Mandatory percentage of recycled or bio-based plastic

In the European Union

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For more information about this study please contact the project leader Geert Bergsma (CE Delft)

CE Delft
Committed to the Environment

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Management summary

The Dutch Transition Agenda for Plastics plans to increase the percentage of recyclate and bio-based plastics to 41% recyclate and 15% bio-based plastics by 2030. This is a considerable increase compared to the current shares of approximately 9% recyclate and 1% bio-based. The Ministry of Infrastructure and Water Management has asked CE Delft to study the extent to which a mandatory percentage of recycled and/or bio-based plastics could help achieve this target and to assess the environmental and economic effects. Because this concerns the European market, this study focuses on a European mandatory percentage of recyclate.

The simplest way to achieve this goal is to introduce a mandatory requirement at the level of polymer producers and importers as this would involve a limited number of companies. The administrative burden would also be relatively limited. Because these producers supply very diverse customers with a wide variety of products, this would resolve the issue that recyclate is easier to apply in some products than in others. Especially if some form of exchange, trade or banking is permitted, this option could quickly result in an increase in the amount of recyclate in plastics. However, it is only an indirect incentive for the separate collection of plastic for recycling, namely mainly through the price of recyclate. For this reason, we recommend that extended producer responsibility schemes (EPR) for recycling be significantly broadened to include all plastics applications.

Another option is to impose sector-specific mandatory requirements for companies that use plastics in products (brand owners). The disadvantage of this is that considerably more companies will have to be regulated, which will result in increased legislation, consultation and costs. In addition, a sector-by-sector approach will only boost the recycling market if a large percentage of sectors using plastics are regulated. A mandatory requirement imposed on only one segment of the market will mainly result in recyclate shifting from unregulated to regulated sectors.

If a 55% share of recycled and bio-based plastics is achieved in Europe by 2030, 80 Mtonne CO_2 emissions per year will be avoided and the use of fossil plastics will decrease by 28 Mtonne. A less far-reaching increase to 30% recyclate and bio-based plastics in 2030, will result in a saving of 37 Mtonne CO_2 emissions and a decrease in the production of fossil plastics of 13 Mtonne. The latter will cost the average Dutch person about € 1 per month, which will be factored into the price of plastics products and packaging.

In addition, the introduction of a mandatory requirement to use recycled and/or bio-based materials creates a level playing field for the material and energy applications of recyclate and bio-based raw materials. Energy from bio-based raw materials (biofuels) and fuels from plastics (recycled carbon fuels or sustainable aviation fuels) are currently subject to mandatory requirements or are likely to be subject to such requirements.

In other words, a rapid transition towards circular plastics seems possible by introducing an EU-wide mandatory requirement (at polymer level) of 30 to 55% recyclate or bio-based plastics by 2030. It would also make sense to extend producer responsibility to all plastics applications. Design for Recycling and improved collection and sorting can also contribute. Both the broad mandatory requirements and the expansion of producer responsibility will need to be elaborated in more detail.

Summary

To reduce the use of fossil raw materials and greenhouse gas emissions, the Dutch Transition Agenda for Plastics plans to increase the percentage of recyclate and bio-based plastics to 41% recyclate and 15% bio-based plastics by 2030. This represents a considerable increase from the current shares of approximately 9% recycled and 1% bio-based and this transition will not happen automatically. Both recyclate and bio-based plastics are either more expensive or barely cheaper than virgin plastics throughout the chain. As a result, in the absence of any government policy, there is no automatic price incentive to use more recyclate. The Dutch Ministry of Infrastructure and Water Management has therefore asked CE Delft to investigate whether the percentage of recycled plastics could be increased by imposing a mandatory requirement for a certain percentage of recyclate and assess what the environmental and economic effects would be. Because this concerns the European market, our investigation focuses on European mandatory requirements. We will also assess, however, whether a scheme is also feasible for the Netherlands alone.

Current supply and demand
Approximately 10% of plastics use in the Netherlands is circular (9% recyclate and 1% is bio-based). Of all plastics waste, about 15% is recycled. The difference between 9 and 15% is due to the fact that demand for new plastics is about 70% higher than the amount released as waste per year. This is because plastics are increasingly being used in products with a longer lifespan, such as cars and houses.

Most of the recyclate is produced from packaging waste, which is subject to active recycling policies. The use of recyclate is still limited in this sector, however, in part because of stringent requirements for food packaging. The material is relatively widely used in agricultural films and building products, especially mixed plastic recycling in thick-walled applications. These applications mainly avoid wood and concrete rather than virgin-plastic production. This means that the environmental benefit of these routes is lower than for mono-material recycling, which replaces primary plastics.

Highly ambitious target of Dutch Transition Agenda
The 40% recycling target of the Dutch Transition Agenda for Plastics (30% mechanical recycling and 10% chemical recycling) is very ambitious. In order to meet this recycling goal for 2030, approximately 94% of all plastic waste discarded in the Netherlands would need to be separated for recycling by 2030. Unless there is a strong commitment to imports, it does not seems practically possible to meet this recycling goal. In addition, the collection, sorting and recycling of the last remaining plastics streams will be relatively expensive. The Dutch 2030 target corresponds to about four times the current level of plastic recycling.

EU targets 18% by 2025
At EU level, the Circular Plastic Alliance has set the target of 10 Mtonne of recyclate (18%) by 2025. Currently in the EU, about 4 Mtonne of plastics are recycled on a total consumption of 55 Mtonne (8%). By 2030, consumption will increase slightly to 59 Mtonne and 35 Mtonne of plastic waste will be generated). In order to achieve this target, approximately 40-45% of all plastics waste must be collected separately for recycling. This is 2.5 times more than is currently the case.

To achieve the even more ambitious target of the Netherlands of 40% recycling by 2030, which is 20 Mtonne more than currently, more than 90% of plastic waste must be separated

for sorting and recycling. Theoretically, this is conceivable over a long period of time. In practical terms, however, this does not seem feasible by 2030.

The EU is also currently discussing a target for recycled plastic that only concerns packaging. Plastics Europe proposes a target of 30% by 2030. Since this only concerns packaging, which is 40% of the market, this would only amount to 12% (30% x 40%) for all plastics. A broader target for all plastics applications (18 to 40%) will very quickly result in a faster increase in the application of recyclate than if the target only concerns packaging (12%).

Structure of the mandatory requirements
There are different ways of shaping mandatory requirements in the EU and its Member States. The simplest option is to introduce a mandatory requirement for polymer producers and importers as this would apply only to a limited number of companies. The administrative burden would also be relatively limited. Because these producers supply very diverse customers with a wide variety of products, this would resolve the issue that recyclate is easier to apply in some products than in others. Especially if some form of exchange, trade or banking is permitted, this option could quickly result in an increase in the amount of recyclate in plastics. However, it is only an indirect incentive for the separate collection of plastic for recycling, namely mainly through the price of recyclate. For this reason, we recommend that extended producer responsibility (EPR) schemes for recycling be significantly broadened to include all plastics applications. One consequence of this is that the use of plastics for the useful application of energy is no longer permitted for existing EPR schemes (automotive, electronics). Existing EPR schemes can also be broadened (packaging) or new EPR schemes can be created (products in construction, agriculture). This can be supplemented by mandatory requirements for Design for Recycling.

Another option is to impose sector-specific mandatory requirements for companies that use plastics in products (brand owners). The disadvantage of this is that considerably more companies will have to be regulated, which will result in increased legislation, consultation and costs. This option can be implemented generically or by using a sector-by-sector approach. A generic implementation does not take into account differences between sectors and/or products and will lead to relatively high costs in some sectors. A sector-by-sector approach has the disadvantage that it will require a lot of consultation with many sectors and will not really stimulate the recycling market until a large percentage of the plastic-using sectors are regulated. A mandatory requirement imposed on only one segment of the market will mainly result in recyclate shifting from unregulated to regulated sectors. An advantage of regulation per sector is that the waste aspect can be regulated at the same time by means of extended producer responsibility.

All in all, imposing mandatory requirements on polymer producers and importers seems to be the most effective option to quickly make plastics more circular in the EU. In addition to this mandatory requirement, more and stricter EPR schemes and Design for Recycling are needed to increase the availability of recyclate.

Policy needed for waste, application and design phase
In order to increase plastics recycling by a factor of 2.5 (EU target) or 4 (NL target) in three to eight years, a rapid transition is needed for both the waste and the application aspects. Packaging and products must also be designed so that they can be recycled more easily. The following is needed for the three major phases of the plastics chain:

1. **Waste phase:**
    - Producer responsibility, collection systems, return bonus systems for all product groups that use plastics.
    - Promptly disallowing energy application in EPRs as a form of recycling. Convert EPR schemes to full recycling of plastic.

2. **Application phase:**
    - A form of mandatory recycling for all plastics products, preferably at the level of polymer production/use in the EU.
    - Possibly additional forms of mandatory percentages for brand owners of large product groups in order to accelerate the switch to recyclate for those products where recyclate is easier to use.
    - Phasing out the use of non-separated mixed plastics in thick-walled building products that replace wood or low-grade concrete to achieve greater climate benefit through the replacement of virgin-plastics.

3. **Design phase:**
    - Introduce mandatory Design for Recycling for packaging and products by means of product regulation, including enforcement.
    - Material innovation and new material choices more in line with the image of circular plastics.
    - Increased tariff differentiation in EPR schemes between products/packaging that are easily or less easily recyclable, such as along the lines of France's Citeo.

Only an ambitious policy package aimed at all three of these phases in the plastics chain will enable a transition to increased circular plastics. It would help if the targets and rules for the next few years could be clarified quickly so that companies can prepare for them. Perhaps a target that is somewhere between the EU target and the Dutch Transition Agenda is also possible, such as 25-30% recyclate.

Is a mandatory requirement imposed only in the Netherlands also effective?
If a mandatory requirement fails to materialise at the European level, in principle the Netherlands can implement it independently. However, imposing a mandatory requirement on producers of plastics may have adverse effects on the competitive position of the Netherlands because it exports a relatively large amount of plastic. When adjusted for exports, the environmental impact of a national mandatory requirement is limited, while the administrative burden is high. A mandatory requirement at product level has the major disadvantage that many products are regulated at European level and many products are produced for the European market. The Netherlands is a small player in this.

Should a mandatory requirement also include bio-based plastics?
The Dutch Biobased Plastics Action Plan states that a substantial increase in bio-based plastics in the market can only be achieved by stimulating it through a subsidy scheme (comparable to bio-energy from the SDE+) or a mandatory requirement (comparable to the mandatory requirement for biodiesel and bio-ethanol in petrol).
This would make sense from the perspective of cascading, where it is preferable to use biomass in products rather than energy. In the current policy situation, the use of biomass for energy and fuel is stimulated but the use of bio-based plastics is not. This was also announced in the letter of the House of Representatives entitled 'Integral Sustainability Framework for Biobased Raw Materials' (October 2020). The imposition of a requirement for bio-based plastics in the Netherlands or Europe is possible, certainly if it is coordinated with the policy for the much larger fuel market (8% of oil goes to plastics and more than 80% to fuel).

It is important to set sustainability criteria for the production of bio-based plastics from the start of any mandatory requirement to use them in products. This is necessary to ensure that bio-based plastics actually deliver an environmental benefit. This can be linked to the requirements that apply or will apply to biofuels (RED) and the 'Integrated Sustainability Framework for Biofuels' as presented to the House of Representatives in October 2020 and the Bio-based Plastics Action Plan, which also contains proposals for sustainability criteria for bio-based plastics.

Conclusions per sector
In each sector there are various opportunities and bottlenecks for the improvement of collection and the use of more recyclate:
- The packaging sector already has many policies in place and producers in most EU countries are already familiar with EPR schemes. Through Design for Recycling and additional waste separation, there is potential for extra recycling. Food safety requirements hinder the use of recyclate in this sector.
- The construction sector is a growth sector that will generate increasing amounts of plastic waste (window frames, insulation, pipes) in the coming years. Regulation can contribute to the processing of this waste into recyclate. A relatively large amount of recyclate is already used in the construction industry. In the electronics sector, a large amount of waste is still exported and the EPR scheme does not yet include a recycling target for plastics. There is still some potential in this regard. In the automotive sector, a relatively large amount of plastic is already removed from cars and recycling targets for plastics are being drawn up at the European level. Design for Recycling will allow more plastics to be released in the coming years.
- The agricultural sector already uses a relatively large amount of recyclate and the collection of agricultural plastic is compulsory. There are still opportunities in other product groups.
- In other sectors, there are opportunities at product level, for example by using recyclate in flooring and textiles.

CO_2 emission reduction of increased circular plastics
The climate impact of a structural shift towards more circular plastics was investigated both with regard to the current situation (2018) and with regard to three scenarios in 2030. If the targets in the Dutch Transition Agenda for Plastics (40% recyclate and 15% bio-based) are realised at European level, the climate change impact of plastics use would fall from approximately 180 Mtonne CO_2-eq./year (175 to 183) in the business as usual scenario to 100 Mtonne CO_2-eq./year (77 to 122). This is a reduction of about 80 Mtonne CO_2-eq./year, or 41%. This includes a very high potential for recycling as 94% of plastic waste is recycled.

Per kg recycled/bio-based plastic, there is a corresponding reduction of about 2.5 to 3 kg CO_2-eq. per kg; 80 Mtonne CO_2-eq./year is saved by using 28 Mtonne extra recycled/bio-based plastic (EU Transition Agenda compared to business as usual, from 8 to 55% recycled or bio-based).

A less far-reaching target of 30% recyclate and/or bio-based plastics by 2030 includes 13 Mtonne of additional recyclate and bio-based material input. This results in a saving of 37 Mtonne CO_2-eq. compared to business as usual.

Cost of increased circular plastics: 30% circularity costs € 1 per month per inhabitant
At EU level, the current additional costs (costs minus benefits) of plastics recycling from the packaging system amount to an average of € 875 per tonne of recyclate across the chain. A Europe-wide increase in recycling of 3.4 Mtonne of recyclate (6% of use) would result in additional costs of approximately € 670 per tonne. For bio-based plastics, the additional

cost of bio-PE is approximately € 230 to 350 per tonne. For the most expensive bioplastics, this can amount to as much as € 4,000 per tonne.

These additional cost estimates depend on the development of the price of oil and virgin-plastic. It is likely that the additional costs for recyclate and bio-based plastics will also increase in the coming years due to the costs of CO_2 emissions via ETS and a possible CO_2 levy on virgin-plastic. In addition, chemical recycling has not been taken into account. This form of recycling is still very much under development and is unable to compete as yet. Especially pyrolysis is often regarded as quite expensive. But on the other hand, there are a large number of companies that are currently investing in this. More precise cost estimates are expected in the coming years. The depolymerisation of PET, which is a relatively efficient form of chemical recycling, costs about as much after further scale-up as it saves in virgin-PET and waste incineration (CE Delft, 2020a). This technique is therefore likely to play a role in the shorter term, alongside mechanical recycling.

A doubling of recycling (10% more recyclate) and 10% more bio-based material to a total of approximately 30% circular plastics (20% recyclate and 10% bio-based) would cost the average European citizen about € 1 per month, which will be reflected in slightly more expensive plastic products and packaging.

Cost-effectiveness of CO_2 emission reduction
For a limited increase in recycling application (from 6% at present to 13% in Europe in 2025), the additional costs are estimated to be on average 200 €/tonne CO_2 reduction. This estimate is spread widely; the range of additional costs based on the cheapest options or the most expensive options is 50 to 1,250 €/tonne CO_2.

For the cheapest mechanical recycling options, 50 €/tonne CO_2 reduction can be calculated and, over time, PET chemical recycling (depolymerisation) could probably take place at no additional cost. However, this technique is still being developed and is only possible for PET and not for other plastics. If all plastics are required to be recycled, the costs incurred for the final few kilograms would be significantly higher. Estimates range up to 1,250 €/tonne CO_2 reduction.

For bio-based, the additional costs are around 200 to 600 €/tonne of material and the CO_2 reduction for the more sustainable options is around 2 kg CO_2 per kg of material. This leads to additional costs of € 100 to 300 per tonne CO_2.

The additional costs of a mandatory requirement are not paid by the government or the taxpayer, but by the consumer of plastic products. It is therefore a form of 'the polluter pays'.

Competition with energy is an extra argument for imposing a mandatory requirement
In the Netherlands and the EU, there is an incentive for the use of biomass for fuels (RED mandatory requirement) and for energy (SDE+ subsidy), but not for bio-based plastics. In policy terms, the use of biomass as a material is actually preferable. As these options are largely based on the same bio-based raw materials and residues, the required use of bio-based plastics could balance this out. In the current policy field, it is unlikely that bio-based plastics will grow strongly in the Netherlands and the EU without some form of mandatory requirement or subsidy.

Recently, plastics recycling has also been subject to competition with the energy application. Within the RED, it is possible that Member States will count recycled carbon fuels (fuel made from plastic) as a renewable fuel. If a larger EU Member State starts doing this, it will have a magnet effect on plastic waste, which will limit recycling to virgin-plastics. The incentive for sustainable aviation fuels (SAF) with a likely target of 2% by 2025, and within which plastic-to-fuel is also an option, will also make plastic recycling more difficult. A mandatory percentage of recyclate for all plastics applications has therefore become more topical and urgent, in order to avoid a situation in which all plastic waste is not quickly converted into fuel, thus reducing recycling (with a higher environmental benefit).

General conclusion: mandatory recyclate or bio-based plus EPR schemes can make plastics 3055% circular by 2030
A rapid transition towards circular plastics in the EU is possible through a mandatory requirement for recyclate and bio-based materials at polymer sale and import levels. In addition, it is likely that the Dutch target of 40% recycling by 2030 is too ambitious. On the other hand, it is likely that it is possible to achieve more than the EU target of 18% for 2025.

In addition to the realisation of 20-30% recyclate, there is also a major step to be taken in the field of sustainably produced bio-based plastics. A target of 15% for 2030 can certainly be achieved. When bio-based raw materials are directed more towards materials and less towards fuel, a percentage of 25% is certainly feasible. This means that a combined mandatory requirement for recyclate and/or bio-based plastics makes a target of 30-55% for all plastics in the EU by 2030 conceivable. It would also make sense to extend producer responsibility to all plastics applications. Design for Recycling and improved collection and sorting can also contribute.

Recommendations
For the introduction of a mandatory share of recyclate and/or bio-based plastics in the EU, there are still a number of practical issues to be resolved and detailed later.
Important issues are:
- What specific targets will apply for the years 2023 to 2030? If we assume a target of 25-30% by 2030, it remains to be determined when the mandatory requirement can be introduced and how quickly it will be increased each year. Conceivably, as with renewable fuels, one could start with a limited percentage of 5% and increase this in steps. This needs to be explored further.
- What specific rules will apply to companies subject to the mandatory requirements? How should they report and what forms of certification are permitted? What kinds of exchanges and banking are permitted? In elaborating on this, the rules for sustainable fuels that are already mandatory for the EU under the RED can be adopted.

More EPR schemes and tightening of existing EPR schemes

On top of a mandatory requirement regarding the use of recyclate, it is also important that collection and recycling agreements for all major plastic-using sectors fall under producer responsibility as soon as possible. In addition, in the short term, existing EPR schemes that allow energy application as a reuse option should eliminate or phase out this option and the collection and sorting targets for plastics could be revised upwards.

Moving towards new combinations and concepts of collection

At present, the collection of broken products and packaging is still organised on a sector-by-sector basis. It is conceivable that new combinations can be created in the long run at such time as a lot of material needs to be collected for recycling. For example, the packaging collection system could be rewarded for also collecting plastics products.

Phasing out low-grade mixed plastics applications

At present, especially in the Netherlands, a fairly large percentage of plastics waste from the packaging sector is still used as mixed plastics to replace thick-walled wood or low-grade concrete in the construction sector. This removes material from the plastic chain and the environmental benefit of these options is also smaller. Consideration could be given to making this option count for less in the recycling administration over time.

Sustainability criteria for bio-based plastics

For bio-based plastics, it is important that sustainability criteria are defined in the short term. These can align with the existing sustainability criteria for biofuels under the RED. This was also announced in the letter of the House of Representatives entitled 'Integral Sustainability Framework for Bio-based Raw Materials'.

Taking into account chemical recycling in proportion to the environmental benefit

New technologies for (chemical) recycling can play a role in achieving more plastics recycling. The preferred methods are depolymerisation and dissolution. But pyrolysis and gasification can also contribute to more plastics recycling. It is important that chemical recycling is included in the monitoring of plastics recycling in a balanced way, preferably in proportion to the environmental benefits achieved.

1 Introduction

1.1 Targets for recycled and bio-based plastic

In the Dutch Transition Agenda for Plastics, the aim is to substantially increase the share of recycling and bio-based plastics by 2030. More than half of the annual Dutch use of plastics of 2,460 kilotonnes, which amounts to 1,370 kilotonnes or 56% of which 41% is circular and 15% bio-based, must be recycled or bio-based by 2030. This is a considerable increase compared to the approximately 9% at present, which is 9% recycling and less than 1% bio-based.

But this increase in recycling and bio-based will not happen automatically. Both recycled plastic and bio-based plastics are either more expensive or not much cheaper than virgin plastics over the whole chain, which means that there is no automatic incentive to use more recyclate in the absence of any government policy. The collection of used plastics still mainly takes place in the packaging and automotive sectors, with many plastics ending up in incinerators. The Ministry of Infrastructure and Water Management has therefore asked CE Delft to investigate whether the percentage of recycled plastics could be increased by imposing a mandatory requirement for a certain percentage of recyclate and to assess what the environmental and economic effects would be.

Because this study concerns the European market with considerable mutual free trade, we have focussed on European mandatory requirements. We will also assess, however, whether a scheme is feasible for the Netherlands alone.

1.2 Target

In this study, we identify the feasibility and effects of a mandatory percentage of recyclate or bio-based plastic in new products. We answer the following questions:

1. What quantities of plastic waste and recyclate from mechanical and chemical recycling are currently available and can be expected to be available in 2030 to meet any mandatory requirement?
2. What are the current and proposed policies on the use of recyclate?
3. At what point in the plastics chain would a mandatory requirement best be introduced considering the technical, economic and legal aspects involved? This also raises the question of whether a manufacturer who must adhere to this mandatory requirement is obliged to apply it to every product or whether it is allowed to take the average of the recycling percentage of all its products.
4. Is it better to introduce a mandatory requirement sector by sector, in line with product policy and producer responsibility (as the EU now intends to do), or is an economy-wide mandatory requirement also possible and in various respects perhaps simpler and quicker to implement? The latter option is similar to the Renewable Energy Directive and the Directive on Biofuels for Transport.
5. What are the advantages and disadvantages of combining this recycling mandate with a mandatory requirement for bio-based plastics?
6. What social costs and benefits can be expected from these measures?
7. How can the mandatory use of recyclate, possibly also with a choice for bio-based, be measured and monitored?

8. Considering the quantities and conceivable targets, what recycling percentage is conceivable for 2030 in the Netherlands and what approximate CO_2 emission reduction would be achieved?

1.3 Approach

We applied several methods to carry out this study. The market survey was based on data from Plastics Europe. To identify the plastics chain and policy options, we conducted interviews with a large number of market stakeholders and used our previous study into a tax on plastics for the Ministry of Finance. The costs of a mandatory share of recyclate are based on cost figures from the interviews, literature study and CE Delft expertise.
The environmental impacts were based on Life Cycle Assessment (LCA) studies previously conducted by CE Delft and on key figures from the literature.

1.4 Scope

The scope of the study concerns a mandatory share at the EU level. All analyses thus relate to the EU27. In addition, we have also assessed whether such a system could be conceivable, feasible and interesting for the Netherlands alone.

1.5 Overview

The structure of the study is as follows:
- In Chapter 2 we bring the market for plastics into focus. How much is used and in what sectors are the plastics released? We also outline current and proposed policies. This answers the first and second research questions.
- In Chapter 3 we indicate at which point in the chain it would be best to introduce a mandatory requirement and describe various options for a mandatory requirement for recyclate. This answers the third and fourth research questions.
- In Chapter 4 we estimate climate effects of more recyclate and bio-based plastics.
- In Chapter 5 we discuss the costs and benefits.
- In Chapter 6 we present the conclusions and recommendations.

2 Plastics market in current and planned policy

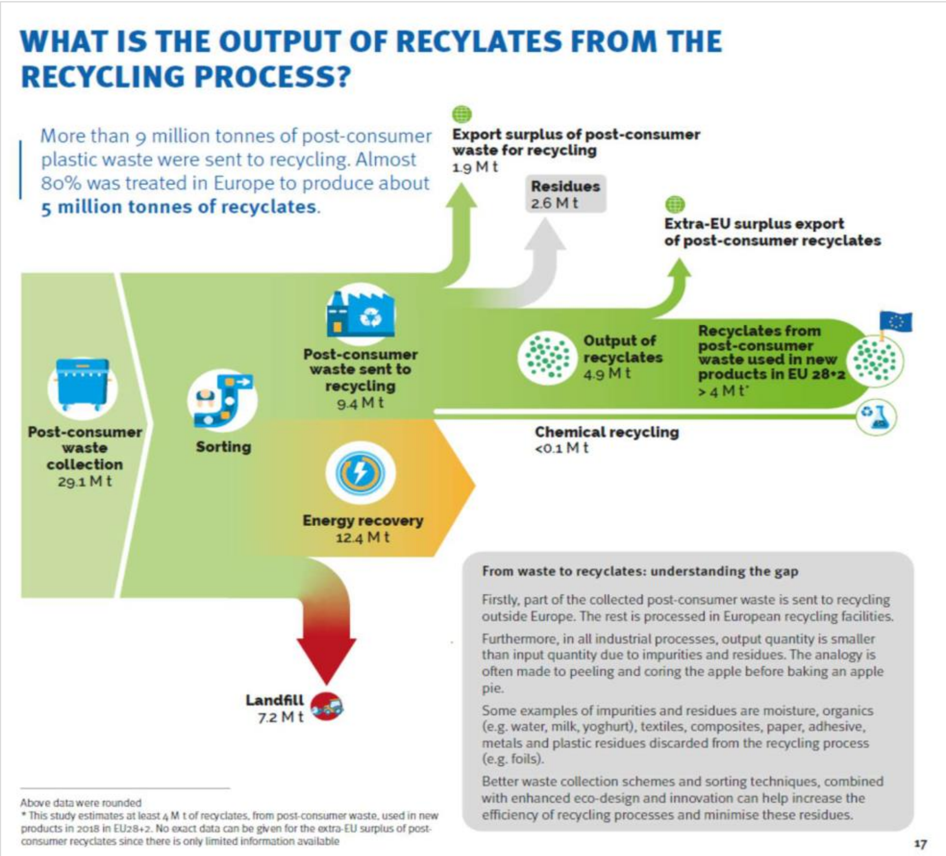
2.1 Introduction

This chapter focuses on the plastics market in Europe. We look at the production, consumption and recyclate quantities. We also show which current and planned policies influence this and what the consequences are for the demand for recyclate.

2.2 Supply and processing of recyclate - current situation

In total, over 50 million tonnes of plastics were consumed in Europe in 2018 and almost 30 million tonnes were released as waste. The amount of waste is lower than consumption because many consumer goods (buildings, cars, etc.) have a long life cycle and the consumption of plastics is increasing every year. Of the (post-consumer) plastics collected, about 4 Mtonne were recycled. This is less than 15% of discarded plastics.
The rest is incinerated, with or without energy recovery, dumped, exported or lost in the production of recyclate. Figure 1 shows what happens to plastic waste in Europe.

Figure 1 – From waste collection to recyclate, 2018, EU + NO, CH



Source: (Circular Plastics Alliance, 2020).

Table 1 shows the consumption, waste collection and use of recyclate per product group. We see that the application of plastics in packaging is still the largest sector. Most of the waste collected also comes from packaging. This is explained by the short life span of packaging; packaging made this year is likely to be discarded this year. In construction, for example, the service life is much longer and the proportion of waste in relation to consumption is much lower. Also, in many countries the packaging sector has an Extended Producer Responsibility (EPR) that includes separate targets for collection and recycling of plastic packaging waste. In other EPR systems (automotive, electronics), there is only an average target for all materials, with plastics relatively outweighed by the heavier metals, and in part the energy application of plastics is also seen as a high-value 'useful' application.

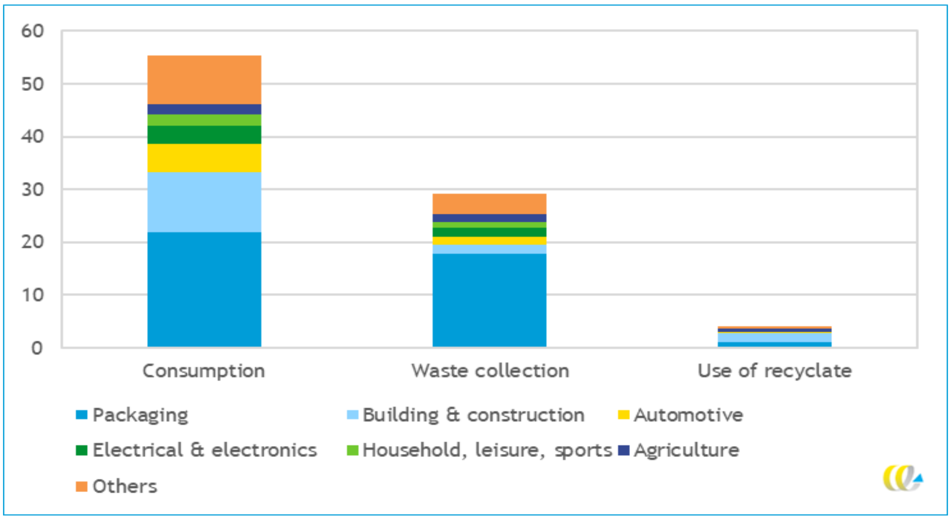
Table 1 - Consumption, waste collection (kilotonnes) and collection relative to consumption, 2018, EU+NO+CH

	Consumption	Waste collection	Waste relative to consumption
Packaging	21,170	17,802	84%
Building & construction	12,737	1,652	13%
Automotive	4,742	1,403	30%
Electrical & electronic equipement	3,643	1,716	47%
Household, leisure, sports	2,017	1,040	52%
Agriculture	2,428	1,512	62%
Others	8,656	3,931	45%
Total	**55,393**	**29,056**	**52%**

Source: Plastics Europe.

Virtually all recyclate coming onto the market is mechanically recycled. The use of chemical recycling is still limited (< 0.1 Mtonne). The following figure shows the consumption, waste collection and use of recyclate by sector.

Figure 2 - Consumption, waste collection and post-consumer recycling by sector, 2018, EU + CH/NO, Mtonne/year



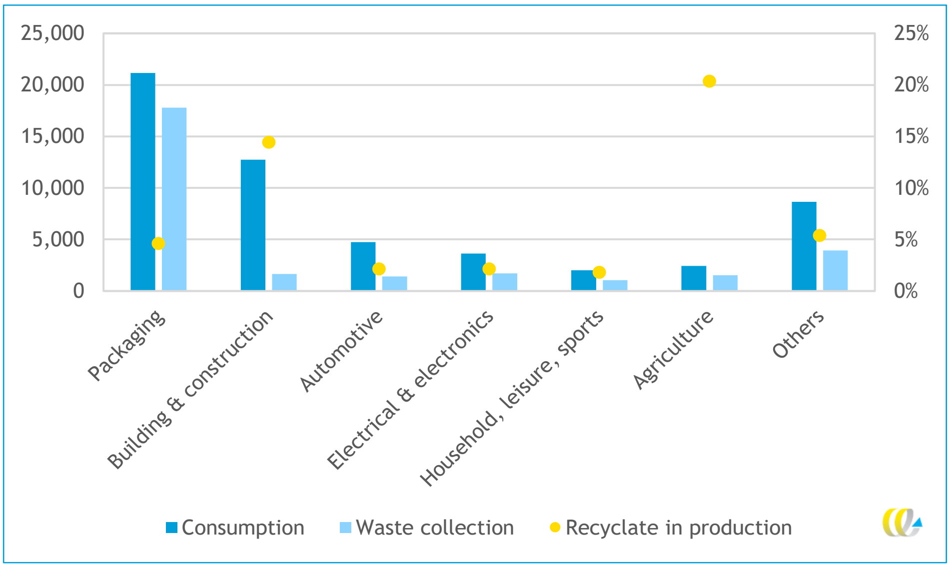
Source: (Plastics Europe, 2020).

NB: Waste collection largely consists of waste collection mixed with other waste, with only a limited part being separate waste collection.

Most recyclate (in kilograms) is used in building and construction. The largest percentage of recyclate per product is used in agriculture (agricultural films). Approximately 20% of the production of plastics for agriculture is recycled. This can be seen in Figure 3. This percentage is also relatively high in construction and infrastructure. In all other sectors it is 5% or lower. In construction, more recyclate is used than is released, so this means that recyclate from other sectors is used. The opposite is the case with packaging.

Compared to the approximately 40% recycling of packaging, there is less than 5% recycling in packaging[1]. The main issue here is that food safety requirements make it difficult to use recyclate in food packaging. Another factor here is that, at least in the Netherlands, the Framework Agreement for Packaging currently allows 55% of plastic recycling to consist of mixed plastics recycling from which thick-walled products are made, such as berm posts, wall cladding and beams for street furniture. These count as uses of recyclate in construction. These applications, where wood, hard wood, concrete and only partially plastic are replaced, are considered to be of lower value than the application of monomaterials that do replace 100% plastics.

Figure 3 – Plastic production, waste collection and recycling in EU28 + NO, CH, kilotonnes and %, 2018



Source: Own calculation based on (Plastics Europe, 2018) and (Plastics Europe, 2020).

We can see that 40% of plastics are used in the packaging market and that the percentage of plastic waste in the packaging market is 60%. In other sectors, there is much more stockpiling in the economy.

Recyclate is mainly used in construction, infrastructure and agriculture, partly due to legislation that imposes strict requirements on the use of recyclate in food packaging. For the proportion of recyclate in products to increase, a greater proportion of discarded plastics must be used as recyclate or the overall consumption of plastics must be reduced. In construction, quite a large percentage of the recyclate used is the low-grade use of mixed plastics that are only suitable for thick-walled applications. In addition, this option replaces other materials such as concrete and wood rather than virgin plastic.

[1] According to Eunomia, the proportion of recyclate in packaging is 12%, but it is unclear whether this includes post-industrial waste. In any case, the share is significantly lower than for glass (56%), paper (> 50%) and cans (~50%).

2.2.1 High and low value use of recyclate

One target of plastics policy is to find the highest possible high-grade application of recyclate. This partly refers to economically high-grade recyclate that replaces virgin plastic. Thick-walled applications that replace cheaper materials, such as low-grade concrete and wood, are not included. Earlier analyses by CE Delft also indicated that the climate benefit of recycling mixed plastics into thick-walled applications is on average about half that of recycling monomaterials into plastic substitution (CE Delft, 2011).
A major cause of this mixed plastics recycling is that many materials in the packaging sector are difficult to recycle as monomaterials due to packaging designs that include laminates and combinations of different materials. Therefore, in order to still achieve the targets in the EPR for packaging, part of the materials are used as mixed materials to replace wood and concrete. Design for Recycling and better sorting (target of Plastic Pact NL) can ensure that the percentage of monomaterials increases and use of mixed plastics consequently decreases. It is therefore logical that the percentage of applications in the construction industry will fall in relative terms.

Formally, the use of remelted plastic in thick-walled products instead of wood is a form of recycling, but it does not achieve the goal of using less virgin plastic. Consideration could be given to not counting this form of plastic recycling as recycling in the long term, or at least not counting it in part.

At present, the distribution of high-grade and low-grade recycling is approximately 60%/40%. In this estimate, we assume that most of the use of recyclate in construction is the use of mixed plastics in thick-walled applications instead of wood and concrete.

2.2.2 Different materials by sector

The fact that there are many different plastics with different properties and different additives makes the use of plastics versatile and practical, but makes recycling generally more difficult. By sector, there are several main groups of plastics that are applied:

Table 2 - Use of plastics by sector

Sector	Main groups of plastics
Packaging	– Sheeting and bags mostly PE – Bottles, HDPE or PP and partly PET – Bottles, usually PET – Containers: PET, PS, PP, etc.
Building & construction	– Many mixed plastics, such as thick-walled recyclate instead of wood or concrete – Window frames and outdoor drainage: PVC – Water pipes: HDPE
Automotive	– Headlights: polycarbonate PC – Bumpers: PP
Electrical & electronic equipement	– Many interiors are made of PP – Shiny exterior often ABS – Food contact materials often PS – Various other components PC – Strong components polyamide
Household, leisure, sports	– Textiles: lots of polyester (PET) and polyamide (PA) – Carpets: polyester and polyamide (PA)

The recyclability of each plastic differs greatly, for example PET is easier to recycle than PE applied in sheeting. Chemicals such as flame retardants are added to certain plastics. As a result, it is not possible or permitted to mechanically recycle these plastics. This applies, for example, to plastics in cars and electronics.

2.3 Supply and processing of recyclate - future situation

Europe: from 4 to 10 million tonnes by 2025

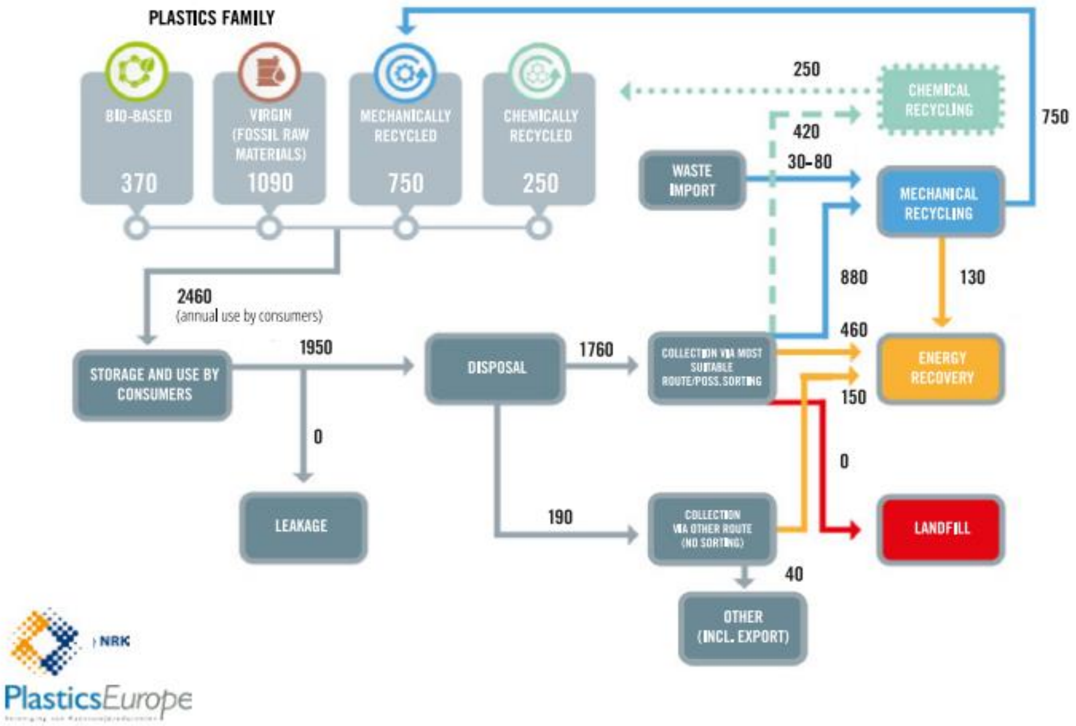
The European Commission launched the Circular Plastics Alliance in December 2018.
This alliance aims to put 10 million tonnes of recycled plastic on the market by 2025. This is therefore more than double the situation in 2018.
The Circular Plastics Alliance has been signed by more than 200 parties from the entire plastics chain (Circular Plastics Alliance, 2020). The plastics industry has stated that it aims to offer 1.2 million tonnes of chemically recycled plastics on the market by 2025 and 3.4 million tonnes by 2030. It intends to invest € 7.2 billion in this.
This will also contribute to the 10 million tonne target in Europe (Plastics Europe, 2021).

The Netherlands: from 250 kilotonnes to 1 million tonnes in 2030

The Transition Agenda for Plastics (2020) includes a target of 1 million tonnes of recycled plastics by 2030. This means a recycling share of 40%. Of these, three quarters are recycled mechanically and one quarter chemically. Of the plastics consumed, only just over 40% is virgin plastics. Of the discarded plastic, 50% is recycled mechanically (input) and just under 25% chemically.

Thus, the Dutch target (a factor of 4 more than at present) is clearly more ambitious than the European target (a factor of 2.5 more than at present). However, the Dutch target year is five years later.

Figure 4 - Target situation for plastic flows 2030



Source: Transition Agenda for Plastics.

The Chemical Recycling Roadmap (Nederland Circulair, VNO-NCW, 2020) includes an even more ambitious 'dot on the horizon' for chemical recycling. By 2030, 10% of the feedstock for plastic production must consist of chemical recyclate. This equates to 555 kilotonnes. This requires an input of 1,000 to 1,500 kilotonnes. The Roadmap shows that bottlenecks are mainly on the input side and that extra steps are needed to achieve sufficient collection and sorting. It must also be ensured that the plastic waste does not end up in other sectors (fuel). If the Chemical Recycling Roadmap is added to the Transition Agenda, thus increasing the proportion of chemical recycling from 250 to 555, the total target for recycling input becomes approximately 50%.

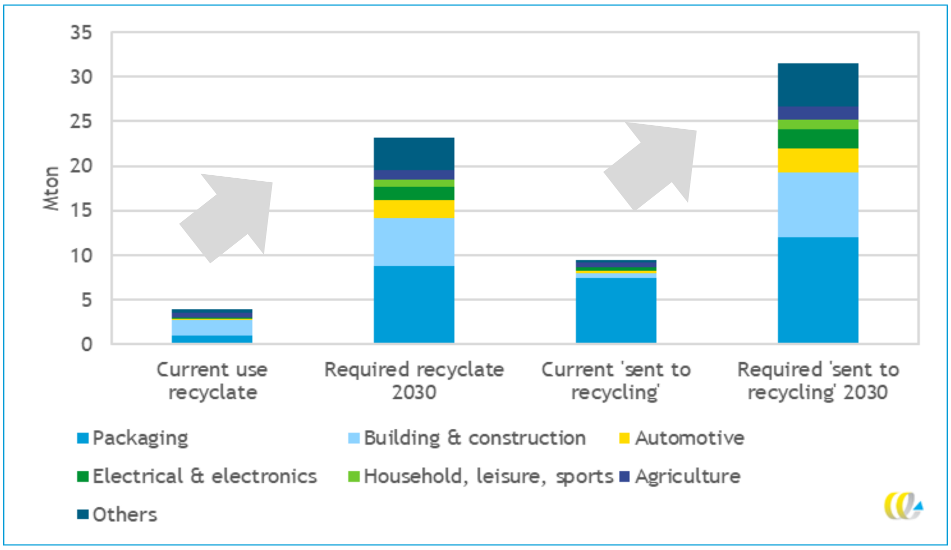
2.4 Supply and processing of recyclate - what is needed in Europe?

If the Dutch target of 40% by 2030 is used for the European market, considerably more waste collection and production of recyclate will be required.

According to Plastics Europe, 55 Mtonnes of plastics were consumed in Europe in 2018. 29 Mtonnes were discarded and nearly 4 Mtonnes of post-consumer recyclate was used. (Nederland Circulair, VNO-NCW, 2020) expects the Dutch consumption of plastics to grow by 0.36% annually and the production of waste by 0-3% annually. Consumption is therefore expected to grow less fast than disposal, partly because more plastics are released in sectors such as construction. If we assume that these growth rates are the same for the whole of Europe and proceed on the basis of a waste growth rate of 1.5% per year, this leads to a consumption of over 57 Mt in 2030 and almost 35 Mt of waste.
It is clear from Figure 5 that we need to increase the amount of required recyclate by more than five times to meet the target of 40% input recyclate. Since 1 kg of waste does not

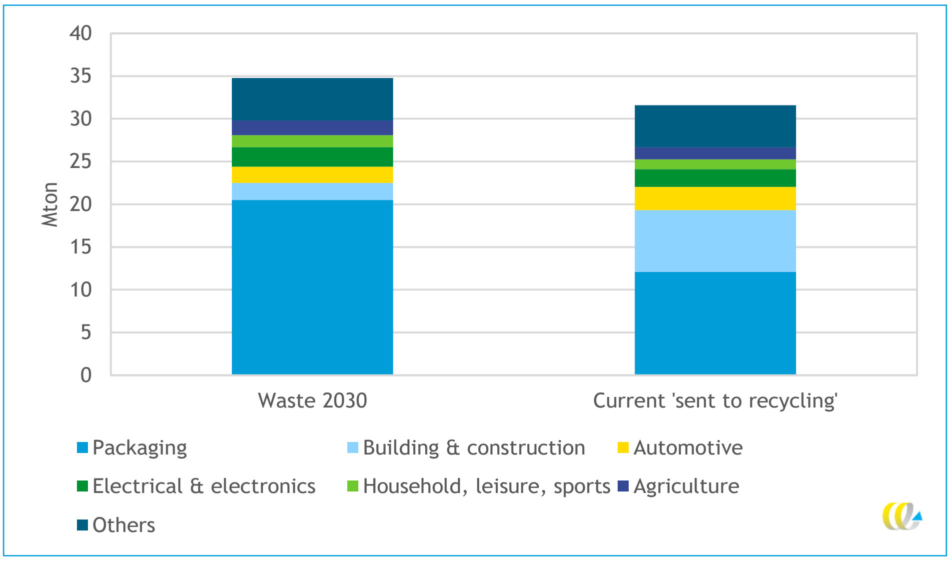
result in 1 kg of recyclate due to disposal, even more waste is needed to achieve the required amount of recyclate[2]. More than three times as much waste must be sent for recycling in order to achieve the target. Besides, the recyclate could also be used through imports.

Figure 5 - Amount of recyclate needed at 40% based on 2018, EU28 + NO/CH, Mtonne



If the amount of waste expected to be collected in 2030 (separated and non-separated) is compared with the waste required to achieve 40% recycling, it is clear that more than 90% of plastics waste must be used and therefore collected separately or post-separated.
At present, the separate collection rate for packaging is 50% and is much lower for other applications.

Figure 6 - Waste 2030 and waste needed to meet 40% target, 2030, EU + NO/CH, Mtonne



2 This assumes 1.26 kg of waste for 1 kg of mechanical recyclate and 1.68 kg of waste for 1 kg of chemical recyclate, based on the transition agenda.

Figure 6 also shows that a closed loop percentage of 40% for all sectors is impossible. In this figure, we have assumed an undifferentiated target of 40% recycling in each sector and equal growth in consumption and waste collection per sector. This last assumption is probably a bit too broad[3], but it will not change the conclusions significantly.
In the construction, electronics, automotive and other sectors there is insufficient recyclate available for a closed loop requirement. Only in the packaging, agriculture and household, textiles and sports sectors is there enough recyclate available to meet the target and these sectors can also help other sectors acquire recyclate as they do now.[4]

Due to stockpiling, the demand for new plastic in the coming decades will exceed the waste supply each year. As a result, there will be a need for virgin plastics to meet demand.
In addition to striving for as much recyclate as possible, this is also an argument for choosing to use materials that cannot be replaced by bio-based plastics.

In the plastics market, the use of recyclate is still limited. On the one hand, there is a lack of demand due to high market/chain prices relative to virgin plastics and a lack of other incentives. On the other hand, supply is still low because many potential recyclables are not yet collected, sorted and recycled, but are instead landfilled, exported or incinerated. In the packaging sector, the proportion of waste collected is already relatively high, partly due to recycling targets in this sector. However, much of this recyclate is still used in other sectors, such as construction. Part of this is low-grade, such as mixed plastics in thick-walled applications in the construction industry.

Another striking point is that the increase in the use of plastics in non-packaging applications, such as cars and construction, leads to a significant increase in stockpiling in the economy. The amount of plastic waste that is released is about 60% of the applicable amount. This limits the maximum percentage of recyclate that can be achieved and means that bio-based materials could be a good addition to achieve the higher targets for circular plastic. In order to achieve the European targets and the Transition Agenda targets, a substantial increase in the use of recyclate is still required and there must also be sufficient supply to meet the target.

We conclude:
- Due to stockpiling in the use of plastics that are not for packaging, a recycling target of 40% as proposed in the Dutch Transition Agenda is very ambitious and theoretically just barely achievable.
- Until 2030, a requirement for a closed loop by sector, such as the use of recyclate from electronics in electronics, either leads to a much lower overall result or to much higher costs, especially in the packaging sector.

2.5 Current policies for the use of recyclate and bio-based plastics

At present, there are various policies that encourage plastic recycling. The most important of these is the producer responsibility for plastic packaging, which includes targets for waste recycling of plastic packaging. In the Netherlands, this is regulated through the

[3] We expect greater growth in the supply of waste in the construction and automotive sectors, while waste in the packaging sector is expected to grow at a slower rate.

[4] Some of the plastic consumed in Europe is produced abroad. Europe has a small export surplus. If a mandatory requirement is placed on the marketing of the plastic, this means that parties abroad must also have sufficient recyclate available. If a large quantity is produced for export in a certain sector and it is not subject to a mandatory requirement, then there is less need for recyclate in that sector.

Framework Agreement for Packaging. There is also the Plastic Pact, where a large number of companies have set voluntary targets for increased plastic recycling.

Especially with regard to the use of plastics in packaging, which accounts for 40% of the plastics market, there are policies for recycling and proposals for new policies. In the current setting, producer responsibility organisations are key players to increase the recycling of plastics. The EU Packaging Directive (94/62/EC) incorporates Extended Producer Responsibility (EPR), to be determined by Member States. Almost all Member States (26 out of 28 in 2019) have included some form of EPR in their packaging policy. In the Netherlands, this led to the Packaging Management Decree (Besluit Beheer Verpakkingen). The Packaging Waste Fund (Afvalfonds Verpakkingen) is responsible for implementing this policy on behalf of the producers. Companies that place packaging on the market are obliged to pay a contribution for the collection and processing of this packaging at the end of its life cycle. This contribution is already differentiated according to the type of materials. For easily recyclable packaging, the rate is lower than for difficult to recycle packaging.

There is one product group for which a mandatory proportion of recyclate has already been established and that is PET bottles for beverages. Article 6 of the SUP Directive (SUP-richtlijn) states that PET bottles for beverages must contain at least 25% recyclate by 2025. By 2030, all plastic beverage bottles will be required to contain at least 30% recyclate. In the Netherlands, it has not yet been decided who will be responsible for this mandatory requirement. The European standards body, the European Committee for Standardisation (CEN), is working on certification. Especially in (EU) countries with poor-quality drinkable tap water, the share of PET bottles in the packaging mix is quite large. In countries with good-quality tap water, the proportion of PET bottles in the packaging mix is much smaller. In the Netherlands, this was about 13% in 2015. Calculated over all plastic use, this is therefore 13% x 40%, which is about 5% of the plastic in use the economy. Thus, a 30% mandatory requirement for PET bottles covers about 1.5% of the plastic used in the Netherlands.

Extended Producer Responsibility (EPR) also applies to electrical and electronic equipment, batteries, end-of-life vehicles and tyres. Plastic is used particularly in cars and electrical and electronic equipment. The EPR scheme for end-of-life vehicles and electrical and electronic equipment does include targets for processing and recovery. However, these targets are not specified for plastics and are mainly achieved by the recycling of metalsRecovery of plastics includes incineration with energy recovery. In this way, incineration of plastic waste that is subject to EPR is also counted as recycling, while the material is no longer available as recyclate. In principle, EPR relates to post-use processing and not to the design phase in which the recyclate can be used.

For textiles, producer responsibility is currently being worked out in a general administrative measure. This will include targets for product re-use and recycling (Ministerie van Infrastructuur en Waterstaat, 2021).

For most other secondary applications of plastics, such as in agriculture and construction, there is not yet any producer responsibility, which means that the free market seeks to keep costs as low as possible. This is usually incineration for energy purposes. Between 1995 and the beginning of 2000, a disposal requirement applied to agricultural films. In this case, the market took over the collection of agricultural and horticultural films and the producer organisation ceased its activities (GroentenNieuws, 2013).

In other countries, EPR schemes also exist for specific types of packaging, such as agricultural films, cartridges and medical packaging[5]. At the EU level, the recycling target for plastic packaging is 50% by 2025 and 55% by 2030.

2.5.1 Bio-based plastics policy

The Transition Agenda for Plastics, which is part of the government-wide programme for the circular economy, sets a target of 15% bio-based plastics consumed in the Netherlands by 2030. The current percentage is around 1% and there is no automatic trend toward this 15%.

For some time now, the introduction of increased policy with regard to bio-based plastics has been under consideration. Proposals for this have recently been made in the 'Biobased Plastics Action Plan', drawn up by industry, NGOs and the government. The following factors ensure that the share of bio-based plastics in the market so far remains very limited (1%):

- bio-based plastics are more expensive than fossil plastics;
- the environmental impacts of fossil plastics are not included in the price;
- the government is steering bio-based raw materials into energy and fuels through the biofuel mandatory requirement in the Renewable Energy Directive (RED) and subsidies for renewable electricity and biogas;
- for bio-based plastics, after the abolition of the rebate for bioplastics from the Dutch Packaging Waste Fund (2020), there are virtually no more incentives.

The introduction of either a subsidy system, possibly implemented administratively by the Packaging Waste Fund as a reduction in tariffs, or a mandatory requirement for the use of bio-based raw materials are mentioned as possible forms of stimulation. In addition, it is stated in this action plan that if this mandatory requirement is combined with a mandatory requirement for recyclate (bio-based or recyclate), there will be greater support from businesses for this than if it were a separate mandatory requirement for bio-based packaging alone.

In the letter to the House of Representatives about the 'policy for bio-based and biodegradable plastics' (10-06-2021/IENW/BSK-2021/97147) from State Secretary Van Veldhoven, she endorses the analysis in the 'Biobased Plastics Action Plan' (Transitieteam Kunststoffen, 2020). Given the price difference between bio-based plastics and fossil plastics and the impossibility of regulating the incentive with a covenant, additional measures are needed. The most interesting option mentioned is a form of compulsory minimum share of bio-based and/or recyclate introduced at European level. Europe is expected to come up with proposals for a mandatory share of recyclate (perhaps only in packaging) and bio-based plastic.

2.6 Exploration of new policies

The Ministry of Infrastructure and the Environment's aim is to promote the market for and use of plastic recyclate by means of more far-reaching policy measures. There are four main tracks:

1. Firstly, the State Secretary has undertaken to work at EU level towards a compulsory percentage of recyclate in new plastics. The European Commission intends to establish the mandatory use of (plastics) recyclate in ongoing revisions of existing sectoral regulations, such as packaging, building materials and end-of-life vehicles. The

[5] zero_waste_europe_IEEP_EEB_report_epr_and_plastics.pdf (zerowasteeurope.eu)

Commission is also working on broadening the scope of the Ecodesign Directive, which in time will allow the introduction of mandatory requirements for recyclate for products that are not yet covered by sectoral rules, such as textiles and furniture. This sectoral approach is currently being explored, particularly for packaging. Many policies are already being developed for this segment. A possible economy-wide mandatory requirement for recyclate and plastics across all sectors would therefore mainly be complementary to policy on packaging.

2. Letter to the House of Representatives on policy on biobased and biodegradable plastics (10-06-2021/IENW/BSK-2021/97147)
   Quote: "*As previously reported to your House of Representatives, the government is committed to a European mandatory minimum percentage of sustainably produced and recyclable bio-based plastics for certain products. This minimum percentage should be in addition to the recycling targets. I believe that a well-founded European approach is desirable for the sake of a level playing field. I expect that a mandatory minimum share will address the price barrier of bio-based plastics (economies of scale) as well as the lack of awareness.*"

The European Commission adopted the 'Circular Economy Action Plan' in 2020[6], as part of the Green Deal.
It states that the Commission intends to make proposals for a mandatory proportion of recycled material for key products such as packaging, building materials and end-of-life vehicles. This is planned for 2021/2022. If there is to be a mandatory percentage, this will be included in the:
- the revision of the Packaging and Packaging Waste Directive;
- the evaluation/revision of the Construction Products Regulation;
- the evaluation/revision of the End-of-Life Vehicles Directive.

In the European context, therefore, a sectoral approach is clearly being adopted. In the Netherlands, the Action Plan on Plastics Recycling proposes to investigate the feasibility of specific minimum percentages or a range per product group and sector. There is also the proposal not to wait for the EU, but to immediately set minimum requirements in the Netherlands if the market shows that this is possible.[7]
In the medium term, it is proposed that virgin producers should be required to add a minimum percentage of recyclate, in line with the Renewable Energy Directive (RED).

In addition, there are also a number of voluntary initiatives aimed at promoting the recycling of plastic packaging. Both at European level and for a number of Member States, including the Netherlands, there is the Plastic Pact. The European Plastics Pact consists of agreements between plastics producers, large companies, governments and recyclers. The pact contains four substantive goals to which signatories have committed themselves by 2025:
- make plastic packaging fully recyclable and suitable for reuse where possible;
- reduce unnecessary plastic consumption and the use of petroleum-based plastics by at least 20%;
- improve the current capacity of collection, sorting and recycling by at least 25%;
- use at least 30% recycled plastic in new packaging and products.

The European Plastic Pact has been signed by fifteen governments. The Dutch Plastic Pact aims to achieve a 35% use of recycled plastic in single-use plastic by 2025 (single-use plastic is mainly packaging). In addition, at least 70% of this SUP packaging and products should be recycled at a high rate.

6 A new Circular Economy Action Plan (europa.eu)
7 PowerPoint presentation (partnersforinnovation.com)

3. In response to the Van Raan motion, CE Delft carried out an initial study for the Dutch Ministry of Finance into the possibilities and effects of a tax on virgin plastics in the Netherlands (CE Delft, 2021). This study shows that a levy early in the chain is possible and can lead to an increase in the share of recyclate, but that it can also have negative effects on the competitive position.
   A levy later in the chain, for example at the sale of the final product, is also possible but provides less of an incentive for recycling and has a greater administrative burden, but hardly any adverse effects on competitiveness.

4. Climate policy is increasingly focusing on the recarbonisation of chemistry: replacing fossil raw materials such as natural gas and oil with bio-based raw materials, recyclates and, in the future, also renewable CO_2.

2.7 Conclusion

We see that most plastics are produced for the packaging market (40%), but other sectors such as the construction and automotive industries are growing more strongly, which means that the share of the packaging market is falling. However, due to stockpiling in other sectors, most plastic waste comes from the packaging market (61%). It is therefore logical that the first policy should now focus on packaging. However, given the declining share of the packaging market in plastics and the expected substantial increase in plastics waste in other sectors, it is also necessary to regulate plastics recycling in other markets more quickly. Both sorting of plastic waste from these other sectors and the application of recyclate in these other sectors are necessary to achieve the intended recycling targets.

For automotive and electronics, there is already a policy on collection, but it is not specific to plastics. And use of plastics for energy also counts as recovery in the context of Extended Producer Responsibility (EPR) and is presented as comparable to recycling. Adjusting EPR schemes so that only recycling counts and energy does not, could make more plastic waste available for recycling.

Together, these streams (packaging, automotive, electronics) constitute about 72% of plastics waste. To achieve ambitious targets, such as 40% use of recyclate, policies are needed for all sectors because almost all plastic waste is needed to have sufficient recyclate.

In the Dutch Biobased Plastics Action Plan, drawn up in consultation between companies, the government and NGOs, it has been established that some form of stimulation is necessary to increase the current 1% share of bio-based plastics to, for example, the targeted 15% for 2030. A form of mandatory requirement is an option for this. Industry prefers to combine a bio-based mandatory requirement with a recyclate mandatory requirement, so that a choice is possible.

3 Options for a mandatory share of recyclate and/or bio-based plastic

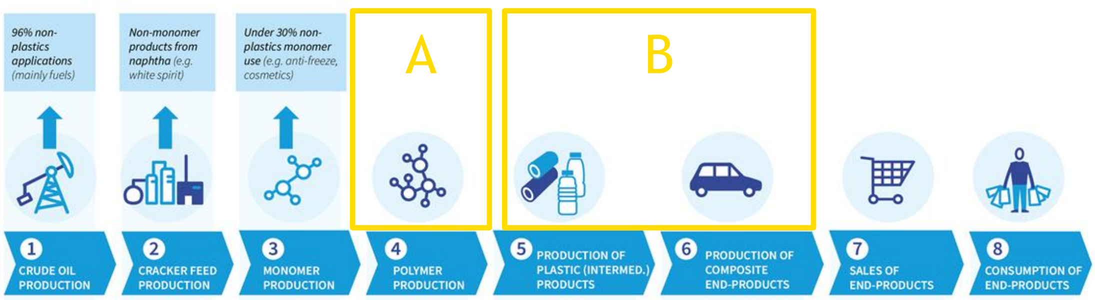
3.1 Introduction

In this chapter we discuss the different options for a mandatory share of recyclate. We discuss the advantages, disadvantages and design aspects. There is already a policy in Europe towards a mandatory share of recyclate in some packaging and for cars. In this chapter, we explore the possibilities of establishing an economy-wide mandatory share. This can be done by a comprehensive mandatory requirement for producers and importers in all sectors, but also by placing a mandatory requirement on polymer producers and importers. We will first consider a variant with only a mandatory share of recyclate. Then we will discuss whether that could also be a mandatory share of recyclate and/or bio-based.

3.2 Various options for a mandatory requirement

There are two places in the plastic chain (see Appendix A for an overview) where it would be obvious to introduce a mandatory percentage, these are the producers of the polymers (Step 4 in the following figure) and the producers of the plastic end products (Step 6 and sometimes Step 5 in the following figure), or the brand owners. Earlier in the chain, for example in the extraction of raw materials, it is not possible to use (mechanical) recyclate. Later in the chain is not very practical, because this would mean, for example, that a shop would have to carry a mandatory share of recyclate in its assortment. In this chapter, we discuss two variants of a mandatory requirement, one placed on the polymer producers and importers and one on the brand owners.

Figure 7 - Plastic production chain



These variants are:
a Obligation for polymer producers and importers.
b Obligation for brand owners (producers and importers of finished products).

Below, we explain the variants in more detail and name the most important advantages and disadvantages. We also address some design issues, which require further elaboration.

3.2.1 Obligation for polymer producers and importers

In this variant, the mandatory requirement is placed on polymer producers and importers. This is the party in the chain that converts chemical building blocks (monomers) into plastic granules (polymers). These plastic granules are then put on the market. In case of a mandatory requirement, the portfolio of polymer producers should consist of at least xx% recyclate. In this way, polymer producers can choose which type of polymers to use the recyclate for. It is therefore not a question of a mandatory requirement per polymer.

Some 50 large polymer producers are active in Europe. There are also parties who import polymers. This has the advantage that enforcement is relatively simple and administrative costs can therefore be kept low. So-called compounders are also active in the market; they mix polymers with additives. These are usually the same parties that make polymers, but may also be specialist parties one link further in the chain. These compounds are also imported. Since the main purpose of the mandatory requirement is to replace virgin plastic, it seems logical to make polymer producers and importers responsible and also to include imported compounds in the mandatory requirement.

A point for attention is how to deal with the import of polymers/plastic products.
The plastics market is a very international market and this can lead to distortions of competition. The mandatory requirement may be imposed at the time of 'placing on the market', which means that a mandatory requirement also applies to the import of polymers. If the mandatory requirement only applies to the import of polymers, the import of plastic products therefore has an advantage over production in Europe. Alternatively, the mandatory requirement can be placed on production. In that case, only European producers are obliged to contribute a mandatory share. This leads to adverse competitive effects. We therefore assume that the mandatory requirement is placed on the marketing of polymers. Should this lead to unwanted effects, the mandatory requirement of imported plastics could be extended step by step to semi-finished and finished products.

Producers of recyclate are often different parties than the producers and importers of polymers. Polymer producers are large multinationals. Recyclate producers are much smaller. There are around 1,000 of these in Europe. This could lead to consolidation in the sector, with polymer producers buying up recyclate producers. It is also possible that polymer producers will opt for chemical recycling rather than mechanical recycling, as this fits in better with their business activities. This may put mechanical recycling under pressure, although in some cases it is preferable from an environmental point of view.
A third point of concern is that polymer producers become responsible for an aspect of the chain that is not their core business.
However, this situation is similar to the introduction of the biofuel blending requirement at the beginning of this century. The producers of fossil petrol and diesel were given the mandatory requirement to add biodiesel and ethanol and did not produce it themselves at that time. This has led them to buy biomaterials, produce them themselves and take over companies that were active in this field. These three options will also come into play here.

If the mandatory requirement lies with polymer producers and importers, there will be no direct incentive to increase the supply of recyclate (especially through better separation of waste). Polymer producers and importers have no influence when products are discarded, nor do they play a role in Design for Recycling.

In the case of a mandatory requirement for polymer producers and importers, it is not possible to differentiate by type of (end) product since the final destination is unknown.

A differentiation by type of plastic is possible if a producer or importer makes several types of plastics. It can then choose to use the recyclate for a certain type of plastic.

Compliance and monitoring could also be done through tradable units, as is the case with biofuels (see next box).

Translation of biofuels directive to plastics

In 2003, the Biofuels Directive set a target of 2% in 2005 and 5.75% in 2010 for biofuels. In 2005, it turned out that Member States themselves had set much less ambitious targets and that the share of biofuels remained at 1%, mainly due to Germany's efforts. As progress was insufficient to meet the 2010 target, the Renewable Energy Road Map[8] decided on legally binding targets. The target for 2020 was set at 10% of total petrol and diesel consumption in transport in the EU. Member States were free to set a national target. However, an overall target had to be achieved together with targets for electricity, heating and cooling. The interpretation per Member State therefore differs and the directive has been adapted over time, among other things on the basis of new insights about the sustainability of biomass.

The current blending requirement in the Netherlands is set out in the Energy Transport Regulations[9]. Suppliers have an annual renewable energy mandate. There are 36 suppliers in the Netherlands that require notification. The supplier must 'book' the volume or number of kWh of the fuel per energy source. Renewable fuel is verified by a verifier. This fuel shall be provided with a verification statement bearing a unique number that can be traced back to him.

Renewable Energy guarantees of origin (GoO) are registrations of quantities of 1 GJ of renewable energy supplied to the market. Guarantees of origin (GoOs) are registered in the Energy for Transport Register (REV). For example, a company that has delivered biofuel to the market and booked it will receive Guarantees of origin (GoOs). The party can use the GoOs for its own annual mandatory requirement, if it has one, or sell them to other parties who can use them to meet their annual mandatory requirement. The GoOs are created on accounts in the Energy for Transport Register (REV) and can only be transferred in the REV. However, companies trade the units outside the registry by making purchases and sales. The GoOs market is thus a self-contained entity of supply and demand for units. The GoOsmarket is relatively small in size with a relatively limited number of participants who are known to each other.

Translation to plastic

The Dutch elaboration of the Biofuels Directive can be translated to the plastics market.
This would mean that instead of GoOs, RE-plastic units (REnewable and REcyclate) could be created in the production of recyclate or products containing recyclate. Subsequently, these units can be traded. A translation of the Biofuels Directive to plastics requires some further thinking. Among other things, it has to be decided where in the chain the mandatory requirement will be placed. In principle, transport fuels are not processed any further, whereas this happens with plastics (granules), for example. Also, the number of parties in the whole plastic chain is many times larger.

3.2.2 Mandatory requirements for brand owners

In the second variant, the mandatory requirement is placed on the brand owners. This is the party responsible for putting a product on the market. This is for example the producer or importer of the laptop or car. In the case of packaging, this will be the producer or importer of the product in the packaging, for example the filler of the shampoo or paint bucket. This is therefore Stage 6 in the chain (and in the case of plastic products sold directly as end products in Stage 5). The brand owner must be able to demonstrate that xx% of the plastic used in the products it puts on the market is recyclate.

8 EUR-Lex - 52006DC0848 - EN - EUR-Lex (europa.eu); EUR-Lex - l27065 - EN - EUR-Lex (europa.eu)
9 wetten.nl - Regulation - Energy Transport Regulation - BWBR0041050 (overheid.nl)

A mandatory requirement for brand owners can be fulfilled in various ways. A differentiated approach involves legislation at sector or product level or agreements on a mandatory percentage of recyclate. The level and requirements of this mandatory share can differ per sector or product, depending on the feasibility of a certain target within a sector or product group.

It depends on the situation at which level the legislation or agreements can be made, in line with current practice. This can lead to agreements for cars, for example, being made at sector level, as the sector contains one homogeneous type of product. For more heterogeneous products, such as in the construction industry, regulation will be able to be product-based.

In the packaging sector, there is already legislation on the collection and processing of plastic waste. This is implemented in most Member States through Extended Producer Responsibility (EPR). Producers are thus jointly responsible for achieving certain goals and for organising this. EPR relates mainly to responsibility during the waste phase of a product and not usually to the production phase. This could be regulated through product policy. The Packaging Directive already contains essential requirements with which packaging placed on the market must comply. For example, there are already requirements for electronic devices (Ecodesign) and chemical substances (REACH).

As with the waste management levy, the mandatory requirement can be placed on the placing of packaging *on the market*. The party that produces, fills or imports the packaging into the Netherlands is liable to pay the levy. In the case of a mandatory share of recyclate, this implies that producers or importers of the end product are responsible for organising the mandatory share and that the mandatory share is therefore also determined at the level of producers or importers. Products produced outside Europe also have to comply with such an obligation. This creates a level playing field for all producers. In practical terms, this means that all producers/importers must be in the picture. This concerns many thousands of parties throughout Europe. A reliable certification system for recyclate must also be available. The Green Deal 'Reliable Proof for Application of Plastic Recyclate' is developing a methodology by which reliable claims can be made for both mechanically and chemically recycled secondary plastics. A system of certificates as used for enforcement of the Renewable Energy Directive (RED) may also be considered.
This should then be passed on as the product moves through the chain. A point for attention in monitoring is that it is impossible to measure at product level whether a product consists of (chemical) recyclate or virgin plastic.

When it comes to putting the end product on the market, it is obvious to include imports (shampoo bottles and laptops produced outside the EU must also meet the requirement). When it comes to producing the final product, imports could be exempted. This does have adverse competitive effects (it becomes more attractive to fill up the shampoo outside the EU).

A mandatory requirement to use recyclate gives producers a direct incentive to use recyclate. They will probably choose the cheapest way to fulfil the mandatory requirement, which is not necessarily recycling from their own sector. Thus, an inscriptive requirement does not directly lead to more recycling and Design for Recycling. However, in the case of scarcity and a high price for recyclate, this may occur.
As it is uncertain where this supply will come from, a deployment target could also be combined with a collection target.

Instead of a differentiated target, it is also possible to choose a generic target that is the same for every plastic product. This can only lead to feasibly high targets if recyclate from other sectors can also be used. There is a risk of reducing the proportion of recyclate in certain products in order to keep recyclate available for other products/sectors. This can lead to the recyclate not being used in the most (cost) efficient way and, if the target is not high enough, the total recyclate share does not increase. A major advantage of a generic target over a differentiated one is that it requires coordination with fewer parties. With a differentiated target, there is a risk of a lengthy negotiation process, as a result of which few mandatory requirements will get off the ground in the short term.

Table 3 summarises the main characteristics of the variants.

Table 3 - Overview of variants

	Polymer manufacturer	**Plastics in finished product**
% Recycling in production/marketing of...	Polymers	Plastics in finished products
Number of parties in NL	6	Many thousands
Number of parties in EU	~50	Many thousands
Differentiation by sector possible	No	Only in the case of differentiated
Differentiation by type of product possible	No	Only in the case of differentiated
Differentiation by type of plastic possible	Yes	Only in the case of differentiated
Advantages	– Limited number of parties, low cost of enforcement	– Takes into account differences between sectors (food grade, etc.) – Direct incentive ‘causer’ – Incentive Design for Recycling – Closed loop option
Disadvantages	– No direct incentive to supply recyclate – Possible consolidation in sector – Problems with import/export/competition – Possible (undesirable) development towards chemical recycling – No closed loop option	– Large number of parties – Risk of a lengthy negotiation process – No direct incentive to organise supply

Source: Eurostat, (CE Delft, 2021).

Within the variants, there are still a number of options that require further elaboration, such as:

— Exchange of 'rights'. If the mandatory requirement is placed on polymer producers, they may be able to buy rights from other polymer producers or recyclers. A mandatory requirement on brand owners may mean that brand owners can buy rights from other brand owners inside or outside the sector. An advantage of trade is that they reduce the cost of using recyclate. If the system works well, it will ensure that the recyclate is used where it is best. It may also make it possible to set higher targets, thus increasing the use of recyclate.
— Closed loop. In order to prevent recyclate from being used in other sectors, it may be required that the recyclate used comes from the same sector as where it is used, i.e.

closed loop. This gives companies a direct additional incentive to increase the supply of recyclate (via Design for Recycling or organisation of the return flow). As already indicated, stockpiling in sectors outside the packaging sector makes a strict closed-loop approach very difficult. In the construction industry, for example, the demand for plastics is far greater than what is discarded annually. This can cause problems in a closed loop. With food packaging, the problem is that not everything can be used.

- In order to spare small businesses, a threshold quantity can be used. Below a certain threshold, there is no mandatory requirement or a much lower one.
- Combination with collection mandatory requirement. A mandatory requirement for the use of recyclate does not automatically mean that there is sufficient recyclate to use. In a well-functioning market, if prices were high enough, supply would automatically follow demand. The market for recyclate does not function well for a number of reasons, such as stockpiling and lack of organisation in the waste phase. As a result, a mandatory requirement on the use of recyclate could lead to very high prices, without creating more supply. It could also create undesirable incentives, such as discarding products unused in order to create more recycling. Policies to create more supply can prevent this, for example by expanding Extended Producer Responsibility (EPR).
- Maximum share of chemical recycling. The environmental benefit of mechanical recycling is generally larger than that of chemical recycling. This is especially true for pyrolysis and gasification. To prevent the obligatory proportion of recyclate from being at the expense of the environmental benefits, a maximum proportion of chemical recycling could be considered.
- Combination with bio-based, with or without maximum, see next paragraph.
- Import of compounds (polymer mixed with additives), semi-finished products for packaging (e.g. tubes from which PET bottles are blown) could also be covered step by step, especially if evasive behaviour is found.

A combination of variants is also possible, e.g. a mandatory requirement for polymer producers plus a stricter mandatory requirement for a number of product groups (such as refuse sacks or PET bottles).

A mandatory requirement only in the Netherlands?
This study investigated the possibilities and effects of a mandatory requirement in Europe. If this does not get off the ground in Europe, the Netherlands can choose to introduce a mandatory requirement independently.
A requirement aimed at plastic producers would mean that plastic granules placed on the Dutch market would have to consist of a compulsory proportion of recyclate. This leads to adverse competitive effects further down the chain. For producers using plastic granules, it becomes more attractive to produce in a neighbouring country because there are no requirements for the granules there. With a European requirement, the problem also arises with competition from outside the EU, but this is more limited.
A requirement for producers of end products has less of a competitive impact, but it does have consequences for production chains, because products sold in the Netherlands have to meet different requirements than products sold in other European countries, while many product regulations (e.g. Ecodesign) are regulated at European level. In a favourable case, European producers adapt their products to the Dutch requirements, but this is not self-evident. Otherwise, it leads to differentiation in products and fragmentation of production chains.

For the Netherlands, the production of polymers is much larger than the consumption of polymers in packaging and products (approximately 5 Mtonne vs. 2 Mtonne). This means that a lot is exported. A large amount is also imported as plastic in products. The Dutch polymer companies therefore mainly produce for foreign customers who, certainly in the open EU market with only a Dutch mandatory requirement, can easily switch to a supplier in another country without a mandatory requirement.

Should a decision be made to impose a Dutch mandatory requirement, taking into account undesirable competition, only a very limited mandatory requirement seems feasible. This has the disadvantage that it will not boost recycling and will lead to administrative burdens.

The introduction of a mandatory requirement at the European level therefore has fewer disadvantages than a Dutch mandatory requirement. Also, the range and thus the ultimate environmental impact is much greater.

3.3 Combination with bio-based of a recyclate obligation

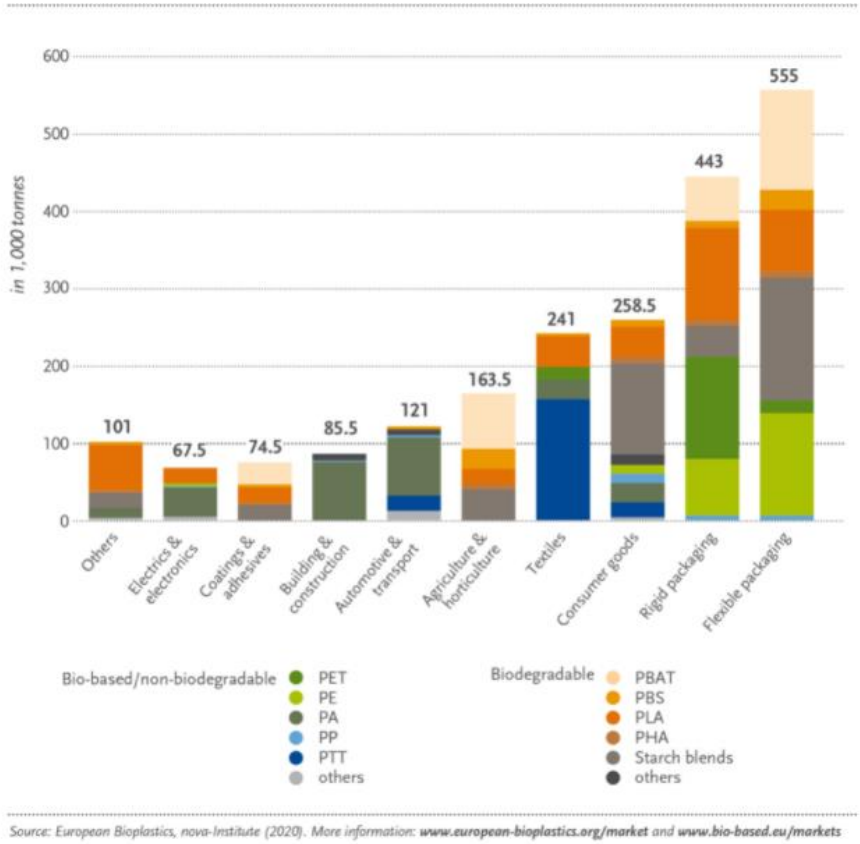
Another aspect to be developed is a combination with bio-based. Both bio-based plastics and the use of recyclate lead to a reduction in the use of fossil virgin plastics and are desirable from the perspective of a transition to a less fossil and more circular economy.

Globally, bio-based plastics account for about 1% of production. In 2020, the production capacity was about 2 Mtonne (European Bioplastics, 2021). Bioplastics can be divided into non-degradable and degradable. Degradable is generally intended to be composted in the waste stage. However, recycling is sometimes possible. An example of this is PLA, which breaks down in an industrial composting plant, but is also suitable for both mechanical and chemical recycling (CE Delft, 2019). In addition, there are so-called drop-in bioplastics such as bioPET, bioPP and bioPE that are identical to fossil-PET, PP and PE and therefore automatically recyclable in the existing systems.

Earlier, CE Delft studied how bioplastics fit into a circular economy for the Ministry of Economic Affairs and Ministry of Infrastructure. An important conclusion was that the focus should be on plastics that are bio-based (made from biological raw materials) but that can also be recycled (CE Delft, 2017).

The most important applications of bioplastics are listed in Figure 8. Non-biodegradable plastics are used to a greater or lesser extent in all product groups, although use in agriculture is the most limited. They are most commonly used in packaging and textiles. Compared to 2014, the use of bioPET in packaging decreased, while the use of bioPA in electronics, construction and automotive, among others, grew strongly.

Figure 8 – Global production capacities of bioplastics, 2020



Source: (European Bioplastics, 2020).
NB: PBAT is biodegradable but not at present fully bio-based.

A combined obligation, in which producers are required to apply either recycled and/or bio-based plastics, has the **advantage** that it gives producers the freedom to choose the best available/cheapest option. This will cause the least disruption to the market. The best available option may differ for each product group. It may be that for a certain product group no recyclate is available, but a bio-based option is. Multiple options make it possible to further reduce the consumption of fossil virgin plastics. A combined mandatory requirement can also lead to more support from stakeholders, because they have something to choose from. **Disadvantage** is that a combined requirement leads to additional certification and administrative burden. It is also possible to opt for a maximum bio-based percentage.

3.3.1 Sustainability and CO_2 emission reduction of bio-based plastics

As previously indicated in the Biobased Plastics Action Plan, when promoting bio-based plastics, there should be both a requirement for sustainable agricultural production and a minimum CO_2 emission reduction percentage. Only bio-based plastics that meet these requirements should be promoted. The CO_2 emission reductions that bio-based plastics can achieve differ, depending on the polymer type, the raw materials used (e.g. primary crops versus residual streams) and the production location/route. Most production is currently on a relatively small scale and still under development, so the CO_2 emission reductions can still increase. Finally, there are methodological issues with bio-based plastics that make a direct comparison with petrochemical plastics more difficult[10].

The current picture is that with a minimum 30% CO_2 emission reduction requirement, bioPET is unlikely to meet this requirement. BioPE and PLA and starch blends can meet these requirements. BioPP from waste streams can also probably achieve this reduction.

3.3.2 Expected proportions of recyclate and bio-based

If a free choice is given to producers to use either mechanically recycled material, chemically recycled material or bio-based plastics, it is impossible to determine in advance what the resulting ratio will be exactly. However, based on the current situation, a rough check can be made of the expectations in the various markets. It should be noted, however, that the introduction of a mandatory requirement for recyclate and bio-based plastics will certainly also lead to innovation that will shift the balance.

Innovations stimulated by a mandatory requirement for recyclate and bio-based:
- Design for Recycling in packaging and products that enables more mechanical recycling;
- more separate collection of waste plastic;
- better sorting of waste plastic into clean recyclate streams;
- chemical recycling, especially high-yield techniques (recyclate from waste) such as depolymerisation (PET) and dissolution (currently PS, development for PE and PP);
- innovation in bio-based plastics with also a better CO_2 performance ;
- shifts in the material mix towards the use of types of plastic that are easier to recycle (e.g. from PE/PP to PET).

Using the above as a qualification, we can nevertheless cautiously estimate what the preferred input per plastic type probably is in Table 4.

Table 4 - Different plastics and opportunities in relation to mechanical, chemically recycled and bio-based plastic

	Mechanical	Chemical	Bio-based
PET	Large, especially bottles	Growing, especially for trays and textiles	Small because CO_2 reduction too small. Currently limited due to limited CO_2 reduction but innovation in BioMEG and opportunities for PEF
LDPE (low density polyethylene sheeting)	Limited	Growing	Large, because cheap option
HDPE (high density polyethylene)	Large	Limited	Reasonably large
PP	Large	Limited	Growing
PS (polystyrene)		Growing	Growing choice of PLA (polylactic acid)
ABS (acrylonitrile butadiene styrene)			
PC (polycarbonate)			
PVC (polyvinyl chloride)	Large for tubes		

[10] These include the handling of the temporary storage of biogenic carbon, (indirect) land use change, the performance/functionality of new polymer types, residual biomass flows and the variability in biomass production systems (e.g. amount of fertiliser used).

Bio-based plastics and recycled plastics also seem to complement each other well if we look at the main flows of plastics. For example, with mechanical recycling and the short-chain chemical recycling (depolymerisation), PET can be recycled well. For PET, recycling is also likely to be dominant in the choice of manufacturers. For PE, bioPE is likely to fill a significant part of the film market in particular, because recycling to film is quite difficult and because bioPE can have a good CO_2 performance and limited additional costs.

3.4 Options for additional recycling and use of recyclate

For each product group, we looked at which sectors are promising for additional recycling and which sectors are promising for the additional use of recyclate (with a differentiated mandatory requirement for the brand owner). Table 5 shows the results. The full analysis is included in Appendix E.

To reach an ambitious target of 40% recycling, almost all discarded plastic needs to be used as recyclate. Therefore, it is important to greatly improve collection for recycling. This can be done by extending producer responsibility for recycling to all uses of plastic.
A reasonably strict collection target already applies to packaging. However, the Extended Producer Responsibility (EPR) could be widened to include other (household) products, such as toothbrushes, clothes hangers, toys and perhaps even broken polyester clothing. Existing EPR schemes for electronics and automotive do not yet include a separate recycling target for plastics. Especially in electronics, there is still a lot of untapped potential, also due to exports. Incineration with energy application also counts as recovery. The EPR scheme for these products can be adjusted. In agriculture, EPR already applies to agricultural plastics in some countries; this could be extended to other products such as pots for horticulture. Construction is a growth market in terms of discarded plastic, as more and more plastic is used and also discarded. In this field, EPR can be applied at product level, e.g. for window frames or pipes.
For the automotive and packaging sectors in particular, more recyclate can be made available through Design for Recycling.

Table 5 - Overview of promising product groups

	EU market share (consumption | waste) (Current)	Extended Producer Responsibility (EPR) (plastic control) (Current)	Potential for mandatory percentage (2030)	Potential for additional recycling (2030)	Remarks
Packaging	40% | 61%	Present in most countries (yes)	Sector/ product level	Design for Recycling, extra separation	Already many policies concerning collection, requirements concerning food grade. European policy obliges percentage of bottles.
Building & construction	20%| 5%		Product level (window frames, insulation, pipes)	Growth market of waste generated, more regulation of demolition; more products EPR	Input much larger than output. Many recyclates from other sectors are currently being used.

	EU market share (consumption | waste) (Current)	Extended Producer Responsibility (EPR) (plastic control) (Current)	Potential for mandatory percentage (2030)	Potential for additional recycling (2030)	Remarks
Electrical & electronics	6% | 5%	Present in most countries (to a limited extent); incineration as useful application	Sector level	Still a lot of untapped potential, exports; improve EPR	No recycling target for plastics in EPR.
Automotive	10% | 6%	Present in most countries (to a limited extent); incineration as useful application	Sector level	In particular, improve recyclability of materials, chem. rec.; improve EPR	No recycling target for plastics in EPR, European targets in the pipeline.
Agriculture	3% | 5%	Some countries for agricultural sheeting	Product level (agricultural sheeting)	More products EPR	Agricultural plastic already subject to mandatory collection.
Household, leisure and sports	4% | 4%	In the pipeline for textiles (Netherlands)	Product level (flooring, textiles)	Expand EPR for packaging	
Others	17% | 14%		Product level		Furniture, machine building, etc.

3.5 Conclusion

In this chapter, we have described two variants for a mandatory percentage of recyclate. We have already seen that the supply of recyclate needs to increase considerably if ambitious targets are to be achieved and that, in fact, all sectors need to 'get on board'. Insufficient supply of recyclate could lead to sky-high prices or to the target not being met. The question is to what extent these three variants will ensure that an ambitious target is met or whether additional policies or requirements are needed.

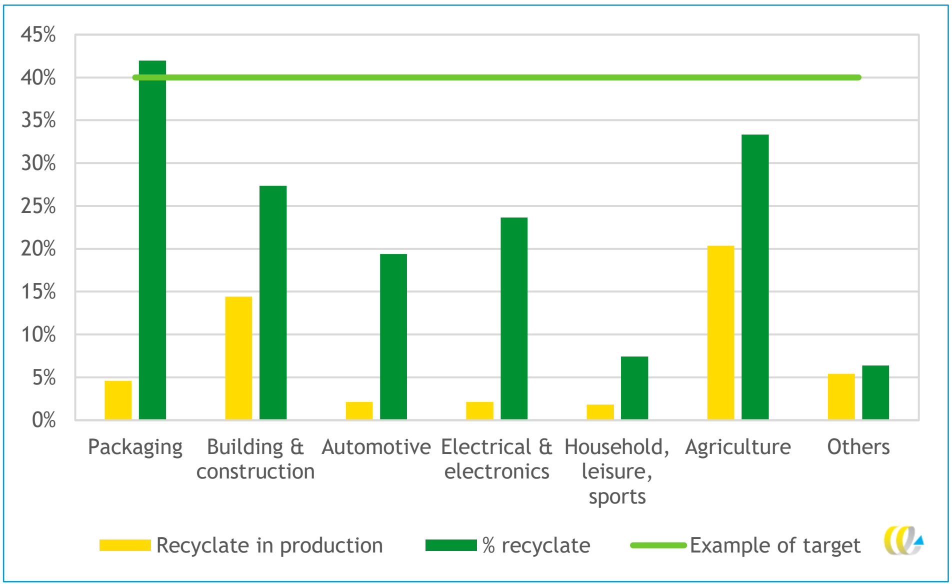
With a mandatory requirement for polymer producers and importers, there is no direct incentive for Design for Recycling and the organisation of a waste infrastructure, because the mandatory requirement for the use of recyclate lies with a different party than the parties responsible for Design for Recycling and the waste phase. It is uncertain whether waste collection based solely on market incentives will get off the ground quickly enough. In order to secure the use of recyclate, a collection incentive is probably needed as well, for example through Extended Producer Responsibility (EPR) schemes. In addition, a further differentiation of EPR tariffs according to recyclability, such as the French Citeo applies, would be interesting to introduce in the various EPR schemes. Design for Recycling and its encouragement is needed to make more plastic waste suitable for recycling. However, a mandatory requirement for polymer producers and importers is relatively easy to implement because the number of parties is limited and well known.

A mandatory requirement for brand owners has the disadvantage of placing the mandatory requirement on many thousands of parties. A differentiated mandatory requirement for brand owners allows for tailor-made solutions and takes into account the suitability of a sector for the use of recyclate. However, there is a risk of a lengthy negotiation process, which would ultimately prevent ambitious targets from being achieved. A generic mandatory requirement - without differentiation by product or sector - has the advantage

that it may be easier to implement. However, there is a risk that the costs will be high in sectors where the use of recyclate is more difficult or that the mandatory percentage for all products will remain at the low percentage possible in the most difficult products.
A combination with a collection incentive increases feasibility. If the target is to use recyclate from the own sector - closed loop - it becomes more difficult to achieve an ambitious target. In the construction sector, for example, much less recyclate can be used because, due to stockpiling, only a limited amount is released each year. With a closed loop requirement, in principle no collection incentive is needed, as brand owners already have an incentive to design for recycling and organise collection in their own sector.

In agriculture, for example, 30% recyclate is already used, whereas this is much lower for packaging. In contrast, recycling is already high for packaging (see figure). Without an exchange of rights, it is unlikely that the highest target can be achieved and potential remains unused. Again, there are no direct incentives for collection and Design for Recycling and an incentive for collection increases the feasibility of a target. An ambitious generic target requiring a closed loop is practically unachievable due to large differences in the use of recyclate and waste generated.

Figure 9 - Recycling percentage by sector, 2018, EU-25 + NO/CH



So we see that in all cases a collection incentive increases the feasibility of a mandatory percentage. It forces parties to organise themselves and provides an incentive for Design for Recycling. A combination with bio-based offers parties additional possibilities for achieving a target in order to reduce the demand for fossil virgin plastics. All sectors will be needed to have enough recyclate for an ambitious target. A differentiated target or a generic target with trade-offs makes the feasibility of the target most likely. A mandatory closed loop requirement does provide an incentive for organising collection and Design for Recycling, but it reduces the overall technical feasibility of an ambitious target.

4 Impact on climate change

4.1 Introduction

The most important environmental impact of the fossil plastic chain is the impact on the climate through the emission of greenhouse gases. This takes place during the production of new plastic products, but also when plastics are incinerated after use in municipal solid waste incinerators (MSWIs). For this first impact analysis, we therefore concentrate on the climate benefit that can occur through the use of recycled or bio-based plastics. Other environmental impacts, such as the use of non-renewable fossil raw materials (which is strongly linked to the carbon footprint) and the leakage of plastics into nature, are not considered here.

In this chapter, we estimate the carbon footprint of the use of plastics in Europe. We do this both for the current situation (data for 2018-2020) and for 2030 in different scenarios. The scenarios examine a structural shift towards more circular plastics. This shows the effects of a higher use of mechanically recycled, chemically recycled and bio-based materials.

Earlier, CE Delft has carried out a similar study for the Dutch situation in 2030, commissioned by Plastics Europe Netherlands and the NRK (CE Delft, 2021). This earlier analysis is translated here into the whole European market in 2030. The analysis for Plastics Europe Netherlands and NRK is explained in the text box at the end of this chapter.

The estimation of the carbon footprint is based on life cycle assessment (LCA).
To determine the carbon footprint of the European use of plastics, we look at the production of the plastics, the conversion into end products, and the end-of-life processing. The carbon footprint represents the contribution to global climate change through the emissions of greenhouse gases such as CO_2, methane and nitrous oxide, and is expressed in CO_2 equivalents (CO_2-eq.). Although it concerns the European use, the complete production chain and end-of-life of plastic products is taken into account, even if it takes place outside the EU.

4.2 Method and scenarios

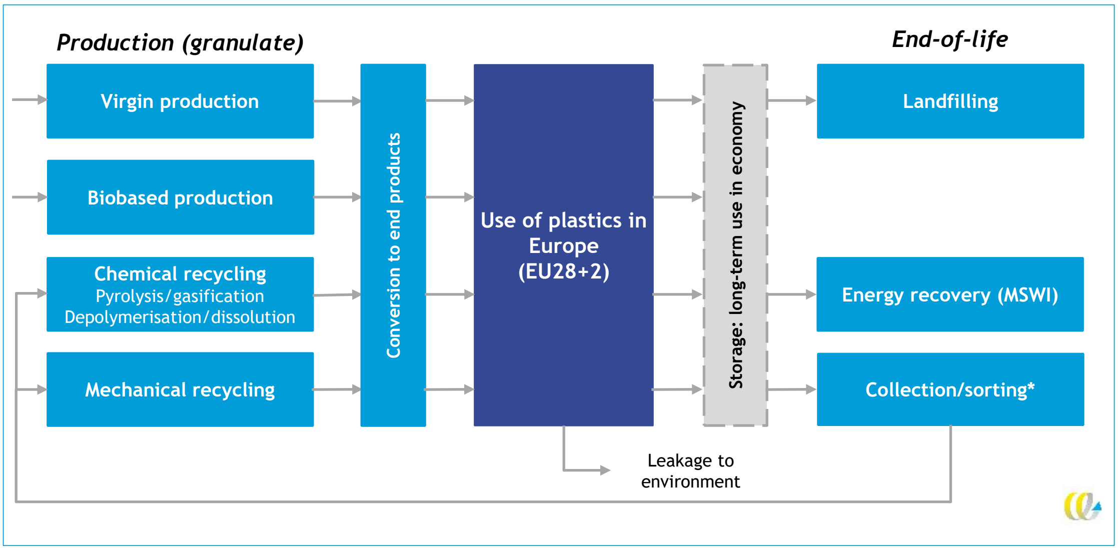
The carbon footprint of the European use of plastics is determined with the model shown in Figure 10. CE Delft has drawn up scenarios for material flows in Europe[11], i.e. how much plastic is used, via which routes it is produced, how much is discarded annually after use and via which routes it is processed. This was done for the current situation (2018) and for three scenarios for 2030. These scenarios are further discussed in Paragraph 4.2.2

The material flows are then linked to representative carbon footprints. For this purpose, we have determined carbon footprints for 2018 for each production or processing route, which reflect, for example, the carbon footprint of the production of 1 kg of virgin plastic.
We assume that process and efficiency improvements will reduce the carbon footprint of production and conversion processes by 2% annually until 2030. The carbon footprints for

[11] Based on the available consumption data, the scope was defined as the European Union plus Norway and Switzerland (EU28+2). The data is from 2019, which means that the UK is still included within the EU28.

end-of-life have been kept constant. The carbon footprints are discussed in more detail in Appendix D.

Figure 10 - Calculation model for carbon footprint of European plastic use (EU28+2)



* In the life cycle assessment (LCA) model, the carbon footprint of the collection and sorting of end-of-life plastics is allocated to the production of recycled plastics ('cut-off approach'). The carbon footprint of these processes is thus reflected in the consumption of recycled plastics, whereas delivering discarded plastics for recycling does not involve a carbon footprint. Since the scenarios include both European consumption and end-of-life, and since an increase in the use of recyclate is linked to an increase in the collection and sorting of material, this choice does not have a major impact on the overall results.

4.2.1 General assumptions scenarios

The following general assumptions were used to draw up the scenarios:

- The use of plastics will increase by 8% in the period between 2018 and 2030. This is based on a recent analysis by Plastics Europe Netherlands for the Dutch situation (Stijnen, 2020). We assume that the trend in the EU is similar. We see this increase as an autonomous development and not as an effect of a mandatory requirement on recycling. However, the climate benefit of using circular plastic increases, because a larger quantity of material is involved.
- The amount of discarded plastic increases by 20% in the same period. Again, we assume that the forecast for the Netherlands is representative for the EU (Stijnen, 2020).
- The percentage of bio-based plastic used is about 1% in 2018. A possible increase towards 15% in 2030 is included in one of the scenarios.
- The amount of plastic collected for recycling (EOL side) is directly related to the amount of recyclate used (consumption side). We use the following losses in the recycling chains for 2030(i.e. how much collected plastic does not end up in new plastic):
  - mechanical recycling: 20%;
  - pyrolysis/gasification: 50%;
  - depolymerisation/dissolution: 0%.
- In all 2030 scenarios, no more plastics are landfilled.
- The carbon footprint of plastic production/conversion decreases by 2% per year due to efficiency improvements. This percentage is used by the Dutch plastics industry as a target. Here we have translated this target to Europe because all European companies

are subject to the same ETS system for CO_2 pricing and because innovations in European industry are often implemented simultaneously.

4.2.2 Scenarios studied

Table 6 shows the material flows used in the analysis, in kilotonnes (kt) per year. The year 2018 is taken as the starting point because of data availability. Three scenarios have been drawn up for 2030.

The **start situation** (2018) is primarily based on a study commissioned by Plastics Europe that mapped out plastic flows in Europe (Conversio, 2019).

For 2030, a **'business as usual'** (BAU) scenario was first formulated. Here the demand for plastics is growing, but there is no change in how this demand is met (distribution of virgin, recyclate and bio-based). The other developments discussed in Paragraph 4.2.1 are taken into account, including the efficiency improvement of 2%/year, no plastic in landfill, and less waste in mechanical recycling.

The second scenario (**'13% recyclate'**) assumes that an additional 3.4 Mtonne of recyclate is used, increasing the percentage of recyclate in total consumption to 13%. This 3.4 Mtonne is based on an analysis by the Circular Plastics Alliance, which indicates that this is the 'untapped potential' for 2025 in Europe (Circular Plastics Alliance, 2021). This study estimated that 3.4 Mtonne extra recyclate could be made available within the packaging, electronics, construction, automotive and agricultural sectors. For the division between mechanical and chemical recycling, we follow the Transition Agenda and the Roadmap Chemical Recycling (I&W/EZK, 2018) (Nederland Circulair, VNO-NCW, 2020).

In the last scenario for 2030 (**'EU Transition Agenda'**), it is assumed that the Dutch Transition Agenda for Plastics is realised at the European level. This means that 40% of the plastics demand is met with recyclate[12] and 15% with bio-based plastic. As a result, less virgin material is needed and much more material is collected for recycling instead of being burned for energy.

12 The recyclate is produced through various mechanical and chemical recycling routes. For the distribution among these technologies, we follow the Transition Agenda (I&W/EZK, 2018) and the Roadmap Chemische Recycling (Nederland Circulair, VNO-NCW, 2020). This means that 75% of the recyclate is produced by mechanical recycling, 16% by pyrolysis/gasification, and 9% by depolymerisation/dissolution.

Table 6 - Material flows for 2018 and 2030, in kilotonne (kt) per annum

Material flows		2018	2030		
			Business as usual	13% recyclate	EU Transition Agenda
Consumption	Virgin production	50,668	54,656	51,256	26,408
	Mechanical recycling	3,980	4,293	6,843	18,154
	Depolymerisation/ dissolution	0	0	298	2,118
	Pyrolysis/gasification	0	0	553	3,933
	Bio-based production	552	595	595	8,932
	Total consumption	55,200	59,544	59,544	59,544
End-of-life	Energy recovery (MSWI)	12,400	29,329	24,739	2,019
	Collection/sorting for recycling	9,410[a]	5,367[a]	9,957	32,677
	Landfill	7,200	0	0	0
	Total end-of-life	**29,010**	34,696	34,696	34,696
'Storage' in economy and leakage to environment[b]		26,190	24,848	24,848	24,848

[a] At the moment there is a large difference between collection and application of recyclate because part of it is applied as mixed plastics as concrete/wood replacements and partly due to a relatively high drop-out rate in sorting. We assume that there will be less use of mixed plastics because it is not economically advantageous and that the drop-out in sorting will decrease and that in BAU the use of recyclate will remain similar. This is a hypothetical reference situation to compare with.

[b] Calculated as the difference between the amount of material used (input) and the amount that ends up at end-of-life (output). It is unknown how much plastic is currently leaking into the environment, but in the Netherlands the sector is aiming to reduce this to 0 by 2030 (I&W/EZK, 2018).

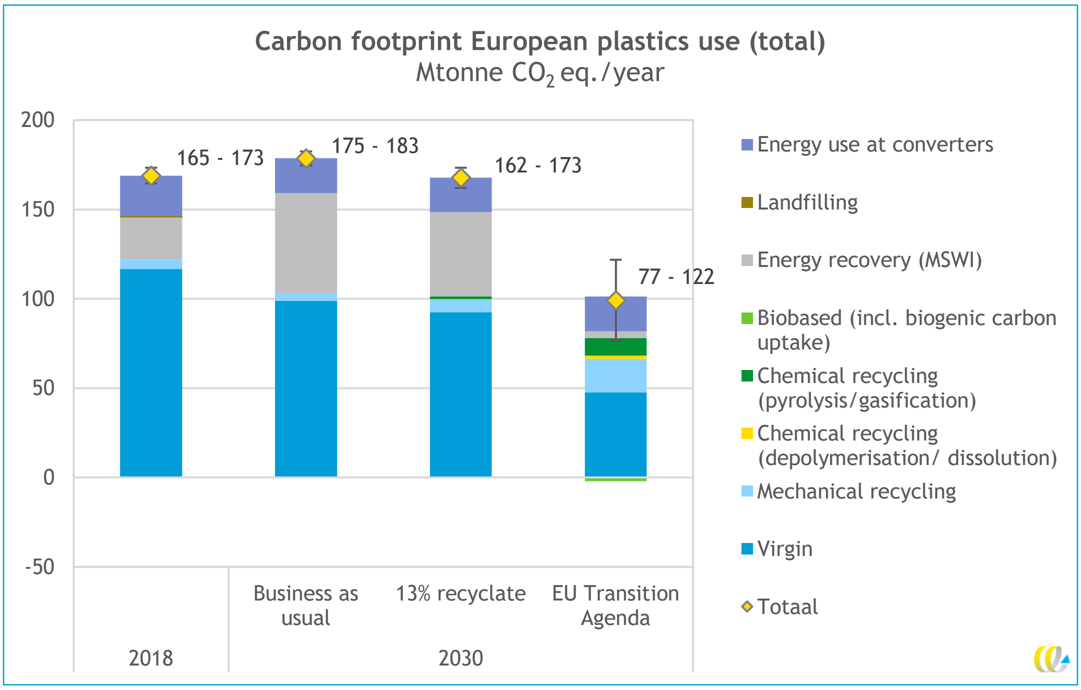
4.3 Results

4.3.1 Total carbon footprint

In Figure 11 we show the total carbon footprint of the European use of plastics in all product groups. For 2018, the total consumption is about 55,000 kt, rising to about 60,000 kt in 2030. The graph shows the contribution of different production routes (e.g. virgin, bio-based and different types of recyclate), energy use at converters, and end-of-life (e.g. energy recovery).

For 2018, we estimate the carbon footprint of the Dutch use of plastics to be approximately 165 to 173 Megatonnes (Mt) of CO_2-eq. per year. About 70% of the CO_2 emissions occur in the production of new fossil plastics. Incineration at end-of-life (approx. 14%) and the energy consumption of the converters (13%) also make a significant contribution.

Figure 11 - Total climate impact of the European use of plastics (production, conversion into finished products and disposal) for 2018 and 2030, Megatonne CO_2-eq./year



In the three 2030 scenarios, different amounts of recyclate and bio-based plastics are used. This also changes the virgin production required and the amount of plastic that ends up in energy recovery. In the business as usual scenario, the carbon footprint for European plastics use increases to 175 to 183 Mtonne CO_2-eq./year, or 6% on average. Although production processes are becoming more efficient (2%/year), overall consumption is increasing. The amount of plastic that is incinerated also increases, because landfilling is stopped and it is assumed that there are fewer losses in mechanical recycling (so less needs to be collected and more material goes to MSWIs).

In the second scenario, the percentage of recyclate rises to 13%, based on an estimate of the unexploited potential. This brings the carbon footprint to about 162 to 173 Mtonne CO_2-eq./year, an average reduction of 1%. This is similar to the current (2018) impact.
The increase in the amount of recyclate thus offsets the developments in the business as usual scenario (increased volume, more incineration).

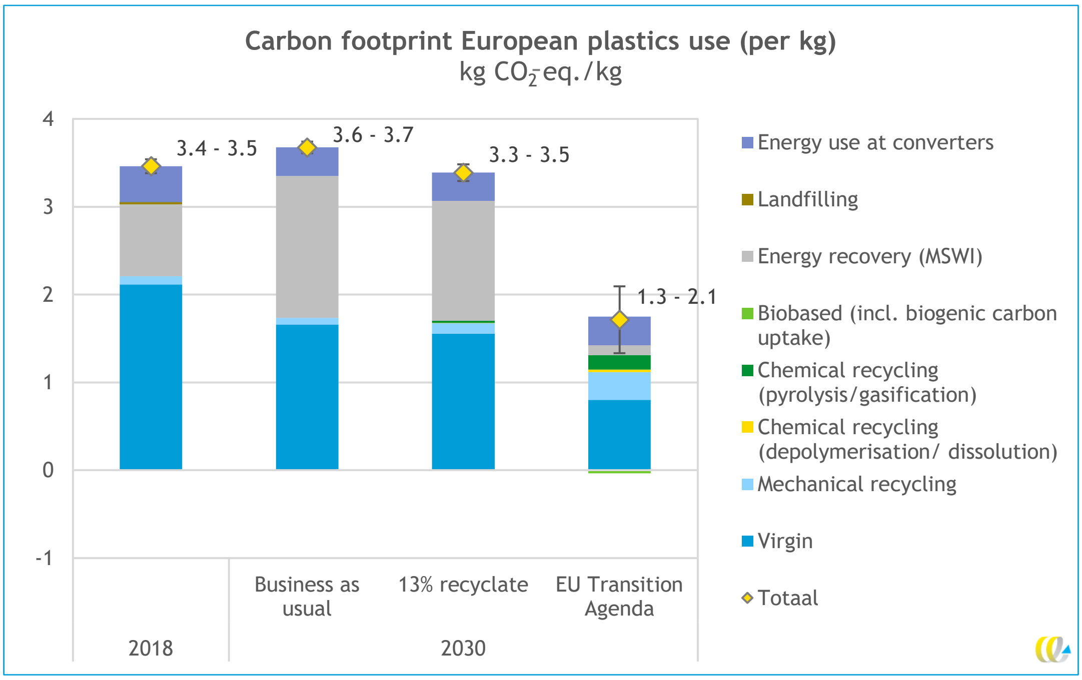
In the scenario of an EU Transition Agenda, the carbon footprint of European plastics use amounts to 77 to 122 Mtonne CO_2-eq./year, an average reduction of 41%. In this ambitious scenario, 55% of the plastics used are produced via circular routes (40% recycling and 15% bio-based). This development greatly reduces virgin production. In addition, 94% of waste plastics are collected for recycling (see Table 6), which means that hardly any plastic ends up in MSWIs.

4.3.2 Carbon footprint per kg of plastic

Figure 12 shows the results of the analysis expressed per kg of plastic. The carbon footprint of the production stages is divided by the total use of plastics (approx. 55,000 to 60,000 kt/year); Table 6) and the carbon footprint associated with end-of-life (EOL) divided by the total amount of discarded material (approx. 30,000 to 35,000 kt/year; Table 6). This makes the contribution of EOL processes relatively larger.

Per kg of plastic, the carbon footprint in 2018 is around 3.4 to 3.5 kg CO_2-eq. In the EU Transition Agenda scenario, this falls to about 1.3 to 2.1 kg CO_2-eq., a reduction of about 51%. In the business as usual scenario, the carbon footprint increases to 3.6 to 3.7 kg CO_2-eq./kg (increase of 6%), whereas in the 13% recyclate scenario it is estimated at 3.3 to 3.5 kg CO_2-eq./kg (decrease of 2%).

Figure 12 - Carbon footprint per kg plastic use in Europe (production, conversion to end products and disposal), kg CO_2-eq./kg for 2018 and 2030



4.3.3 Carbon footprint per circular option

Table 7 Includes an indicative overview of the net carbon footprint reductions achieved by different circular options in this model calculation. Negative numbers indicate a CO_2 emission reduction.

It is important to note a number of comments on this table:
- In this table, the carbon footprints for 2030 are used (see Appendix D). This means that 2% efficiency improvement per year in all production processes has been taken into account.
- We attribute direct and indirect effects to the circular option (see the second column). This means, for example, that we assume that the use of additional recyclate leads to fewer plastics being incinerated in MSWIs and that the recyclate is responsible for this effect.
- Losses in recycling chains have been taken into account (see Paragraph 4.2.1).

- For depolymerisation, specific values were calculated for PET plastic (virgin production, incineration, production of recyclate via depolymerisation).
- It is assumed that 1 kg of bio-based plastic or recyclate can replace 1 kg of virgin plastic. This is a rough approximation; if the circular plastics have different properties, more or less material may be needed.
- Averages have been taken into account throughout; shifts in the margin may vary.

We can see that in this model the circular options in 2030 lead to a reduction of between 2 and 3 kg CO_2-eq. per kg. In particular, avoiding energy recovery in MSWIs by recycling plastics contributes greatly to the savings. This is particularly the case with pyrolysis. Compared to virgin production, production of recyclate using pyrolysis results in slightly higher emissions, but because this technology requires 2 kg of input for 1 kg of recyclate, the net CO_2 reduction per kg of recyclate is still quite good because 2 kg of incineration is avoided. However, pyrolysis requires a relatively large amount of input for 1 kg of recyclate and is therefore less circular than the other techniques.

For the bio-based options, the variation in CO_2 emission reduction is quite large. This is between 1 and 3.1 kg CO_2 per kg bioplastic. With sustainability criteria and a CO_2 emission reduction standard, it is possible to steer towards the use of bio-based plastics with a higher CO_2 reduction. The better bio-based plastics can achieve comparable CO_2 emission reductions per kg of material as the recycling options.

NB: Because the CO_2 emission reduction values in Table 7 are expressed per kg of recyclate application and the avoidance of incineration in an MSWI is favourable, technologies with a relatively low efficiency (a lot of plastic waste needed for 1 kg of recyclate) are relatively favourable. This method of analysis is therefore not suitable for comparing technologies in all their aspects. High efficiency is also important for a good overall result.

Table 7 – Estimated net carbon footprint of various circular options in 2030 from scenario analysis

Circular option	**Effects**	**Carbon footprint,** kg CO_2-eq. per effect	**Net carbon footprint,** kg CO_2-eq./kg extra recyclate or bio-based
1 kg extra mechanical recyclate	1 kg production of recyclate (mechanical recycling)	0.3 tot 1.8	-3.2 (-2.4 to -3.9)
	1 kg less virgin production	-1.8	
	1.25 kg less AEC incineration	-2.4	
1 kg additional recyclate from depolymerisation (PET)	1 kg production of recyclate (depolymerisation)	0.8	-2.6
	1 kg less virgin production (PET)	-1.7	
	1 kg less AEC incineration (PET)	-1.7	
1 kg extra recyclate from pyrolysis	1 kg production of recyclate (pyrolysis)	2.5	-3.1[a]
	1 kg less virgin production	-1.8	
	2 kg less AEC incineration	-3.8	
1 kg extra bio-based plastic	1 kg production bio-based[b]	-1.3 to 0.8	-2.0 (-1 to -3.1)
	1 kg less virgin production	-1.8	

[a] Pyrolysis scores very favourably here because we have allocated the avoidance of 2 kg of incineration to 1 kg of recyclate. After all, 2 kg of plastic waste is needed for 1 kg of recyclate. This makes the score per kg of recyclate favourable, whereas it would be lower when expressed per kg of available waste.

[b] This already includes the uptake of CO_2 by plants. In addition, the literature sources used also include a factor for indirect land use change due to expansion of agricultural production. The lower value (-1.3 kg CO_2-eq./kg) is based on bio-based plastics produced from residual streams rather than primary crops (such as bioPP from used cooking oil).

4.4 Conclusion climate effects

In this chapter, the climate impact of a higher percentage of recyclate and/or bio-based plastics in European plastic consumption has been estimated. We have considered the carbon footprint of the (worldwide) production, conversion into end products and final disposal of plastic products. Indirect savings in the use phase (e.g. replacement of less efficient materials or fuel savings) are not included.

Estimates and assumptions are used here and different sources are combined, which makes the results uncertain. As the analysis focuses on European consumption, the effects may be different if the production in Europe is considered.

In the business as usual scenario for 2030, we estimate the carbon footprint for European plastics use to be 175 to 134 Mtonne CO_2-eq./year, an increase of 6% compared to 2018. In a scenario for an EU Transition Agenda, the carbon footprint of European plastics use amounts to 77 to 122 Mtonne CO_2-eq./year, a reduction of 41% on average. In this ambitious scenario, 55% of the plastics used are produced via circular routes (40% recycling and 15% bio-based). This development will greatly reduce virgin production. In addition, 94% of waste plastics are collected for recycling (see Table 6), which means that hardly any plastic ends up in MSWIs.

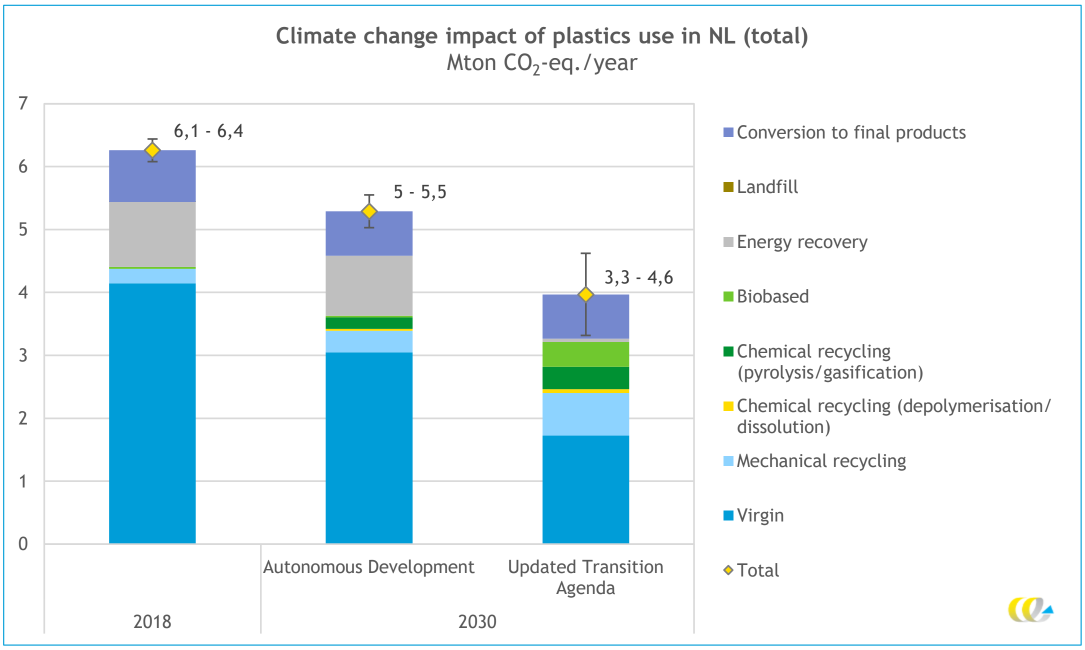
The maximum scenario of 40% recyclate and/or bio-based in Europe saves 80 Mtonne CO_2. Per kg recyclate or bio-based plastic, there is thus on average a reduction of about 2.5 to 3 kg CO_2-eq. per kg of recycled or bio-based plastic.; 80 Mtonne CO_2-eq./year is saved by deploying 28 Mtonne extra recyclate and bio-based material (EU Transition Agenda compared with business as usual).

Scenario analysis of circular plastics in the Netherlands for Plastics Europe Netherlands and NRK

CE Delft has carried out a similar scenario analysis for Plastics Europe Netherlands and NRK, specifically focusing on the Dutch situation (CE Delft, 2021). In this analysis, the same method was used, but the material flows were focused on the Dutch situation, different scenarios were investigated and the carbon footprints of production or waste processing processes were adapted to the Dutch situation where possible. An important difference is that a higher carbon footprint for bio-based plastics was taken into account. In the study for Plastics Europe Netherlands and NRK, a mix of bio-based plastics without sustainability criteria was used in the calculations, based on the current use of bio-based plastics. In this study, we assume that sustainability criteria including a CO_2 standard will apply to bio-based plastics in addition to the mandatory requirement.

The following figure shows the overall results for the Dutch consumption of plastics. In the 'Updated Transition Agenda' scenario, in which the material flows from the Transition Agenda are adjusted based on new insights, the carbon footprint decreases by about 37%. This is comparable to the scenario in this report (EU Transition Agenda). Expressed per kg of plastic, the carbon footprint in this Dutch scenario decreases by about 50% (not shown).

Figure 13 - Total carbon footprint of the Dutch use of plastics (production, conversion into end products and disposal) for 2018 and 2030, Megatonne CO_2-eq./year



Source: CE Delft calculation for Plastics Europe Netherlands and NRK (2021)

5 Analysis of economic effects

5.1 Introduction

In this chapter, we analyse the economic effects of a mandatory percentage cycle of 40%. We look at costs and benefits (Paragraph 5.2) and employment (Paragraph 5.4).
In Paragraph 5.5 we present the conclusion.

5.2 Costs and benefits of using additional recyclate

A mandatory percentage cycle leads to different costs and benefits. In order to use the recyclate, additional plastic waste must be collected, sorted and processed in recycling plants. There may also be additional costs for the design of products (Design for Recycling) and there may be (temporary) costs for adapting production lines for the use of recyclate in the products. Finally, if the quality of the recyclate is lower than that of virgin raw materials, there is a loss of income because lower-quality products are sold. This will be reflected in a lower willingness to pay on the part of consumers and lower revenues for the plastic products. Offsetting these costs, there are also benefits. Mandatory use of recyclate leads to avoided costs of purchasing virgin raw materials and avoided costs of collection and alternative treatment (mostly incineration in AVIs or cement kilns).

The cost and benefit items are summarised in Table 8.

Table 8 - Overview of costs and benefits

Costs /benefit items	Description	Who will bear the costs/benefits?
Costs of additional collection, sorting and recycling	– Costs for collection of the plastics (personnel costs, rubbish trucks), sorting (investment costs, O&M costs), recycling plants (investment costs, O&M costs) and their organisation (EPR).	– Municipalities incur costs but are reimbursed for them by EPR on packaging. – Producers via EPR. – Producers.
Costs of use of recyclate and Design for Recycling (temporary costs)	– Cost of adapting products/product lines to use recyclate. – Costs of Design for Recycling.	– Party in the chain charged with mandatory requirement (brand owner, polymer producer).
Lower willingness to pay for products	– If the quality of recyclate is lower than virgin, consumers will be less willing to pay for products.	– Producers of plastic products.
Saved virgin raw material costs (or recyclate yield)	– The party that is obliged to use the recyclate has saved the costs of virgin raw materials. Products do incur costs for the purchase of the recyclate, but this is a revenue item for the seller and therefore neutral in the chain.	– Producer of plastic products.
Avoided costs of incineration + landfill	– Saved costs for alternative collection and processing of plastics.	– Municipalities for household waste, this is reflected in lower rates for waste collection. – Companies for commercial waste.

In the following box, we show the total structural additional costs. We will elaborate on this in the next section.

Costs on the waste side:
- collection costs + sorting costs + recycling costs - recycle yield - savings in regular processing

Costs on the application side:
+ temporary changeover costs + recyclate costs - virgin cost savings - (possible lower revenue from plastic products)

If we add up the costs of the waste side as well as the costs of the application side, the price of recyclate falls out, as it is both a revenue and a cost item. In addition, switching costs are temporary and not structural. The additional costs are structural:

Additional costs total structural
+ collection costs + sorting costs + recycling costs - savings in virgin material costs - savings in regular processing - (possible lower yields of plastic products)

Here, the price of recyclate can be seen as an approximation of the virgin costs saved minus lower plastic product yields. If the quality of recyclate is comparable to that of virgin, the price difference between recyclate and virgin will probably not be great and there will hardly be any lower returns for plastic products. If the quality of the recyclate is much lower, the lower price of recyclate is likely to translate into less revenue for the plastic products.

And should a mandatory requirement be introduced, it is to be expected that prices for recyclate and the price paid for waste plastic will increase due to scarcity. This is beneficial for collectors, EPR systems, sorters and recyclers. This is unfavourable for purchasers of recyclate. However, when added together, the social costs will change little. For many companies, the higher costs will also be offset by lower contributions to their EPR system.

5.2.1 Quantitative elaboration

Ideally, all cost items from Table 8 would be estimated and quantified separately. Unfortunately, cost data for the use of additional recyclate is hardly available.
Many of the interview partners (with the exception of the packaging sector) (see Appendix A for an overview) were unable to provide cost data, even rough overall indications.
They indicated that the costs are highly dependent on the quality of the plastics and additives, the type of plastic and the market price of the virgin raw materials saved.
In this section, therefore, we estimate the additional costs of using recyclate, based on data that is available.

An important source for this is the Circular Plastics Alliance (Circular Plastics Alliance, 2021). In this project, an estimate was made of the necessary investment required to use 10 Mtonnes of plastic recyclate in Europe in 2025. This study estimated that 3.4 Mtonne extra recyclate could be released within the packaging, electronics, construction, automotive and agricultural sectors. This will require a total investment cost of € 7.6 billion (range of € 7.6 to 8.6 billion). The amounts of recycling and investment required are summarised in Table 9. The range used by the Circular Plastics Alliance is shown in brackets.

Table 9 - Investments per sector to provide additional recyclate by 2025

Sector	Extra collection and sorting	Extra recycling-capacity	Extra recyclate (Mtonne/year)	Investments in collection and sorting (€ billion)	Investments in recycling (€ billion)	Total investments (€ billion)
Packaging	3.4	3.2	2.8	1.9 (1.6-2.2)	4.5 (4-5)	6.3 (5.5-7.1)
Electronics	0.4		0.3	0.2 (0.2-0.3)	0 (0-0)	0.2 (0.2-0.3)
Construction	0.3	0.1	0.1	0.2 (0.1-0.2)	0.1 (0.1-0.1)	0.2 (0.2-0.3)
Automotive	0.1		0.1	0.1 (0.1-0.1)	0 (0-0)	0.1 (0.1-0.1)
Agriculture	0.3	0.4	0.2	0.2 (0.2-0.2)	0.6 (0.5-0.6)	0.8 (0.7-0.9)
Total	4.5	3.7	3.4	2.5 (2.1-2.9)	5.1 (4.5-5.7)	7.6 (6.6-8.6)

Source: (Circular Plastics Alliance, 2021).

If we assume a fifteen-year lifespan for the investments and a required return of 10%, the annual annuity costs of the investments are € 10 million (automotive) to € 830 million (packaging). Converted per tonne of recyclate, this amounts to 100 (electronics) to € 650 per tonne (construction).

These are investment costs only. In the waste and recycling sector, investment costs are usually relatively limited compared to operational costs. This is because the work is relatively labour intensive. For example, a lot of staff are needed for collecting and sorting waste. There are also, for example, costs for means of transport and maintenance costs for equipment and inventory. Data from the CBS show that in the Netherlands operational costs are almost five times higher than depreciation on investments (CBS, 2021). If we apply this factor to the total costs, we see in Table 10 the costs per sector per tonne of recyclate.

Table 10 - Costs of recycling per sector per tonne of recyclate

	Extra recyclate (Mtonne)	Investment costs per tonne of recyclate (€/tonne)	O&M costs per tonne recyclate (€/tonne recyclate)	Total costs (€/tonne recyclate)
Packaging	2.8	300 (260-340)	1,470	1,770 (1,730-1,810)
Electronics	0.3	100 (80-120)	1,470	1,570 (1,550-1,590)
Construction	0.1	650 (560-750)	1,470	2,120 (2,030-2,220)
Automotive	0.1	180 (150-210)	1,470	1,650 (1,620-1,680)
Agriculture	0.2	450 (400-510)	1,470	1,920 (1,870-1,980)
Total	**3.4**	**300 (260-340)**	**1,470**	**1,770 (1,730-1,810)**

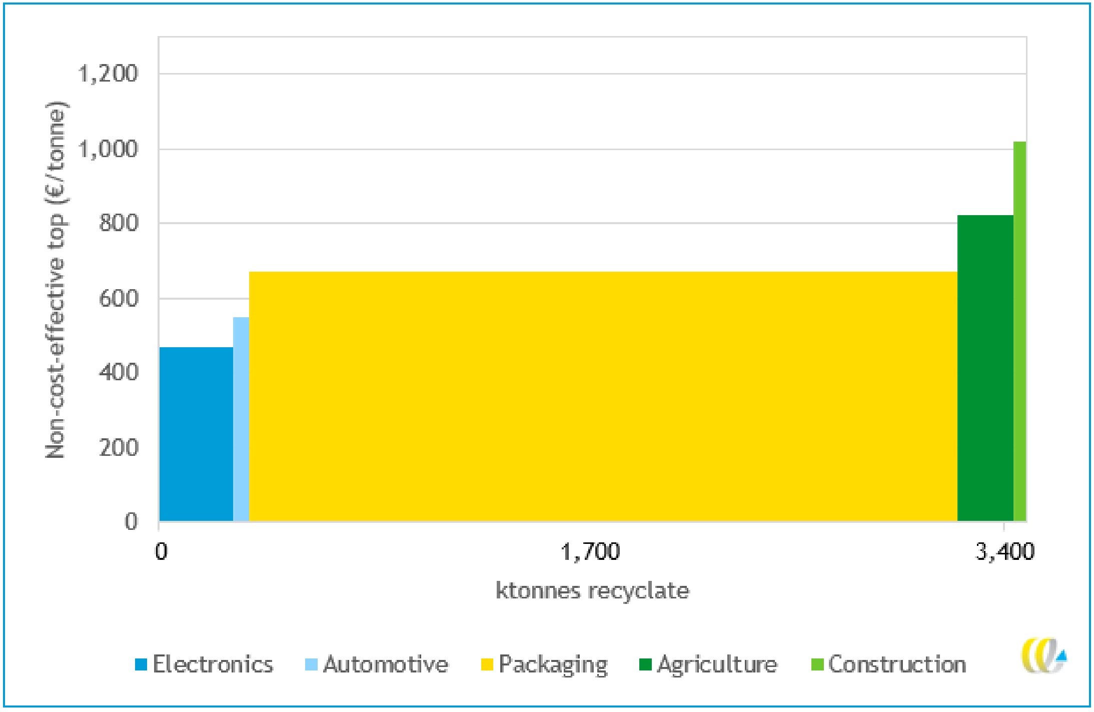
Source: Own calculation based on (Circular Plastics Alliance, 2021) (CBS, 2021).

We see that the average cost is € 1,770 per tonne of recyclate (range € 1,730 - € 1,810). The differences between sectors are relatively large, especially costs for construction are estimated high by the Circular Plastics Alliance. We see that there is a relatively high level of waste: for every tonne of recyclate, three tonnes of waste are needed.

Revenues from recyclate are on average around € 1,000. The range around this is large. PVC recyclate is worth around € 100, while PET can be worth up to € 1,300 per tonne. (Vraag&Aanbod, 2021). These revenues are an approximation of the avoided costs of virgin plastics plus the lower revenues of plastic products because they are not perfect substitutes. The avoided costs for the incinerator are about € 100 per tonne. This leads to an average uneconomic cost of € 670 per tonne.

The following figure shows a cost curve with the potential on the x-axis and the average estimate of the not cost-effective top per sector on the y-axis.

Figure 14 – Non-cost-effective top recycling costs per tonne (€; Y-axis) and potential (kilotonne; x-axis), potential according to Circular Plastics Alliance

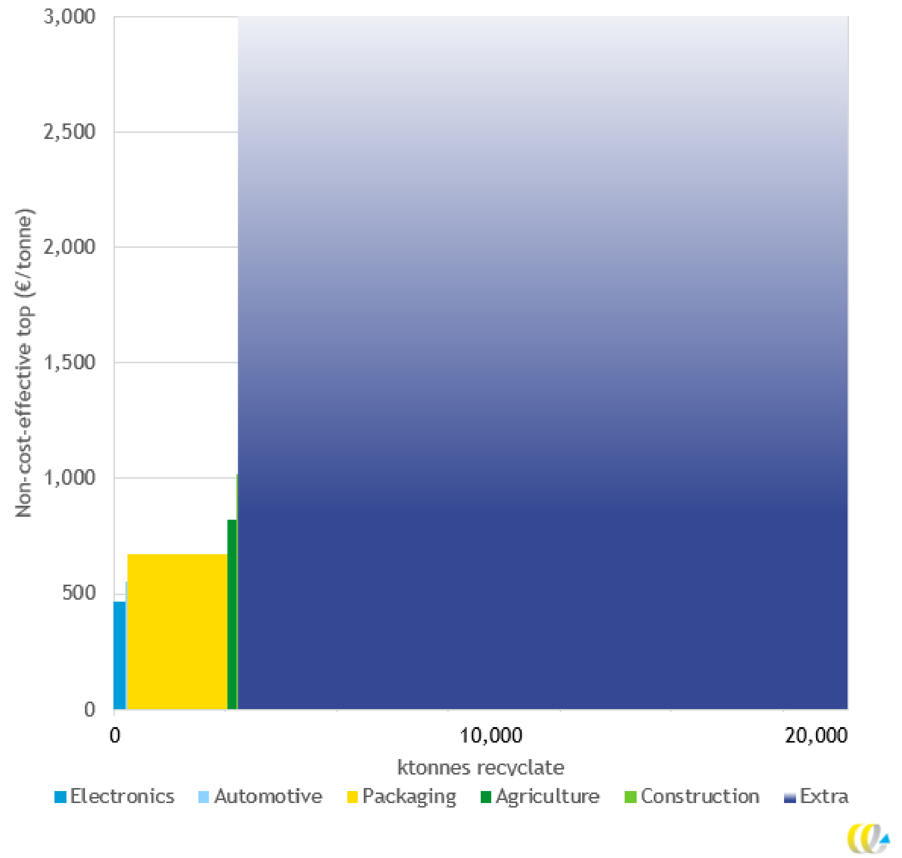


It should be noted that this estimate is based on an additional 3.4 Mtonne at the European level. This contributes approximately to 6% additional recycling. Together with the current commitment, this would bring the figure to around 13%. To reach the 40% target, an additional 20 Mtonnes of recyclate will be needed (see Paragraph 2.4). (Or should this gap be largely filled with bio-based plastics)

If more recyclate is used, the costs can rise sharply, because the less attractive potential must also be exploited. The Circular Plastics Alliance study only looks at the potential that can be tapped relatively easily, for example by making full use of existing recycling capacities or by increasing design for recycling. The cost curve in Figure 15 shows that the not cost-effective top can potentially be much higher. It could also be lower, if innovation and economies of scale make strong cost reductions possible.

By the way, scarcity of recyclate can push up the price and even exceed that of virgin. Regulations can have a strong influence on this, as was seen earlier with the price of PET.

Figure 15 - Recycling cost curve per tonne (€; Y-axis) and potential (kilotonnes; X-axis), recyclate needed at 40% target



In addition to annual costs, there are also start-up costs related to Design for Recycling. One of the interview partners indicated that more Design for Recycling in electrical appliances could be in the order of tens of euros per electrical appliance (per tonne of plastic this would be thousands of euros). This means that if the supply of recyclate from electronics is very high, the costs can rise sharply in this sector. Incidentally, (Circular Plastics Alliance, 2021) estimates the costs for Design for Recycling at around 1.5 billion Euros for the potential of 3.4 Mtonne. These are one-off costs for adapting the production, recycling and sorting processes.

Chemical recycling costs

The above cost figures are based on mechanical recycling. At present, the costs of chemical recycling are still quite high and uncertain because the techniques are still being developed. The collection and sorting costs are similar to those for mechanical recycling. Although the recycling costs are generally still somewhat higher than for mechanical recycling, the revenues are also higher because the quality of the recyclate is better than for mechanical recycling. Conversion costs are also lower (generally zero) because the material is similar to virgin material. The unprofitability of the whole chain will strongly depend on any cost reductions for chemical recycling in the future.

In (CE Delft, 2020) an estimate of the cost of PET production via depolymerisation. Further increases in scale will result in costs of between € 590 and € 820. This does not include costs for collection and sorting. Costs for collection and sorting amount to around € 600 per tonne, based on Circular Plastics Alliance. This leads to total costs of € 1,190 to € 1,420 per tonne of material. This makes the not cost-effective top lower than for mechanical recycling. If we compare this with a return of approximately € 1,300 for recycled PET, this option is approximately as cost-effective. If we also include € 100 in avoided incineration costs, the not cost-effective top is at most € 20 per tonne of recyclate. It should be noted that depolymerisation is one of the cheaper options for chemical recycling and that this does not imply that all chemical recycling is cheaper than mechanical recycling.

Packaging

The 10 Mtonne potential is dominated by packaging, according to the Circular Plastics Alliance. It is therefore interesting to compare how the cost figures compare to current practice figures for the cost of using recyclate from packaging waste.

For household packaging, the cost is € 700 per tonne of collected waste, according to the Packaging Waste Fund. Of this € 700 per tonne, € 500 are for the cost of collection, sorting and marketing and € 200 for the cost of recycling.[13]
However, the cost of a tonne of recyclate is higher, as one kg of waste is not converted one-to-one into one kg of recyclate. With an effectiveness of 80% (1 tonne of waste leads to 800 kg of recyclate), the cost per tonne of recyclate is € 875 (€ 700 /0.8). The estimates based on the Circular Plastics Alliance (€ 770 per tonne of recyclate) are therefore slightly lower than the figures from Dutch practice (€ 875 per tonne of recyclate), but the order of magnitude is similar.

Use of bio-based

The use of bio-based instead of recyclate can be a cheaper way of reducing the use of virgin plastics. The additional costs of bio-based vary greatly depending on the type of plastic. (CE Delft, 2020) estimates the additional cost of bio-based ethylene, an important raw material for plastics, at € 230 to € 350 per tonne of ethylene. As the production process towards polyethylene is the same as with virgin ethylene and there are hardly any rejects, this leads to a not cost-effective top end of € 230 to € 350 per tonne of plastic.

A more detailed analysis shows a cost difference of between € 167 and € 4,000 per tonne of plastic. For the cheaper options, this means additional costs of approximately € 200 to € 600 per tonne of plastic. (CE Delft , 2020). The additional costs are therefore lower than for the use of recyclate. The production costs of bioplastics can also be further reduced through learning and scale effects. However, the price and availability of biomass are uncertain factors. For example, the blending mandate requirement for fuels creates demand from the fuel sector. This increases prices and additional costs. Without mandatory requirement in the plastics sector, the willingness to pay for biomass is likely to be less than in the fuels sector and there will be limited market demand.

[13] Because it concerns the fee that municipalities receive per tonne of plastic, the costs of € 875 per tonne are representative of the additional costs that must be incurred in the chain to achieve separate collection and marketing (the saved costs for collection and incineration of residual waste are already included).

Effects on the business case for recycling
This sorted waste is then sold. Currently, in the Netherlands, the waste management levy from the packaging waste fund (Afvalfonds Verpakkingen) is used as a payment for municipalities for the separate collection and sorting of packaging waste. This sorted waste is then sold (positive/negative amount) to a recycler. The latter processes it into usable recyclate and sells it to a market player who uses it in new products. Because producers of packaging in the Netherlands are obliged to pay for the processing of waste, there is a relatively large supply of packaging waste. A mandatory percentage recycling in a certain product group will lead to an increasing demand for recyclate. In principle, the recycler will sell the recyclate to the party who is willing to pay the most for it. More demand will increase the price of recyclate. As a result, the recycler will also be willing to pay more for sorted waste. This may lead to a reduction in the waste management fee.
In a well-functioning economy, increased demand will also lead to increased supply: waste streams that until recently were not cost-effective to sort and process will become so. To achieve sufficient supply, demand and price must be sufficiently high and a well-functioning organisation is needed.

5.3 Costs per Dutch person per month

The total plastic consumption in the Netherlands is approximately 2 Mtonne per year (= 2 billion kg per year). Per capita this is about 120 kg of plastic per year is equal to 10 kg of plastic per month. Of these, approximately 10% are recyclate or bio-based (9%+1%). Doubling the use of recyclate or bio-based (from 10 to 20%) involves additional costs. These amount to approximately € 650 per tonne of material (see section 5.2.1). 10% additional recycling equals 1 kg additional plastic per month. That would cost € 0.65 per month per Dutch person (or € 7.80 per year per Dutch person or € 17 per household per year). These additional costs are incorporated into the prices of plastic products.

If an additional 10% of bioplastics are used on top of this and the cheaper options are chosen (approximately € 325 per tonne of additional cost), the additional cost rises by approximately 50%. This means that the additional costs of making about 30% of plastic circular (recycling or bio-based) in 2030 would amount to about € 1 per Dutch person per month (€ 12 per year).

5.4 Employment opportunities

More recycling leads to higher employment in Europe. Recycling is more labour-intensive than incineration or landfilling. A study by CE Delft shows that each additional kilotonne of plastic recycling leads to 1.73 FTE extra employment compared to landfilling/incineration (CE Delft, 2013).
According to (Ellen MacArthur Foundation, 2015), recycling leads to 2 FTEs per kilotonne, while incineration/dumping leads to 0.1 FTEs. The net result is therefore 1.90 FTEs per kilotonne. This is in line with earlier figures from CE Delft. At an average extra labour intensity of 1.8 FTE per kilotonne, a target of 40% extra use of recyclate leads to about 40,000 extra FTEs in Europe in 2030. Additional (temporary) employment may also be associated with building recycling capacity and increasing recycling designs.

5.5 Conclusion

The total additional costs for the EU as a whole of a mandatory percentage cycle are very uncertain. Based on indicative figures, there still seems to be potential at the European level for the deployment of 3.4 Mt of additional recyclate at an additional cost of € 600 to 700 per tonne of recyclate. It should be noted that with 3.4 Mtonne, you arrive at approximately 13% use of recyclate and that this is therefore not yet sufficient to achieve

40% recycling. The cost per tonne may increase as the percentage of recyclate rises further. On the positive side, chemical recycling techniques, in particular, are still being developed and the costs may fall further in the future due to innovations. The use of bio-based can also reduce costs, but the costs may increase due to biomass scarcity caused by mandatory requirements in other sectors, such as mobility.

Recycling is more labour-intensive than incineration, so a mandatory percentage can lead to additional employment. At a rate of 40%, this would amount to 40,000 FTEs in 2030. Additional (temporary) employment may also be associated with building recycling capacity and increasing recycling designs.

6 Conclusion

In this chapter, we summarise the various conclusions from the previous chapters. For the sake of clarity, we have divided this into several subsections. The cost-effectiveness section combines the costs and CO_2 results from Chapter 4 and 5.

6.1 Current supply and demand for circular plastic

About 9% of the current new use of plastics in the Netherlands is recyclate and about 1% is bio-based. Expressed as a percentage of the amount of waste, the recycling of all plastics is about 15%. This difference between 9 and 15% is due to the fact that the amount of demand for new plastic is about 70% higher than the amount released as waste per year. This is because plastic is increasingly used in products with a longer lifespan, such as cars and houses. Furthermore, recycling mainly concerns plastics from the packaging sector. Other plastic sectors are lagging behind. Currently, 40% of plastics go into packaging and 60% of plastic waste has been packaging. This percentage of plastic to and from packaging is likely to decrease as plastic application increases, especially in the construction and automotive sectors (light vehicles are more fuel efficient).

Most of the recyclate is produced from waste from the packaging sector, as there is an active recycling policy for that sector. The use of recyclate is still limited in the packaging sector, partly due to strict requirements for food packaging use. A large share of the material goes towards agricultural films and building products. Application in construction is largely mixed plastic recycling in thick-walled application. This mainly replaces wood and concrete, so no virgin plastic production is avoided. The environmental benefit of these routes is therefore also lower than that of recycling monomaterials as plastic substitutes.

In the last two years, the packaging sector (A-brands) has shown increasing interest in using recyclate, especially in non-food packaging (paint buckets, shampoo bottles, etc.).

6.2 Transition Agenda target of 40% recyclate by 2030 highly ambitious

In the Netherlands, the Transition Agenda for the Circular Economy for Plastics has set a target in which 40% of annual Dutch plastics use is met by recyclate and 15% with bio-based plastics. Of that 40%, 30% should be filled with mechanical recycling and 10% with chemical recycling. This recycling target in particular is very ambitious. In order to meet this recycling goal for 2030, approximately 94% of all plastic waste discarded in the Netherlands would need to be separated for recycling by 2030 (see Table 6). Unless there is a strong commitment to imports, it does not seems practically possible to meet this recycling goal. In addition, it is to be expected that the collection, sorting and recycling of the last most difficult plastic streams will be relatively expensive. The Dutch 2030 target corresponds to about five times more plastic recycling than at present.

6.3 EU target 18% by 2025

Currently, according to Plastics Europe, 4 Mtonnes of plastic recyclate are used in the EU for a total consumption of 55 Mtonne (8%). In 2030, consumption will increase slightly to 57 Mtonne and 35 Mtonne of plastic waste will be released. In the EU, the Circular Plastic

Alliance is currently using a target of 10 Mtonne of recyclate by 2025. This is equivalent to approximately 18% use of recyclate and is still ambitious. This means that approximately 40 to 45% of all plastic waste (not only packaging) must be collected separately for recycling. This is a factor of 2.5 more than currently.

For the EU too, the Dutch target (to apply 40% recyclate by 2030, or 20 Mtonne more than today) leads to the necessity to keep more than 90% of the plastic waste separate for sorting and recycling. Theoretically, this is conceivable over a long period of time. In practical terms, this is hardly feasible by 2030.

The EU is also currently discussing a target for recycled plastic for packaging only. Plastics Europe sets a target of 30% by 2030. Since this only concerns packaging, which is 40% of the market, this would only amount to 12% (30% x 40%) for all plastics. A general target for all plastics applications (18-40%) will very quickly result in more (additional) recycling than a target for packaging only (12%).

6.4 Structure of the mandatory requirements

A mandatory requirement shaped as a duty for polymer producers or importers is the easiest to implement for the EU/Member States due to the limited number of companies that would be covered. The administrative burden for this option would also be relatively limited. Furthermore, this option does not have the problem that recyclate is easier to use in some products than in others, because these manufacturers supply a wide range of customers for all kinds of products. Especially if some form of exchange, trade or banking is permitted, this option could quickly result in an increase in the amount of recyclate in plastics. However, under this option, the incentive for separate collection of plastic for recycling is rather indirect (mainly through the price of recyclate). Therefore, it is recommended that this option should also definitely encourage collection for recycling through a strong expansion of producer responsibility for recycling all plastic applications. This also means that in existing EPR schemes (automotive, electronics) the use of plastic for energy (recovery) should no longer be allowed. Existing EPR schemes can also be broadened (packaging) or new EPR schemes created (products in construction, agriculture). This can be supplemented by mandatory requirements for Design for Recycling.

A mandatory requirement for companies that use plastic in products (brand owners) is also an option, but has the disadvantage, compared to a mandatory requirement at polymer level, that many more companies need to be regulated, which will require more regulation and costs. This option can be used differentially or generically. However, generic deployment does not take into account differences between sectors and/or products and will lead to relatively high costs in some sectors. A sector-by-sector approach has the disadvantage that it will require a lot of consultation with many sectors and will only really stimulate the recycling market once a large part of the plastic-using sectors is regulated. For example, if there is only a 30% recycling obligation for packaging, this will result in 12% recycling for the total market and only a limited increase in collection for recycling.
A mandatory requirement for only a part of the market mainly causes recyclate to shift from unregulated to regulated sectors. The advantage of regulating by sector is that the waste side can be regulated at the same time through producer responsibility and collection in the same sector consultations.

All in all, a mandatory requirement for polymer producers and importers supplemented by increased availability of recyclate through more and stricter EPR schemes and Design for

Recycling seems to be the most effective option for making plastics rapidly more circular in the EU.

6.5 Policy needed for waste phase, application phase and design phase

To increase plastics recycling by a factor of 2.5 (EU) or 5 (NL) in 3 to 8 years, a rapid transition is needed on both the waste and application side. In addition, packaging and products must be designed so that they can be recycled more easily. The following is needed for the three major phases of the plastics chain:

1. **Waste phase:**
   - Producer responsibility, collection systems, return bonus systems for all product groups that use plastics.
   - Quickly disallow energy application in EPR schemes as a form of recycling. Convert EPR to full recycling of plastic.

2. **Application phase:**
   - A form of mandatory recycling for all plastics products, preferably at the level of polymer production/use in the EU.
   - Possibly additional forms of mandatory percentages for brand owners of large product groups in order to accelerate the switch to recyclate for those products where recyclate is easier to use.
   - Phasing out the use of non-separated mixed plastics in thick-walled building products that replace wood or low-grade concrete to achieve greater climate benefit through the replacement of virgin plastics.

3. **Design phase:**
   - Introduce mandatory Design for Recycling for packaging and products by means of product regulation, including enforcement.
   - Material innovation and new material choices more in line with the image of circular plastics.
   - Increased tariff differentiation in EPR schemes between products/packaging that are easily or less easily recyclable, such as along the lines of France’s Citeo.

Only an ambitious policy package aimed at all three of these phases in the plastics chain will enable a transition to increased circular plastics. Focusing on the waste phase alone, as has been the case to date, leads to difficult sales of recyclate, lower prices for recyclate and many low-grade applications of mixed plastics. Theoretically, steering only with a mandatory requirement could work well through higher recycling prices that also stimulate collection and sorting. In practice, steering for this reason alone will lead to collective collection systems not being established, or only to a limited extent. This will lead to recycling scarcity, high recycling prices and resistance to the targets. A combined steering of both collection for recycling and deployment of recyclate, preferably at European level, could make the EU targets possible. It would help if the goals and rules for the next eight years were made clear fairly quickly. Perhaps a target that is somewhere between the EU target and the Dutch Transition Agenda is also possible, such as 25-30% recyclate.

6.6 Is a mandatory requirement imposed only in the Netherlands also effective?

If a mandatory requirement fails to materialise at the European level, in principle the Netherlands can implement it independently. However, imposing a mandatory requirement on producers of plastics may have adverse effects on the competitive position of the Netherlands because it exports a relatively large amount of plastic. Because the Netherlands exports a relatively large amount of plastic, it can lead to a situation where the environmental impact of the mandatory requirement is limited when corrections are made for exports, while the administrative burden is high. A mandatory requirement at product level has the major disadvantage that many products are regulated at European level and many products are produced for the European market. The Netherlands is a small player in this.

6.7 Bio-based plastics

In the Netherlands, the Transition Agenda has set a target of 15% bio-based plastic by 2030. The current application rate is about 1%. The Biobased Plastics Action Plan indicates that a substantial increase of bio-based plastics in the market can only be achieved by stimulating bio-based plastics by means of a subsidy scheme (comparable with bio-energy from the SDE+) or a mandatory requirement (comparable with the mandatory requirement for biodiesel and bio-ethanol in petrol) (Transitieteam Kunststoffen, 2020). This would also be logical in terms of cascading, where biomass is preferably used in products and not for energy purposes (Biomass in Balance, SER 2020). The current policy situation, in which biomass for energy and fuel is stimulated and bio-based plastics are not, steers companies towards the energy application of biomass. It is important to note that bio-based plastics are largely made from the same raw materials that are now mainly used for biofuels.

A potential mandatory requirement for bio-based plastics in the Netherlands or Europe is possible, certainly if it is coordinated with the policy for the much larger fuel market (8% of oil goes to plastics and more than 80% to fuel).

It is important, however, that from the start of any mandatory requirement for the application of bio-based plastics, sustainability criteria are set in the form of a minimum CO_2 reduction percentage and sustainability requirements for production to ensure that bio-based plastics actually deliver an environmental benefit. This can be linked to the requirements that apply or will apply to biofuels (Renewable Energy Directive (RED)) and the 'Integrated Sustainability Framework for Biofuels' as expressed in the letter to the House of Representatives 199826 dated October 2020 and the Biobased Plastics Action Plan, which also contains proposals for sustainability criteria for bio-based plastics.

Bio-based plastics and recycled plastics also seem to complement each other well in some cases. For example, with mechanical recycling and the short-chain chemical recycling (depolymerisation), the recycling rate of PET can be increased relatively easily. In contrast, bioPET currently offers lower CO_2 emission reductions. For PET, recycling is likely to become dominant. For PE, bioPE is likely to fill a significant part of the film market in particular, because recycling to films is quite difficult and because bioPE can offer high CO_2 emission reductions and limited additional costs.

6.8 Conclusions per sector

In each sector there are various opportunities and bottlenecks for the improvement of collection and the use of more recyclate. In the packaging sector, there is already a lot of policy and most countries are already familiar with EPR scheme. Through Design for Recycling and additional separation, there is potential for additional recycling. Food safety requirements hinder the use of recyclate. The construction sector is a growth sector that will generate increasing amounts of plastic waste (window frames, insulation, pipes) in the coming years. Regulation can contribute to the processing of this waste into recyclate. A relatively large amount of recyclate is already used in the construction industry. In the electronics sector, a large amount of waste is still exported and EPR does not yet include a recycling target for plastics. There is still some potential in this regard. In the automotive sector, a relatively large amount of plastic is already removed from cars and recycling targets for plastics are being drawn up at the European level. Design for Recycling will allow more plastics to be released in the coming years. In the agricultural sector, a lot of recyclate is already being used. There are still opportunities in other product groups. In other sectors, there are opportunities at product level, for example by using recyclate in flooring and textiles.

6.9 CO_2 emission reductions from increased circular plastics

In Chapter 4, we estimate the carbon footprint of the use of plastics in Europe. We do this both for the current situation (data for 2018-2020) and for three scenarios for 2030. With this, we investigate the impact of a structural shift towards more circular plastics.
The following three scenarios were used:

- 'Business as usual'. In this scenario, the demand for plastics is growing but there is no change in how this demand is met (distribution of virgin, recyclate and bio-based).
- '13% recyclate'. This scenario assumes that an additional 3.4 Mt of recyclate is used, increasing the share of recyclate in total consumption to 13%. This 3.4 Mtonne is based on an analysis by the Circular Plastics Alliance, which indicates that this is the 'untapped potential' for 2025 in Europe (Circular Plastics Alliance, 2021).
- 'EU Transition Agenda'. This scenario assumes that the Dutch Transition Agenda will be realised at European level. This means that 40% recyclate is used and 15% bio-based plastic is applied.

If the targets in the Dutch Transition Agenda for Plastics (40% recyclate and 15% bio-based) are realised at European level, the climate change impact of plastics use would fall from approximately 180 Mtonne CO_2-eq./year (175 to 183) in the business as usual scenario to 100 Mtonne CO_2-eq./year (77 to 122). This is a reduction of about 80 Mtonne CO_2-eq./year, or 41%. This includes a very high potential for recycling as 94% of plastic waste is sent to recycling.

Per kg recycled/bio-based plastics, there is a corresponding reduction of about 2.5 to 3 kg CO_2-eq. per kg; 80 Mtonne CO_2-eq./year is saved by using 28 Mtonne extra recycled/ bio-based plastic (EU Transition Agenda compared to business as usual, from 8 to 55% recycled or bio-based).

Without additional recycling towards 2030, our analysis indicates that there will be an increase in CO_2 emissions. While there is a benefit from the agreed efficiency improvements in production processes of 2% per year, the increase in use (8%) and the intended shift from landfill to incineration in Europe results in a 6% higher carbon footprint for plastic than in 2018.

A less far-reaching target of 30% recyclate and/or bio-based plastics by 2030 includes 13 Mtonne of additional recyclate and bio-based material input. This results in a saving of 37 Mtonne CO_2-eq. compared to BAU.

6.10 Costs and benefits of more circular plastics

The current additional costs (cost-benefit) in the entire plastic recycling chain from the packaging system amount to an average of approximately € 875 per tonne of recyclate. For a Europe-wide increase in recycling of 3.4 Mtonnes of recyclate (6% of consumption), the costs are about € 770 per tonne, according to an own analysis based on Circular Plastic Alliance. The saved costs for incineration of € 100 per tonne should be deducted from this.

The additional cost of bio-based plastic is approximately € 230 to € 350 per tonne. For the most expensive bioplastics, this can amount to as much as € 4,000 per tonne. In these additional costs for circular and bio-plastics, we have not yet taken into account that the costs of CO_2 emissions via ETS and a possible CO_2 levy for virgin plastics will probably increase in the coming years.

Chemical recycling is still very much in development and cannot yet compete. Pyrolysis in particular is often regarded as quite expensive. On the other hand, a large number of companies are currently investing in this and also see a future in it. More precise cost estimates are expected in the coming years. Depolymerisation of PET, which is a relatively efficient form of chemical recycling, costs, according to SDE++ analyses by CE Delft, TNO and PBL, after further upscaling, about as much as it saves in terms of costs in virgin PET and waste incineration, and is therefore likely to play a role alongside mechanical recycling in the shorter term.

If these costs are translated into a doubling of recycling in the Netherlands (10% more recyclate) and 10% more bio-based material to a total of approximately 30% circular plastic (20% recyclate and 10% bio-based) then this would cost the average Dutch person about 1 Euro per month, which will be channelled into slightly more expensive plastic products and packaging.

6.11 Cost-effectiveness

As indicated above, the additional cost estimate is rather uncertain. For the calculation, we combined the CO_2 numbers from Chapter 4 with the cost estimates from Chapter 5.

For a limited amount of additional recycling (from 6% today to 13% in Europe in 2025), there is an estimate and for that volume we arrive at approximately € 200 per tonne CO_2 in additional costs. The spread in the estimate is large, and calculation with the cheapest options and the most expensive options gives a range of € 0 to € 1,250 per tonne CO_2 in additional costs.

For the cheapest mechanical recycling options, € 50 per tonne CO_2 reduction can be calculated and, over time, PET chemical recycling (depolymerisation) could probably take place at no additional cost. However, this technique is still being developed and is only possible for PET and not for other plastics.

If all plastics really had to be recycled, it now seems that the costs for the last kilograms would be much higher. Estimates range up to € 1,250 per tonne CO_2 reduction.

For bio-based, the additional costs are around € 200 to € 600 per tonne of material and the CO_2 reduction for the more sustainable options is around 2 kg CO_2 per kg of material. For bio-based, the average additional costs are therefore estimated to be between € 100 and € 300 per tonne CO_2. These additional cost estimates are highly dependent on the development of oil and virgin plastic prices. Obviously, these prices vary quite a lot. In addition, there is also the effect of an increase in the price of recyclate through the introduction of a mandatory requirement for recyclate, which will reduce the additional costs, especially when viewed from the EPR and the waste perspective.

Table 11 - Cost-effectiveness in euro per tonne CO_2 emission reduction circular policy plastics

	Additional costs (see 5.1 and 5.2) €/tonne recyclate or bio-based plastic	**CO_2 reduction (see 4.3.3)** tonne CO_2-eq./tonne recyclate or bio-based plastic	**€/tonne CO_2 reduction additional costs**
From 6% to 13% recyclate (3.4 Mtonne extra) by 2025 in EU	On average 600 to 700 (440 to 3,370)	On average 3.2 (2.4 à 3.9)	203
Most expensive recycling options	4,000	On average 3.2	1,250
Least expensive recycling options	167	On average 3.2	52
Chemical recycling of PET scaled-up (depolymerisation)	Approximately cost-effective	Approx. 2.6	Approximately 0
Bio-based plastic (on average)	200 to 600	2.0	100 to 300

All in all, a package of about twice as much recycling as today, supplemented by a substantial quantity of sustainably produced bio-based plastics seems an interesting option with additional societal costs of about 100 to 300 Euro per tonne CO_2 emission reduction. (Here we have not yet taken into account an expected increase in the CO_2 price in Europe for fossil emissions via ETS and taxation). With the introduction of a mandatory percentage recycling and/or bio-based plastic, plus more and stricter producer responsibility, these costs do not end up with the government but with the companies that use plastic and ultimately with the consumers.

6.12 Competition with energy is an extra argument for imposing a mandatory requirement

In the case of bio-based plastics, it has been an issue for some time that there is an incentive in the Netherlands and the EU for the use of biomass for fuels (Renewable Energy Directive (RED) mandate) and for energy (SDE+ subsidy), but not for bio-based plastics. While policy application for material is actually preferable. As these options are largely based on the same bio-based raw materials and residues, a mandatory requirement for bio-based plastics could also balance this out. Without a form of mandatory requirement or (alternatively) without a subsidy, it is unlikely in the current policy field that bio-based plastics will grow strongly in the Netherlands.

However, the recycling of plastics has also recently entered the competition with energy application. In the context of the Renewable Energy Directive (RED), it is possible that Member States will count recycled carbon fuels (fuel made from plastic) as a renewable fuel. If a (larger) EU Member State starts doing this, it will have a knock-on effect on plastic waste, which will limit recycling to new plastics. Also, the incentive for sustainable aviation fuels (SAF) with a probable target of 2% by 2025, within which plastic-to-fuel is also an option, will make plastic recycling more difficult. A mandatory percentage recycling for all plastics applications has become more urgent because of these coming policies for the much larger fuel sector, in order to avoid that all plastic waste will be converted into fuel, making recycling (with a higher environmental benefit) less possible.

6.13 General conclusions: obligation plus Extended Producer Responsibility (EPR) plus recycling of bio-based

A form of obligation for the use of recyclate seems almost inevitable at EU level in order to come close to the ambitious targets set by the Netherlands in its Transition Agenda for Plastics. Because this means that 94% of all plastic waste must be recycled, a clear and strict policy must be introduced on both the waste side and the application side. This requires stimulating the use of recycled plastics via a mandatory requirement as well as stimulating keeping waste separate and sorting it via EPR schemes.

In the EU, an 18% recycling target is set for 2025. This, too, requires firm control of both the waste and the use phase, for as many applications of plastic as possible, especially since this goal is coming earlier.

In terms of costs, the cheaper recyclate options and the cheaper bio-based options at around € 100 per tonne CO_2 emission reduction are interesting in the context of climate policy. However, with higher targets, especially for recyclates, there are also sectors where the costs are much higher. A generic European obligation with exchange possibilities could ensure that the cheaper options are chosen in particular.

Because the 40% recycling target as conceived by the Netherlands is actually not possible, it is strongly advisable to also allow in a mandatory requirement bio-based plastics (that meet sustainability criteria). . This allows companies to choose the most efficient option for each case. A circularity target of 30-55% plastic is then also achievable.

An EU-wide mandatory percentage of recycled and/or bio-based material of about 25-30% by 2030 seems quite feasible, also at reasonable costs. Especially if that target can be set soon, allowing the entire chain to optimise through innovation. It would also make sense to extend producer responsibility to all plastic applications. Designs for recycling and improved collection and sorting can also contribute.

6.14 Recommendations

To introduce a mandatory percentage of recycled and/or bio-based plastics in the EU, there are still a number of practical issues to be resolved and detailed later.

Important issues are:
- What specific targets will apply for the years 2023 to 2030? If we assume 25-30% by 2030, it remains to be determined when the mandatory requirement can be introduced and how fast it will grow. As with renewable fuels, it is conceivable to start with a limited percentage of, say, 5% and to increase this in stages. The details of this need to be explored further.
- What specific rules will apply to companies subject to the mandatory requirements? How should they report and what forms of certification are permitted? What kinds of

exchanges and banking are permitted? In the elaboration of this, the rules for sustainable fuels that are already obligatory for the EU under the Renewable Energy Directive (RED) can be followed closely.

More EPR and tightening of existing EPR

In addition to a mandatory requirement for the use of recyclate, it is also important to define collection and recycling agreements for all major plastic-consuming sectors under EPR schemes as soon as possible. In addition, in the short term, existing EPRs that allow energy application as a reuse option should eliminate or phase out this option and the collection and sorting targets for plastics could be adjusted upwards.

Moving towards new combinations and concepts of collection

At present, the collection of broken products and packaging is still organised by sector. It is conceivable to make new combinations in the long run when a lot of material needs to be collected for recycling. For example, the packaging collection system could be rewarded for also collecting plastics products.

Phasing out low-grade mixed plastics applications

At present, particularly in the Netherlands, a fairly large proportion of plastic waste from the packaging sector is still used as mixed plastic that replaces thick-walled wood or concrete in the construction sector. This removes material from the plastic chain and the environmental benefit of these options is also smaller. Consideration could be given to making this option count for less in the recycling administration over time.

Sustainability criteria for bio-based plastics

For bio-based plastics, it is important that sustainability criteria are defined in the short term that are in line with the sustainability criteria that already exist for biofuels under the Renewable Energy Directive (RED).

Include chemical recycling in proportion to environmental benefit and/or plastic-to-plastic yield

Chemical recycling can play a role in achieving more plastics recycling. The preferred technologies are depolymerisation and dissolution. However, pyrolysis and gasification can also contribute to more recycling of plastic. It is important that depolymerisation is included in a balanced way in the monitoring of plastic recycling.
In the report '*Monitoring chemical recycling. How to include chemical recycling in plastic recycling monitoring?*' CE Delft this is further elaborated.

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A Parties interviewed

The interviews were informative in nature. Findings and conclusions in this report are from CE Delft.

Table 12 - Parties interviewed

Affiliation	Name	Sector
Afvalfonds Verpakkingen	Coen Bertens; Paul Claessens	Recycling packaging
ARN	Janet Kes	Recycling auto's
Bouwend Nederland	Helen Visser	Construction
Coolrec	Tom Caris	Electronics recycling
Morssinkhof	Matthijs Veerman	Recycling
Philips	Eelco Smit	Electronics
Plastics Europe	Theo Stijnen	Plastic sector
Prezero	Freek Bakker	Waste separation
RecyclingNetwerk	Rob Buurman	Ngo

B The production of plastics and the use of recyclate and bio-based

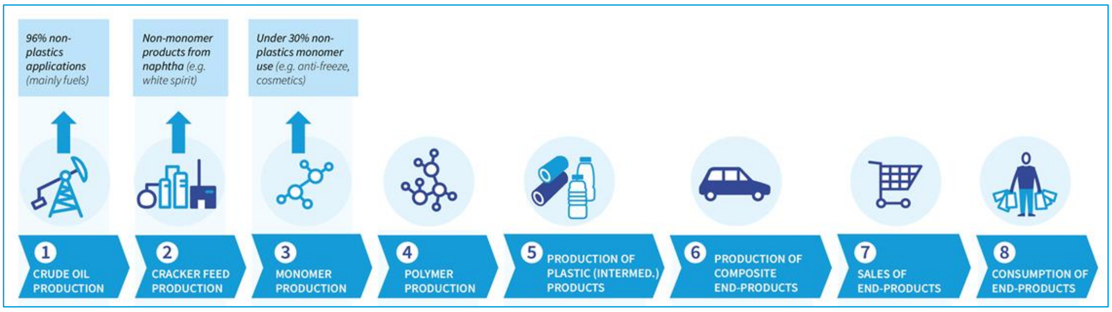
B.1 Introduction

In this chapter, we provide insight into the production chain of plastics and we show where in the chain recyclate and bio-based can be used. This is important to be able to determine where in the chain a mandatory requirement can be deployed.

B.2 The production of plastics

The following figure shows the production chain of fossil virgin plastics.

Figure 16 – Plastic production chain



Source: (CE Delft, 2021).

The following stages are involved:
1. Most plastics are made from crude oil[14]. This crude oil is pumped up from the ground.
2. Crude oil is converted in a refinery into various oil products, such as petrol, diesel, paraffin and naphtha. By far the largest proportion of oil (94 to 96%) (BPF, 2019)[15] in Europe is used for applications other than plastics, especially motor fuel. Various refinery products, especially naphtha and LPG, form the raw material for plastics as cracking feed.
3. This cracking feed[16] is then used in a cracking plant to make *simple* chemical products, the so-called monomers. Examples are ethylene and propylene. These are gaseous substances. Other substances, such as benzene, can also be made from cracker feed.

14 In addition, plastics can be made from bio-based materials and natural gas condensate or refinery gas can also be used for the production of monomers. This natural gas route is not common in Europe, but it is in the United States.

15 Incidentally, the United Nations predicts that this percentage will increase to 20% by 2050 (UN, 2018).

16 In Europe, an average of 63% of the cracking raw material consists of naphtha, the rest being LPG and other natural gas liquids (PBL, 2021b).

Most of the monomers are used to make polymers/plastics. In the case of ethylene and propylene, it is more than 70% (Naeff, 2021, The Essential Chemical Industry, 2017). Other important applications for monomers are detergents, pharmaceuticals, antifreeze and cosmetics.
4. Plastic producers make polymers, such as polyethylene and polypropylene, by linking the monomers together (also called polymerisation). Polymers are produced in granular form or as powders.
5. Producers of plastic products purchase the polymers and use various techniques, such as injection moulding, blow moulding and rotational moulding, to make plastic products. These can be plastic intermediate products (e.g. dashboard, computer casing, empty packaging) or products made entirely of plastic (e.g. toys).
6. The plastic intermediate products are then processed into an end product, such as cars, computers, washing machines and filled packaging.
7. The plastic and composite products are delivered to the end user through the final sales channel. This is often the retail sector, but can also be, for example, a company that supplies plastic products through a government tender or sells to another company without the involvement of the retail sector.
8. The consumer buys and uses the final product. This can also be a business consumer or a government. After use, the plastic becomes waste and is either separated for recycling by consumers or incinerated in a waste incineration plant with energy production.

B.2.1 Use of recyclate

Recyclate can be divided into chemical recyclate and mechanical recyclate. Mechanical recycling is currently the most common technique in the Netherlands and the rest of the EU and is applied mainly to packaging. In the Netherlands, around 250-300 kilotonnes were mechanically recycled in 2015/2016 and the target is to triple this to 750 kilotonnes by 2030. Chemical recycling is still in its infancy; the target is 250 kilotonnes in 2030 (KIDV, 2016). In Europe in 2018 about 5 Mtonne of recyclate was produced, of this about 4 Mtonne was used in new products (Plastics Europe, 2020).

In mechanical recycling, post-consumer or post-industrial plastic is sorted, cleaned and shredded into grinding or regranulate. The converter (Step 5) can reuse this grind or regrind for the production of plastic products.
The composition of recyclates can be adjusted through compounding. Recycling companies are also involved in compounding. The production of mechanically recycled plastics is usually done by other companies than the production of polymers. However, branch integration is taking place. Producers of virgin polymers buy up recyclates and process them together with virgin plastics they have developed. These *RC compounds* may contain up to 70% recyclate (Centexbel-VKC, sd).

Chemical recycling is a collective term for techniques in which the chemical structure of the discarded plastic is changed and broken down into its original building blocks. These can be polymers, monomers or molecules, depending on the technique. These building blocks can be reused in the chain. Depending on the technique, this will be in Stage 2, 3, 4 or 5. Because the polymers obtained by chemical recycling have the same quality (purity) as that of the virgin plastics, they can be used to make higher-grade plastics with more applications than mechanically recycled plastics. Chemical recycling also makes it easier to meet the requirements for food packaging.

B.2.2 Use of bio-based

Besides recyclate, bio-based can also be used as an alternative to fossil virgin plastic. There are various groups of bio-based plastics that can be used at different points in the chain.

A bio-based plastic is called a drop-in if the end product cannot be chemically distinguished from the fossil product. Examples are bioPE, bioPP and bioPET. There are also bio-based plastics that consist of new polymers such as PLA that cannot be made from fossil sources.

1. **Drop-in chemicals via biomaterial cracking.** These are chemically identical to their fossil alternatives. An example is biodiesel or pyrolysis oil that can be used in a naphtha cracker for the production of monomers. This biodiesel replaces other cracker feed, but the monomers produced (ethylene, propylene) are chemically identical. The higher the percentage of bio-based raw materials in a cracker, the more 'bio-based' the final plastics will be. Another example: bioPE is made from ethanol based on the fermentation of sugar crops such as sugar cane or sugar beet.
2. **Drop-in bio-based plastic via biochemical production**: Bio-based monomers such as bio-ethylene can also be produced by other means, for example through the dehydration of bio-ethanol produced from the fermentation of sugar crops such as sugar cane and sugar beet. These monomers can be converted into polymers via polymerisation. These polymers are also chemically identical to polymers from the fossil route.
3. **Bio-based polymers such as PLA and PHA** are made from bio-based sources that have no identical fossil equivalents and are therefore marketed as alternatives to fossil polymers.
4. **Polymers that are partially or fully bio-based** can be used for the production of plastic products. A producer of plastic products can therefore choose between fossil raw materials, partially bio-based raw materials and completely bio-based raw materials.

C Problem analysis

Virgin plastics have a negative impact on the environment

The use of virgin plastics can have negative effects on the environment, particularly due to CO_2 emissions from plastic production and waste incineration, pollution of the living environment and the plastic soup. Plastics can break down into so-called microplastics, which are harmful to human and animal health. Plastics (both small and large pieces) are particularly problematic in nature because they degrade very slowly.

Since the 1960s, the use of fossil-produced plastics worldwide has increased enormously (twenty-fold). The use of virgin plastic is expected to increase further from 370 Mtonne today to about 1.1 Gtonne in 2050 (CPB, 2017). In addition to the increase in use, the recycling of plastics started later than that of other materials such as metal, paper and glass, so that the net recycling rate of all plastics in the Netherlands is around 15%. This is much lower than for many other materials and allows for more virgin production. In other European countries, the recycling rate is not much higher.

In order to reduce the environmental impact of plastics, many countries, including the Netherlands, have set ambitious targets for recycling and the use of recyclate. However, it is questionable whether these objectives will be achieved without additional policies.

Climate effect of chemistry is substantial

In the Netherlands, there is a large chemical sector that produces a large proportion of materials to (eventually) produce plastics (5.5 Mtonne), about 2/3 of them net for export. Partly because of this, the Dutch chemical sector is a relatively large emitter of greenhouse gases. In the 2019 Climate Agreement, this sector was considered the one with the highest emissions of all industrial sectors (18.8 Mtonne). Using recyclate instead of virgin plastic reduces the carbon footprint per kg of plastic between 50 and 80% (depending on the material and the recycling technique).

Untapped supply of recyclate

Of the nearly 30 million tonnes of post-consumer plastic waste produced annually in Europe, about 4 million tonnes currently end up as recyclate in a product (Plastics Europe, 2020). The vast majority of plastic waste is still landfilled or used in an incinerator. So there is still a lot of unused recyclate supply in Europe today.
In some countries, certain types of plastic (especially packaging) are already well recycled, while in other countries this is not yet developed.

Unused potential due to lack of incentives (outside packaging sector)

Especially for the packaging sector, much has already been organised and high targets for producer responsibility have already been set, but other sectors are lagging behind. As a result, these sectors lack incentives to organise collection and sorting in order to increase supply.

Unused potential due to insufficient focus on plastics in producer responsibility (white and brown goods and cars)

In the packaging sector, there is a separate recycling target for plastics. The automotive and white and brown goods sectors do not, even though they are subject to producer responsibility. There, plastic is one of the materials that counts in the recycling rate averaged across all materials. And because plastic recycling is generally somewhat more difficult than metal recycling, these sectors concentrate on recycling metals rather than plastics.

Unused potential due to lack of design for recycling

By already taking the waste phase into account in the design of a product or packaging, the supply of recyclate can increase significantly. At present, some plastic waste is not offered for recycling because it is too expensive to recycle, and some may end up being incinerated anyway because, for example, it is multi-layer and therefore cannot be separated.
In principle, the responsibility for Design for Recycling lies with the brand owners. As long as they are not responsible in the end-of-life phase of the product, there is no incentive to make their design more suitable for recycling. The price differentiation that the Packaging Waste Fund applies (€ 0.41 per kg for plastic packaging that can be recycled well and € 0.67 per kg for plastic packaging that cannot be recycled well) already has a limited steering effect in this regard. Perhaps a much larger price differentiation such as that used by the French company Citeo (factor of 11 price difference) would have more effect.

Fluctuations in demand due to fluctuating oil prices and lack of mandatory requirements

The demand for recyclate is strongly linked to the oil price. In the period 2017-2020, the oil price decreased and the demand for recyclate decreased, especially at the beginning of the corona crisis. The costs of recyclate are largely in the collection and sorting of waste and therefore it is possible that costs for virgin plastic are lower than costs for recyclate. Without mandatory requirements, many producers will opt for virgin plastic and recyclers will not be able to sell their product. An uncertain business case also inhibits investment in new recycling capacity.

Lower demand than technically possible due to legislation

Due to legislation, the demand for recyclate is lower than technically possible. This applies in particular to food packaging. Because recyclate can be contaminated, it cannot just be used in food packaging (or other applications), it is not *food grade*. In order to be suitable for food packaging, the origin of the recyclate must be known, or there must be closed-loop recycling. At present, food grade rPET is available (from deposit schemes), but not yet food grade rPP and rHDPE.
As a result, much recyclate from food packaging ends up in other products.

Lower demand due to unfamiliarity of customers

Many users of plastic are unfamiliar with recyclate and therefore do not always know its potential.

D Carbon footprints environmental analysis

Table 13 shows which carbon footprints (use or end-of-life) were used in the environmental analysis (Chapter 4).

Table 13 - Carbon footprint per material flow for plastics, kg CO_2-eq./kg (cradle-to-gate or waste processing)

Material flows		Carbon footprint		Explanation/sources
		2018	2030	
Use	Virgin production	2.3	1.8	Eco-profiles Plastics Europe, weighted to European demand for polymer types (Plastics Europe, 2021) (Plastics Europe, 2020)
	Mechanical recycling	0.4 to 2.3	0.3 tot 1.8	CE Delft (2021)
	Depolymerisation/ dissolution	1.0	0.8	Screening LCA Ioniqa, CE Delft, (2018)
	Pyrolysis/gasification	3.2	2.5	BASF ChemCycling (BASF, 2020)
	Bio-based production	-1.0 to 1.0	-1.3 to 0.8	EU BIOSPRI project (COWI/UU, 2018), adjusted by CE Delft (see explanation under table), (IFEU, 2021), (Moretti, et al., 2021)
End-of-life	Energy recovery (MSWI)	1.9	1.9	Calculation by CE Delft. Direct CO_2 emissions and energy recovery in MWI determined on the basis of polymer structures, incineration values and European MSWI efficiencies. Assumption: 40 km transport to MSWI. Weighted by European demand for polymer types.
	Collection/sorting for recycling	0.0	0.0	No carbon footprint; the carbon footprint of collection and sorting is included in the use of recycled materials, and is therefore not attributed to disposal.
	Landfill	0.1	0.1	Ecoinvent (Ecoinvent, 2016), *Waste polyethylene terephthalate {CH}| treatment of waste polyethylene terephthalate, sanitary landfill*

A few comments are important here:

- For a number of material flows, a range of carbon footprints was used (bio-based and mechanical recycling). This was done because for these flows the uncertainty in which types of plastic are used is relatively large (especially for 2030).

- The carbon footprints for 2018 are based on the sources listed in Table 13. For 2030, it is assumed that an annual efficiency improvement of 2% is achieved in all production stages.

- The carbon footprints for use take into account all stages up to and including the production of granulate. Further processing into end products is calculated separately on the basis of the earlier analysis for Plastics Europe Netherlands and NRK (CE Delft, 2021).

- The carbon footprint of additives in plastics was not modelled.

- The use of recycled material can contribute to reducing plastic incineration in AECs by increasing the amount of material to be collected, sorted and recycled. In some product-level studies, the carbon footprint of the avoided incineration is attributed to the recycled product. This study does not include this 'bonus', so the values may differ from other studies. We choose this option because the model takes into account the entire European consumption and disposal of plastics, so that in the material flows (Table 6) a higher input of recycled material is already associated with a reduction in material sent to AECs. Vice versa, no 'environmental bonus' for avoiding primary plastic production is awarded for sending material to recycling.

- In the model, the carbon footprint of the collection and sorting of end-of-life plastics is allocated to the production of recycled plastics ('cut-off approach'). The carbon footprint of these processes is thus reflected in the consumption of recycled plastics, whereas delivering discarded plastics for recycling does not involve a carbon footprint. Since the scenarios include both European consumption and end-of-life, and since an increase in the use of recyclate is linked to an increase in the collection and sorting of material, this choice does not have a major impact on the overall results.

- For bio-based plastics, the recent European BIOSPRI study (COWI/UU, 2018) (Moretti, et al., 2021) for bio-based plastics from primary crops and an IFEU LCA for bio-based plastics from residual streams were used (IFEU, 2021). The following adjustments/choices have been made:
  - Results are converted to 1 kg plastic granulate.
  - The carbon footprint of indirect land use change (ILUC) is included.
  - The conversion of granulate to end product (included in the BIOSPRI study) was calculated by CE Delft and subtracted from the results. This makes them comparable with the other carbon footprints in the model.
  - The (temporary) storage of biogenic carbon in bio-based plastics is included.
  - With this, carbon footprints for the production of bioPET, bioPE, PLA, starch plastics (from primary crops) and bioPP from discarded cooking oil have been determined. With these results, CE Delft has chosen a range for 2018 of -1.0 to 1.0 kg CO_2-eq./kg bio-based plastics. The low value roughly corresponds to a situation in which a mix of bio-based plastics from primary crops and from waste streams is used. The higher value represents a situation with mainly bio-based plastics with a relatively low carbon footprint (bioPE, PLA) produced from primary crops.

E Opportunities per sector and products

In this Appendix, we discuss the likelihood of success of a target per sector or specific product group. This is particularly relevant for a sector-specific approach, but also provides insight into the level and feasibility of generic targets. We also show the current status of recycling and what opportunities or problems there are here.

Packaging

According to Rebel Group, the packaging market offers the greatest opportunities for the use of recyclate. This is the largest market in Europe as well as in the Netherlands with 40%. Packaging already has the largest intake, but the use of recyclate is still limited, partly due to legislation. Much recyclate from the packaging sector disappears into other sectors. This is partly high-grade (e.g. film to agricultural sheeting) and partly low-grade (mixed plastic as a substitute for wood and concrete).

We distinguish between food packaging and non-food packaging:

- **Food packaging.** For food packaging, there are opportunities in particular for PET bottles and trays. For PET bottles, the SUP directive already sets a mandatory percentage by 2025. PE and PP still present challenges in terms of food safety.

- **Non-food packaging.** For non-food packaging (detergents, paint buckets, shampoo), there are many opportunities for the application of PE and PP recyclate. Various household products are already packaged in up to 100% recyclate (Shout, Neutral, Marcel's Green Soap). For pallets, bin liners, crates and others, the potential is already 100%. Yet here the percentage of recyclate in most packaging is still much lower.

(Polymer Science Park, sd) shows that there is still much untapped potential in the use of recyclate in the packaging and automotive markets. It recommends that a follow-up step be taken to increase the percentage of recyclate for eleven promising product groups.
The starting point is to determine a minimum percentage of recyclate and to have this laid down in European standards and stimulated through legislation and regulations. These are product groups with sufficient volume and the ability to use 100% recyclate. This only resulted in packaging. These include: household bags, cups, bottles, buckets, non-food, flower pots, single-use pallets, crates and trays, wheelie bins and waste bins. In other product groups, redesign to achieve a higher percentage is possible. Because packaging is covered by EPR and there are separate collection targets for plastics, collection is already relatively high. With more Design for Recycling and more commitment to separate collection or post-separation, this percentage could be a bit higher.

Electrical & electronic equipment

Electronical and electronic equipment account for 6% of European consumption.
In electronics, hardly any recyclate is used, while a relatively large amount of plastic is

used. The technical and visual requirements of producers are high. According to OVAM, the potential for using recyclate for the housing of electrical appliances is less than 50%.
At company level, however, recyclate is already being used successfully. An example: Philips has designed a number of products for the application of recyclate and uses this recyclate, for example, in vacuum cleaners and irons.[17] However, recyclate is mainly used for the dark and invisible parts, as it is thought that the use of recyclate for visible parts does not match consumer demand. Nor can it be used on parts that come into contact with food, such as the water tank in a coffee machine.[18] However, within electronics there is also potential for bio-based. For example, Philips will soon be launching a line of bio-based kitchen appliances.

The collection of plastic recyclate from electronics is also still limited. The EPR scheme of electrical and electronic equipment does include targets with regard to processing and recovery, but these are not always met and are not specified for plastics and relate more to metals. Useful use also includes incineration with energy recovery. This EPR scheme could be expanded with collection targets for plastics. In practice, the percentage of discarded plastics in the electronics market that is ultimately used in Europe for the production of recyclate is still limited. Much waste is still exported, landfilled or incinerated.
European companies lack incentives to retain waste for the European market. As products from this sector are already collected, it is obvious to focus on this potential source of secondary plastics. Moreover, there is still a lot of potential in improving collection and recycling.

Building & construction

20% of European plastic production is used in construction. A relatively large amount of recyclate is already being used in construction, which also comes from other sectors.
The sector is attractive for the application of (mixed) recycled material of PE and PP, also as a replacement for other materials such as wood and concrete. The latter often involves a mix of different types of plastic that can only be used with a thick wall. A study for OVAM shows that 100% recyclate must also be possible from mono-material for a number of applications (cable ducts, facade cladding).

An important characteristic of plastic use in construction is that the input far exceeds the output due to the long lifespan of buildings and the growing use of plastic. In addition, construction is a diffuse sector that does not contain a single product, but a collection of products that consist wholly or partly of plastic, such as frames, insulation material and pipes.

During construction, however, attention is already being paid to recycling. PVC from construction is mainly used for sewage pipes and pipes for electrical wiring. An important motive for keeping plastic separate are the requirements imposed on other separated waste streams. As long as it is permitted for some applications that 1% of rubble consists of plastic, further sorting is not necessary. If these requirements become stricter, this will mean that more plastic will be released separately.

17 Caseguide-Ontwerpen-met-Recyclaat-digitaal-spreads.pdf (partnersforinnovation.com)
18 Philips: "A nice shiny blue vacuum cleaner is not yet possible with recycled plastic" [in Dutch] | KRO-NCRV

Much is already being collected separately on the construction site. Profit can be made from the demolition of buildings. Here, the amount of plastics will continue to increase in the coming years, because more and more plastics are used in buildings and these will also be discarded.

Agriculture

In agriculture, the use of recyclate in products is highest. These include, for example, agricultural plastic. Plastics in agriculture are attractive product groups where price is often more important than quality. There are also various recycling initiatives.
In agriculture, in addition to recycling, there is also a discussion about plastic pollution of soil by agricultural sheeting. Bio-based plastic in film that breaks down in the ground could be an interesting alternative for this. In eight other European countries (Belgium, Finland, France, Germany, Ireland, Italy, Sweden, Spain) agricultural plastics are already covered by a EPR scheme. In the Netherlands, too, agricultural plastic is already being collected separately. Other plastics are not yet regulated.

Automotive

The automotive market is a major user of plastic. Cars that are currently scrapped contain about 40-50 kg of plastic. Approximately one third of this is easily recyclable. The rest is less recyclable because it contains, for example, substances of very high concern or flame retardants. Since cars are registered and fall under EPR, recycling is already well organised. In the Netherlands, 98% of an end-of-life car is recovered.
A car on the market today contains on average more than 100 kg of plastic, but the percentage of recycled material used is still low. Recyclate (PE and PP) is used for non-visible parts in particular. About half of the materials used are suitable for (partial) replacement by rPE and rPP. According to OVAM, the potential of using recyclate for automotive purposes is 30%. According to Polymer Science Park, the potential for using recyclate is great, but redesign is needed for some components.
There are also obstacles and strict requirements concerning consumer safety and health. Several brands have already made commitments around a percentage of plastic recyclate. Volvo and Renault want to use 20-25% recyclate by 2025.

Household, leisure and sports

The European carpet industry is already working extensively with yarns from recycled PA. A lot of recyclate is also used in the textile sector (Centexbel-VKC, sd). Nevertheless, the percentage is still modest. Certainly closed-loop recycling is still limited: less than 1% of the total supply of textiles is recycled back into clothing. Worldwide, polyester is the most commonly used fibre for textiles (51.5%), in the Netherlands it is 19%. In the Netherlands, an EPR scheme for textiles is being prepared that also includes a recycling target. France already has producer responsibility for textiles and Sweden is in the process of introducing it (Rebel & Tauw, 2021).

Others

Products/product groups with great potential include park furniture, flower pots.