposite of a linear economy is a circular economy. In a pure circular economy there is no such thing as waste, only renewable energy is used and resource use is optimised. The focus is on reduce, reuse and recycle as waste management strategies.

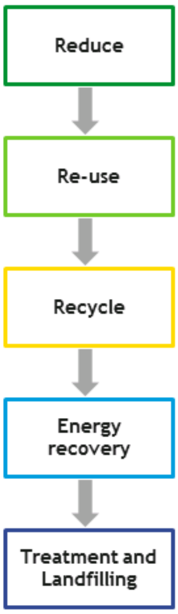


Box 2: Climate change and the circular economy

Material production and consumption accounts for a large part of our carbon footprint. An estimate of the greenhouse gas emissions of Scotland, for example, shows that material consumption accounts for 74% of those emissions (34). This estimate also includes the production of materials consumed in Scotland but produced elsewhere.

According to the Ellen MacArthur Foundation and McKinsey (43), European CO_2 emissions could be reduced by as much as 48% by 2030 and 61% by 2050 by applying the principles of the circular economy in the sectors mobility, food and the built environment. By using recycled materials and becoming 25% more material-efficient in half their industries, Sweden, Finland, the Netherlands and Spain could reduce their CO_2 emissions by an estimated 3-10% (31).

Box 3: The waste management hierarchy



A range of strategies are available for the management of waste. The 'waste management hierarchy' is a ranking of strategies based on sustainability that is used by the European Union in its Waste directive (32).

Ranked highest is the reduction of demand for virgin materials. This can be achieved by prevention — reducing overall demand for products — and by minimizing the use of materials in products.

One tier lower on the waste management hierarchy is the reuse of entire products instead of manufacturing new products. The reuse of entire products includes also extension of product lifespan through design and product repair. The first two tiers prevent waste from being created.

The next tier is recycling: reuse of the materials incorporated in products, by recovering them from waste after products have reached their end of life and are disposed of.

One tier further down is energy recovery: heat and electricity generation by incineration.

Ranked lowest is landfilling of waste. According to the waste management hierarchy, landfilling should only be considered when all other options are unfeasible.

In the ideal situation, waste that is created should be treated in such a way as to reduce the environmental impact of consumption to a minimum, including human health effects. In reality, waste management worldwide is still far from ideal.

2 Status quo: waste management in Europe

"Whether it is re-used, recycled, incinerated or put into landfill sites, the management of household and industrial waste comes at a financial and environmental cost."

— Being wise with waste - European Commission

To assess the potential CO_2 emissions cuts achievable by shifting from a linear to a circular economy, current waste generation statistics and waste treatment routes have to be considered.

As Figure 1 shows, European countries differ substantially in the amount of MSW produced per capita. Dutch citizens produce around 500 kg municipal solid waste (MSW) per person per year (5). Roughly speaking, the richer a country becomes, the greater the importance of recycling, since more waste is generated.

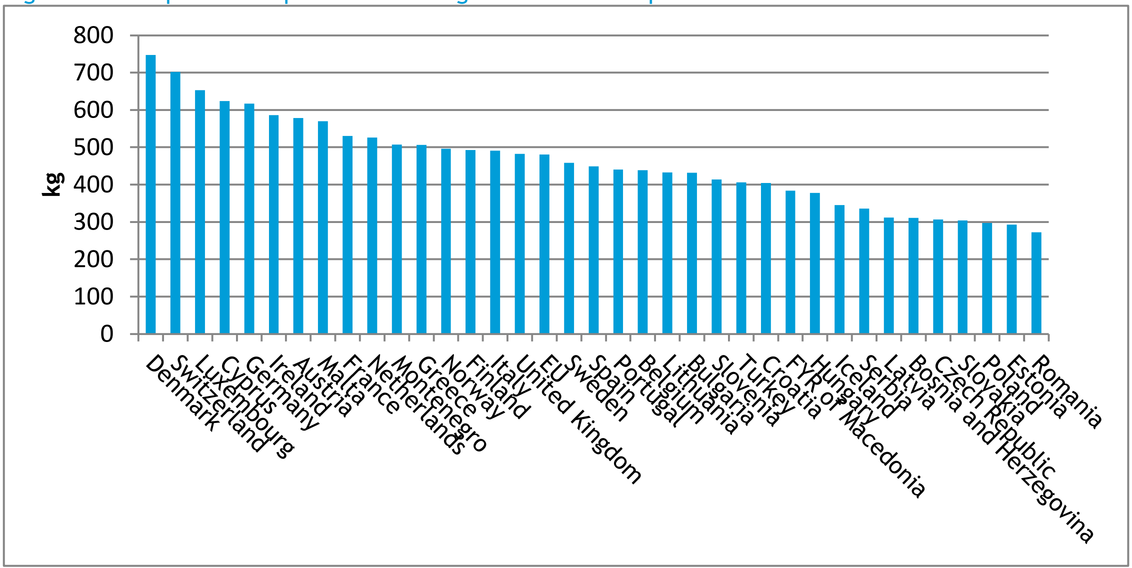
Table 2 shows the total amount of MSW generated annually in the Netherlands, in Europe and globally.

Table 2 Annual MSW generation

	Total MSW
Netherlands	8,400 kt
EU-28	241,000 kt
World	1,300,000 kt

Sources: (5), (6), (7).

Figure 1 Per capita Municipal Solid Waste generated in Europe



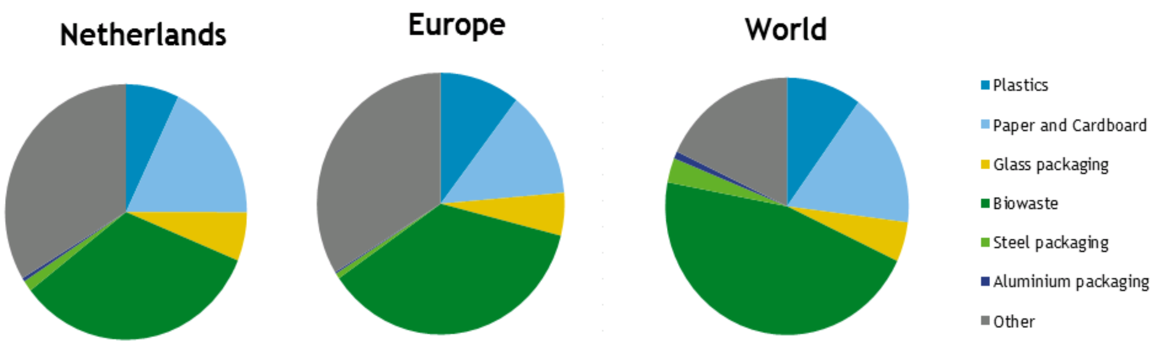
Source: (8)

Municipal solid waste is made up of a number of different fractions, with a distinction often made between fine and coarse MSW. The first consists of plastics, paper and cardboard, organic waste, metal packaging, nappies, textiles and small electronic devices. The coarse fraction includes larger household appliances, furniture and minor amounts of construction materials. Figure 2 shows the composition of MSW in the Netherlands, in Europe and globally.

These MSW fractions are treated differently; some components are recycled more often than others. In the Netherlands as well as Europe, over 60% of paper and cardboard and glass gets recycled. In the case of plastics and organic waste, in contrast, less than 50% is recycled up to now.

In many parts of the rest of the world, recycling is lagging behind, though, with less than 15% of any of the fractions being recycled.

Figure 2 Composition of Municipal Solid Waste



Based on sources: (5), (7), (9), (10), (11), (12), (13), (14), (15), (16), (17)

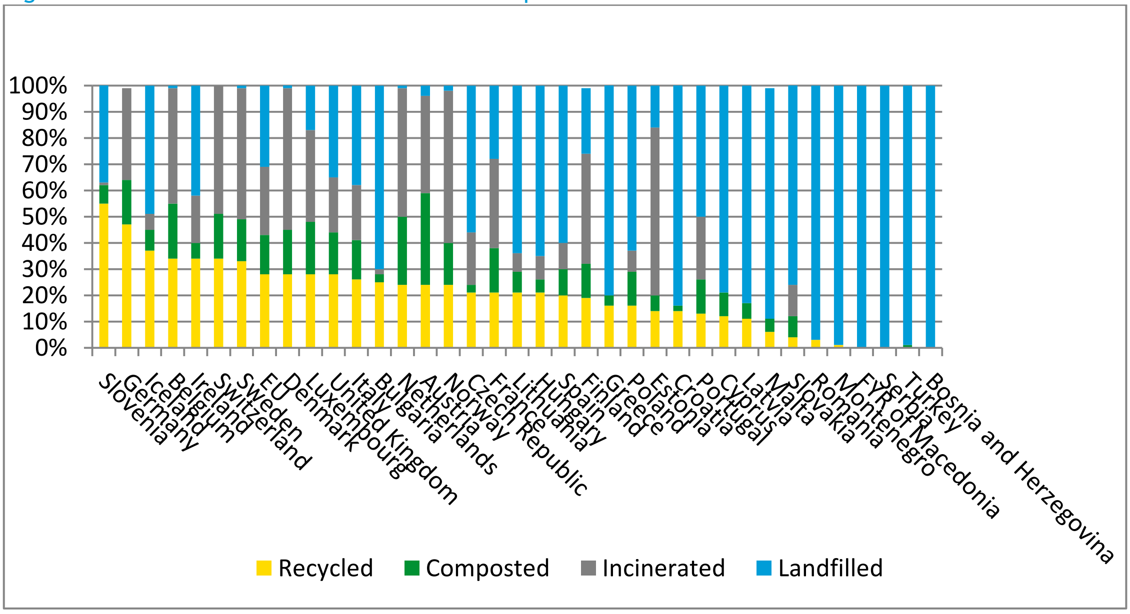
Given the differences in waste management strategies between countries, the impact of waste production differs significantly. For instance, in the Netherlands there is no landfilling of MSW, despite the fact that annually 500 kg of MSW per capita is being produced.

In the European Union (EU) as a whole, landfilling is still often employed as a waste treatment route: 31% of EU MSW is landfilled. On average, 28% is recycled and 26% incinerated, with a smaller share (15%) being composted (8). Worldwide 15% of MSW is recycled and 9% incinerated; the rest ends up in landfill (7).

Figure 3 shows the large differences in waste management strategies across the European Union. Macedonia and Romania still landfill almost 100% of their municipal waste, Croatia and Bulgaria around 75%. Other member states recycle a substantial share of their MSW, such as Germany (50%). In some countries landfilling is banned and incineration of MSW has become the main treatment route, as is the case in Switzerland, Sweden, Denmark and the Netherlands.

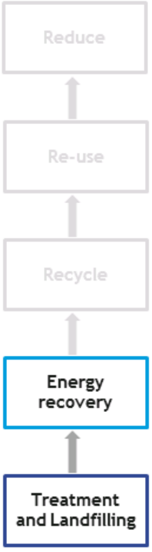
Member states can learn from the most efficient waste management strategies of other countries. By applying these strategies can stimulate the EU as a whole move higher up in the waste management hierarchy.

Figure 3 Waste treatment routes of MSW in European countries



Source: (8)

3 Moving from landfill to energy recovery



"We try not to let our waste go to waste by sitting idly in a county landfill; we're committed to finding more creative homes for it. And these efforts help curb climate change."

— General Motors

On average, 31% of all European waste was being landfilled in 2013. Landfilled waste consists mainly of waste from construction and mining, municipal waste and agricultural and industrial waste. In the Netherlands there's a ban on landfilling combustible materials. None of the fine fraction of MSW is now landfilled: everything is either incinerated, with energy recovery, or recycled.

Worldwide greenhouse gas emissions can be reduced by 5% if the fine fraction of MSW is combusted rather than landfilled. This is almost half of all European greenhouse gas emissions. Chapter 6 gives further background on this reduction potential.

The emission of greenhouse gases from landfills originates above all from the biowaste in MSW. Reduction of landfill emissions is possible by keeping biowaste out of landfills by incinerating it instead.

This avoids:

- methane emissions from the waste;
- CO_2 emissions from power plants, because electricity and heat are produced by combusting biowaste;
- extraction of fuel resources.

The European Commission has recognised the problem of landfilling. New legislation is proposed to reduce landfilling of municipal waste to a maximum of 10% by 2030. This proposal still needs to pass the European Parliament.

Since large amounts of waste are still being landfilled, greenhouse gas emissions can be avoided by incinerating waste instead of landfilling it. Box 4 explains how Europe can reduce its greenhouse gas emissions by 150 Mt CO_2 by incinerating the biowaste in MSW instead of landfilling it. This is equivalent to the EU's entire CO_2 emissions reduction in 2011 (18).

Box 4: Biowaste in Municipal Solid Waste (MSW)

In 2008 101,000 kilotonnes of MSW was landfilled in Europe, of which almost 36,000 kt was biowaste (16). If MSW is incinerated with energy recovery instead of landfilled, a total of 150 Mt CO_2 emissions can be avoided.

Landfilled MSW containing approximately 30% biowaste leads to emissions of 138 grams of CO_2 and 50 grams of methane per kg MSW landfilled (21). The greenhouse gas emissions from 1 kg of landfilled MSW thus total 1.4 kg CO_2-equivalent.

If waste is combusted instead of landfilled, it not only avoids the emission of greenhouse gases. It also means the waste can be used to generate electricity and heat. On average, in Europe 1.5 GJ electricity and 3.6 GJ heat are generated per kilotonne of MSW (22). Incineration of 1 kg MSW leads to an emission of 0.5 kg CO_2, but an avoided emission of 0.6 kg CO_2 due to electricity and heat generation.

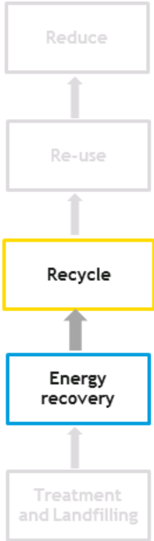
Burning MSW as a fuel thus means a net reduction of 0.1 kg CO_2 emissions.

Moving from energy recovery to recycling

4

"We want to move to a circular economy, enabling more packaging to either remain in loops or have the best possible opportunity to recycle."

— Unilever



On average, 26% of all European waste was incinerated with energy recovery in 2013. But incinerating materials means they are lost, leaving demand for virgin materials unchanged. Incineration, especially of abiotic materials, is not in line with the ideas of the circular economy.

Recycling is the recovery of materials used in products after they have reached their end of their life and are discarded. For most materials, the environmental impact of the recycling process is substantially less than the production of new materials. As a result, and because recycling almost always leads to lower CO_2 emissions than incineration, recycling more waste can reduce greenhouse gas emissions.

The fraction of a material that can be recycled depends on both the material's properties and the product in which it is used. Some products are not designed for recycling, for instance because components cannot be separated. This means recycling is unfeasible or very difficult owing to components that cannot be separated.

Across the world, a reduction of at least 1% of global greenhouse gas emissions has already been achieved by moving from combustion to recycling. Over 6% emissions reduction is still achievable through increased recycling of MSW. Chapter 6 provides more background on this reduction potential.

A large reduction in greenhouse gas emissions can be achieved by recycling plastics instead of combusting them. Box 5 shows that Europe can reduce its carbon emissions by 5.4 Mt by recycling plastic packaging waste rather than combusting it. This is almost 8% of the reduction achieved through greater use of renewable energy and reduced electricity demand in Europe in 2012 (18).

Box 5: Packaging waste - Plastics packaging

Packaging is made out of a range of materials, including paper and cardboard, plastic, wood (crates and pallets), metal and glass. At end-of-life this packaging either ends up in municipal solid waste or is collected separately.

The European Commission has earmarked the plastics sector as one of the priority areas for a circular economy (4). Through improved separate collection and certification schemes, more plastic can be recycled instead of combusted.

In 2012, 4,500 kt of collected plastic packaging was incinerated (14). In theory, all this plastic could be recycled. By recycling this entire quantity of plastic packaging waste instead of burning it, 5.4 Mt of CO_2 emissions can be avoided.

Moving from incineration to recycling reduces the emission of greenhouse gases by 1.2 kg of CO_2 per kg of plastic packaging waste.

This is calculated as follows, per kg recycled plastic:

- no incineration leads to an avoided emission of 1.1 kg CO_2-eq.;
- recycling processes itself have a CO_2 emission of 0.9 kg CO_2-eq.;
- avoided virgin material has an avoided emission of 1 kg CO_2-eq.

The net result is an avoided emission of 1.2 kg CO_2-eq. per kg recycled plastic.

This (simplified) calculation takes recycling into a mixed plastic product as a starting point. This mixed plastic product avoids the use of both wood, concrete and virgin plastic in a variety of applications (23).

5 Moving from landfill to energy recovery to recycling

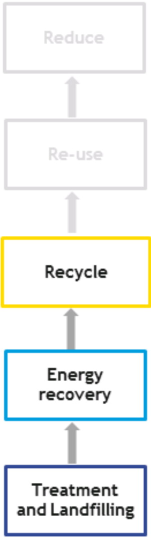


Table 3 shows, for a limited amount of waste fractions, the results of already achieved and potential climate benefits of increased recycling. The packaging waste fractions that have been taken into account are plastics, paper and cardboard, glass packaging, biowaste, steel and aluminium. These fractions account for 66% of total MSW in the Netherlands and Europe and for 82% in the entire world. MSW makes up 10% of all waste generated.
Increaced recycling of just these waste streams leads to an avoided CO_2 emission of 180 million tonnes. For comparison, the most polluting coal-fired power plants in the EU emitted between 6.8 and 37.2 Mt CO_2 per year in 2013 (20).

The amounts of plastics, paper and cardboard, glass, biowaste, steel and aluminium in MSW have been obtained from different sources: (5), (7), (9), (10), (11), (12), (13), (14), (15), (16), (17). These waste streams are currently treated in different ways, being landfilled, incinerated or recycled. The amounts of waste being treated via different treatment routes have been multiplied by the CO_2 benefit of moving up the waste hierarchy (as determined in previous chapters).

The results for recycling are based on a direct shift from landfill to recycling, so excluding incineration as in-between step.

The achieved benefits are calculated for the shift from landfill to incineration for the amount of packaging waste currently being incinerated, and for the shift from landfill to recycling for the amount of packaging waste currently being recycled. The potential benefits are calculated for the shift of landfill to recycling for the amount of packaging waste currently being landfilled, and for the shift of incineration to recycling for the amount of packaging waste currently being recycled.

Table 3 shows the results from all this. Data on the benefits of moving up the waste hierarchy have been obtained from Ecoinvent database v.3, (21), (22), (23), (24), (25), (26).

Table 3 Reduction of greenhouse gas emissions due to increased recycling of 2/3 of MSW compared with annual greenhouse gas emissions

			
TOTAL GREENHOUSE GAS EMISSIONS (2013/2014)	187 Mt	4,500 Mt	39.6 Gt
Reduction achieved by incinerating instead of landfilling	6 Mt 3%	70 Mt 2%	0.2 Gt 1%
Reduction achieved by recycling instead of landfilling	7 Mt 4%	150 Mt 3%	0.5 Gt 1%
TOTAL REDUCTION ACHIEVED	13 Mt 7%	220 Mt 5%	0.7 Gt 2%
Potential climate benefits of further recycling	1 Mt 1%	180 Mt 4%	2.3 Gt 6%

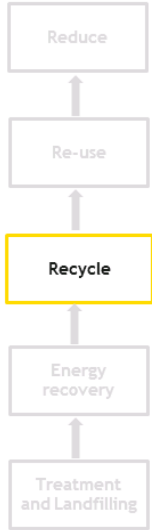
Total greenhouse gas emissions based on: (1), (2), (27). Municipal Solid Waste makes up 10% of all waste generated. It does not include industrial waste or construction and demolition waste.

The potential benefits would be far higher if other waste fractions were also taken into consideration.

The potential benefits would also be higher if recycling methods and collection rates were optimized.

Closing the loop – Climate benefits of improved recycling in a circular economy

6



"Creating a closed loop for textiles, in which unwanted clothes can be recycled into new ones, will not only minimize textile waste, but also significantly reduce the need for virgin resources as well as other impacts fashion has on our planet."

— Karl-Johan Persson, CEO of H&M

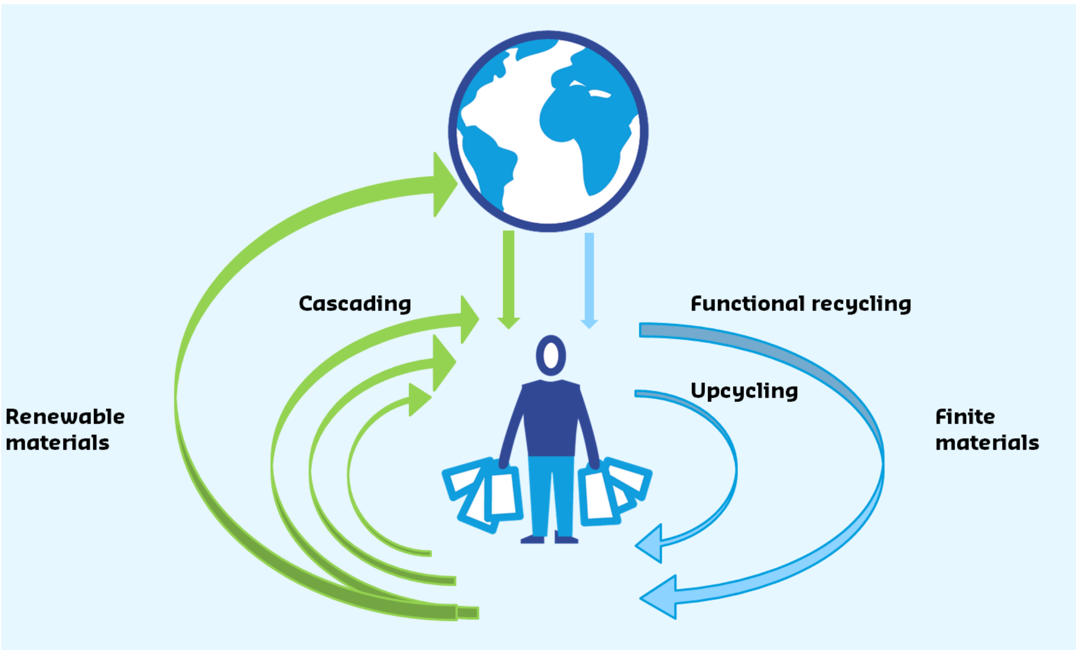
The environment benefits of recycling can be increased still further by ensuring that multiple recycling loops are created. This happens when materials are recycled into materials of the same quality (functional recycling) or a higher quality (upcycling). In this way, demand for the same virgin material is reduced. To 'close the loop' for the materials we use, either functional recycling or upcycling is required.

For renewable (biobased) materials, cascading is the best way of recycling. Cascading means creating multiple recycling loops: every time a biobased product is discarded, the recycling route is selected which leaves as many options open as possible for the end-of-life treatment of the new products and avoids incineration for as long as possible.

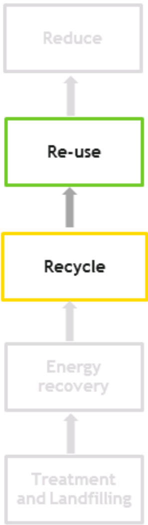
Odegard et al. (28) have calculated that between 332 and 407 Mt of $_{CO2}$ eq. can be saved in Europe solely by cascading biomass, equal to a reduction of European greenhouse gas emissions by 7% to 9%. This is at least twice the overall CO_2 emissions reduction that Europe managed to achieve in 2011 (18).

Currently, downcycling is applied for many materials and products that are recycled. For example: concrete from buildings is used as bedding material for new roads instead of for producing new concrete.

Box 6: Closing the loop: Cascading, functional recycling and upcycling



7 Moving from recycling to reuse



One step higher in the waste management hierarchy than recycling is reuse, whether of components or even entire products. Reuse also includes extending product lifespan, by applying modular design, for example. Refitting a product with replacement components may accommodate reuse. The advantage of reuse over recycling is twofold:

- Reuse avoids recycling processes.
- Reuse avoids production of the product from (recycled) materials.

For complex products, reuse is therefore likely to lead to more greenhouse gas reduction compared with recycling.

Exceptions are energy-intensive products like refrigerators, which benefit most from energy-saving innovations and can therefore better be recycled than reused.

In the current economy, many products become obsolete before the technical lifetime of most components. Indeed, some products are designed in such a way that they have an artificially limited lifespan. This so-called planned obsolescence may include:

- Not accommodating old software.
- Use of inferior materials.
- Making a product difficult to repair.
- Programmed obsolescence, whereby the software disables product use.

Extending the lifespan by one year can reduce the CO_2 emissions of a tablet by 21% and of a laptop by 19% (29).
Box 7 shows that extending the life of all European smartphones to six years can reduce greenhouse gas emissions by 4.1 Mt. This is comparable to half the emissions reduction in 2011 through road transportation policies (18).

Box 7: Extending the life of smartphones

Smartphones are discarded after 1 to 2 years' use (35) (36). If a smartphone has a lifespan of 2 years, approximately half its lifetime greenhouse gas emissions are due to the electricity used for charging it (37). The rest of the impact is due to production and transportation of the phone. If a phone is discarded after less than two years, production of its materials and components has a larger impact than the use phase (41).

Between 10 and 50% of the greenhouse gas emissions occurring during a phone's lifespan are due to production of the motherboard and the integrated circuits it contains, while a further 6 to 10% is due to the screen (37) (39) (40). By using these components as long as possible, the environmental impact of a mobile phone can be reduced, because this avoids the need to produce new components.

FairPhone has embedded the idea of lifespan extension in its product design. The company offers dual SIM, so you need only one phone for both work and private use. Fairphone sells components for their phone in its webshop and links to instruction videos on how to replace broken or outdated components.

Over a period of six years, a minimum of 3 different smartphones are currently used, leading to 39.5 kg CO_2 emissions (37). The lifespan of a smartphone can be extended by replacing several of its components. To be able to use the phone for six years, two extra batteries, one extra screen and two extra cameras are needed (37). If a FairPhone smartphone is used for six years, 28.3 kg of CO_2 is emitted (37). This means that 11.2 kg CO_2 can be saved per smartphone whose lifespan is extended.

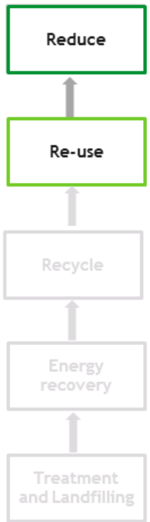
The European Union (EU28) had 506.8 million inhabitants in 2014 (38). In Eastern and Central Europe 55% of the population had a smartphone in 2015, while in Western Europe this was 85% (42). On average, 73% of the European population has a smartphone. If instead of using this phone for two years a phone was used for six years, then 4.1 Mt CO_2 could be saved.

Moving from reuse to reduce

8

“We introduced a pioneering lease model to ensure we remain the owner of the raw materials and get them back at the end of the day.”

— Lease your Jeans, Mud Jeans



The final approach that can be taken in a circular economy is to reduce the demand for materials. Reducing materials demand leads to a reduction in greenhouse gas emissions because less energy is needed for materials extraction and production.

Demand reduction can be achieved in four different ways:

- Using materials more efficiently.
- Moving from product ownership to product use.
- Redesigning products to have less or less polluting materials.
- Reducing overall demand for a product.

Resource efficiency is seen as an important target for the European Union, but there are major differences in how this is interpreted by the various member states. The overall strategic objectives set by member states are generic in nature, with no clear pathway as to how to reduce materials use (30).

Although moving away from ownership towards a sharing economy has not been targeted much by the European Union, companies in a range of industries have shown that business models aimed at servicing products can be profitable.

Three different approaches can be distinguished:

- Product lease: in this case, ownership of the product remains with the producer, stimulating reuse and recycling at the end of the lease.
- Product share: in this case, a product like a car can be used by different people as they need it, optimising product use.
- Turning a product into a service: in this case, a product is not sold as a product but as a service. An example is given in Box 7.

The previous pages have provided examples of greenhouse gas reduction by moving towards a circular economy. However, it is important to keep in mind the original purpose of doing so. Moving up the waste management hierarchy is only beneficial if:

- It is technically feasible.
- It does not lead to higher environmental impacts than it prevents.

For complex products, it is necessary to aim for redesign of the product and/or reuse of components.

The last step is, where possible, to aim for an overall reduction in the demand for products, i.e. de-growth of the economy.

Box 8: Providing a product as a service - Philips lighting

Philips, a large electronics company, has developed a business model in which it delivers light systems as a service. Instead of purchasing an entire light system, a consumer can opt to purchase a light service. This means that Philips makes the investments for the light system, maintains the system and recycles it at the end of its lifetime.

Philips has developed a lighting system for Schiphol Airport. This new system uses 50% less electricity than the lighting system used before. The light fixtures are expected to last 75% longer than conventional fixtures.

9 Conclusion

It has been shown that moving up the waste hierarchy from landfilling towards more recycling for even a small number of waste streams can significantly reduce annual greenhouse gas emissions. Increased recycling of 2/3 of municipal solid waste can reduce global greenhouse gas emissions by 6%. The EU's greenhouse gas emissions could be reduced by 4%.

In our calculations, only 2/3 of MSW has been taken into account. Municipal solid waste makes up 10% of all the waste generated. The potential reduction in greenhouse gases summarized in

Table 3 would be much higher if other waste fractions were also taken into account.

Table 4 Reduction of greenhouse gas emissions due to increased recycling of 2/3 of MSW

			
Already achieved	6.7%	5.0%	1.8%
Potential	0.5%	4.1%	5.9%
TOTAL	7.2%	9.0%	7.7%

Summary of Table 2. Municipal Solid Waste makes up 10% of all waste generated. It does not include industrial waste or construction and demolition waste. Because of rounding, totals may not add.

For individual product groups, especially for complex products, (design for) reuse could lead to a further reduction of greenhouse gas emissions. Extending the lifespan of computers and tablets by one year reduces the greenhouse gas emissions of these products by around 20%. Reuse of products is not limited to reusing entire products; reuse of components also reduces the need to produce new components and thus reduces carbon emissions.

Lastly, reducing demand for materials can also reduce CO_2 emissions because of the decreased energy demand for materials extraction and production. Demand reduction can be achieved by using materials more efficiently, by moving from product ownership to product use, by redesigning products with less or less polluting materials and by reducing the overall demand for products.

Decreased materials use, increased recycling and resource optimisation can and should be seen as strategies to reduce greenhouse gas emissions.

European climate policies do not generally refer to circular economy policies as means of reducing greenhouse gas emissions. Rather, the main focus is on energy and transport. By means of several case studies, this document has shown that the circular economy can in many cases also be seen as an effective climate strategy. Including circular economy options in European climate policies can make these policies more efficient and cost-effective. It also makes it more likely that the Paris climate goals will indeed be secured.

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