Policies for circular plastics

Suggestion based on recent research

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Clients

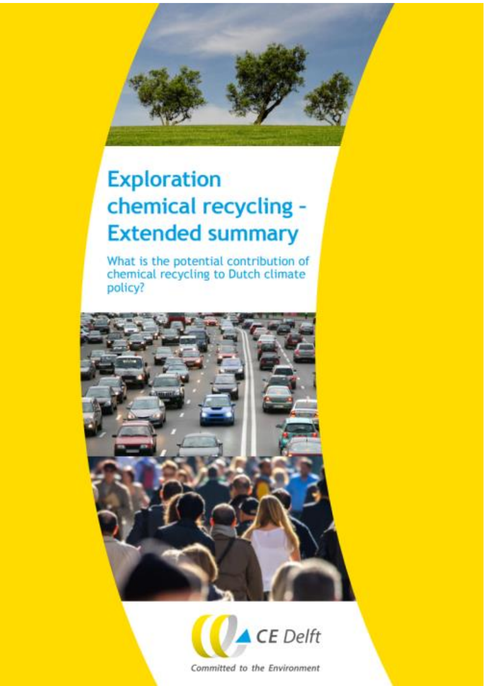
Industries
(Small and medium size enterprises, transport, energy and trade associations)

Governments
(European Commission, European Parliament, regional and local governments)

NGOs

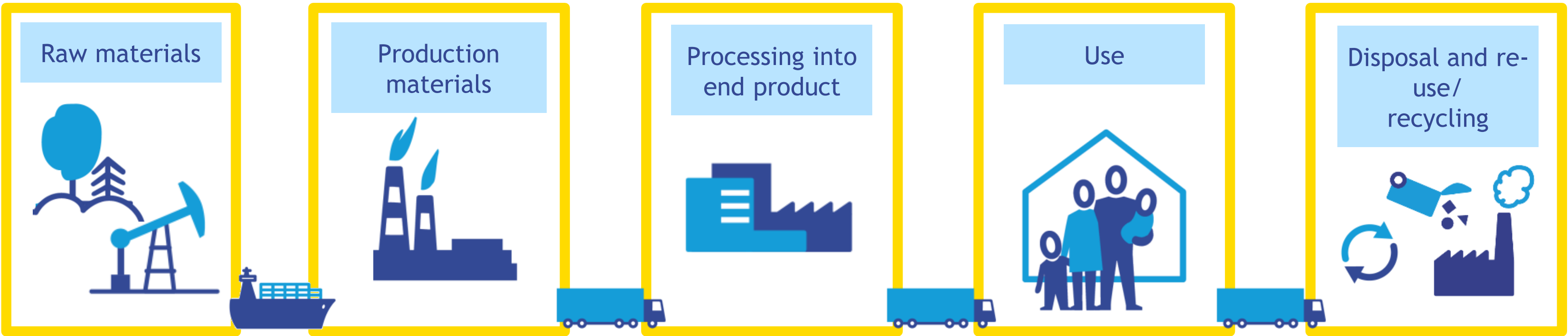
Recent CE Delft studies on circular plastics

- CO_2 reduction with circular plastic, scenario analyses 2030 for Plastic Europe Netherlands and NRK
- Monitoring chemical recycling, ongoing, for the Dutch Min of Environment
- Carbon footprint analyses for Clariter, Ioniqa, Synova, Cure/Cumapol, AkzoNobel, Indorama, Ministries and Rotterdam
- Reviews of LCA studies for Eastman, Shell, BASF
- Chemical recycling in the Dutch Waste policy, for Dutch Ministry of Environment
- Exploratory study on chemical recycling, for Dutch Ministry of Economic Affairs



Current circularity of plastics

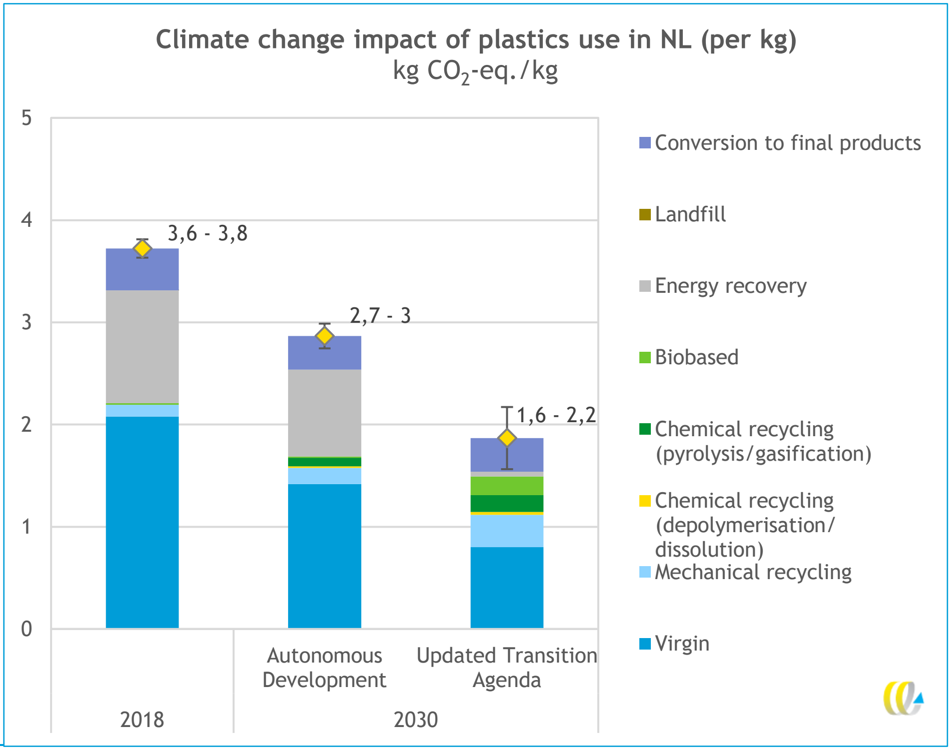
- In total, Dutch consumers use 2 Mton of plastic per year
  - Or: 10kg per person per month
- 40% of plastics are used in packaging. Share for products is growing.
- How is this demand for plastics met?
  - 9% through recycling of discarded plastics
  - 1% with biobased plastics
  - 90% with virgin plastics



Ambitions Dutch government and industry 2030

- The Dutch Transition Agenda Circular Plastics includes targets for 2030 (supported by both industry and government):
  - 40% recyclate in new plastic
  - 15% biobased plastic
  - 2%/yr efficiency improvement (general plastic industry policy)

- CO_2 emissions per kg plastic can be reduced by 50% in 2030 when these ambitions are realized[1]



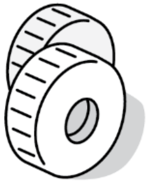
[1] Source: CE Delft, 2021. CO_2 reduction with circular plastics in the Netherlands. https://cedelft.eu/publications/co2-reduction-with-circular-plastics-in-the-netherlands-scenario-analysis-for-2030-and-several-case-studies/

Or should we stop using plastic?

No, in many cases plastics are efficient and reduce CO_2 emissions during the use phase. Examples:

- Food packaging prevents spoilage

- Use of plastic composites in airplanes saves fuel



- Car tyres made from better rubber saves fuel

Important aspects for policies on circular plastics

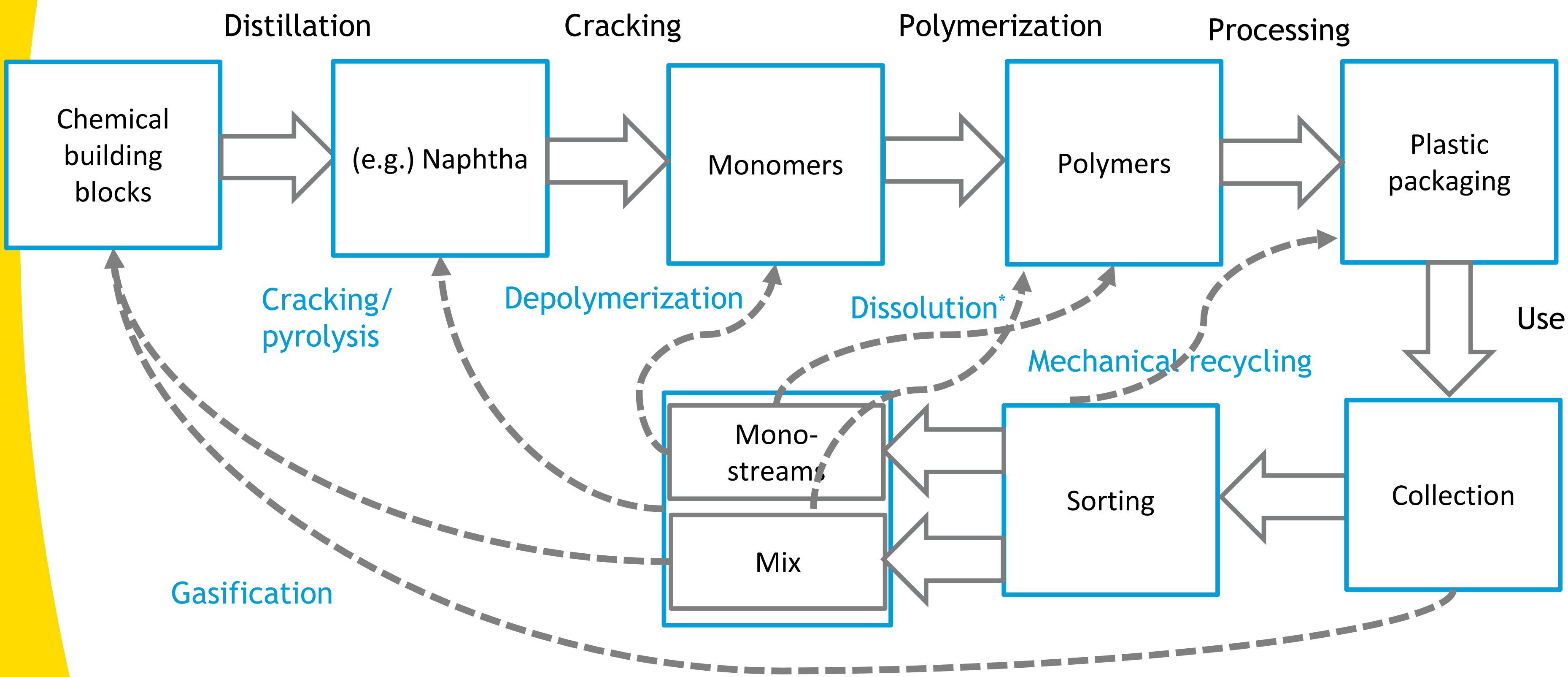
- Maximise the CO_2 reduction per kg of plastic waste
  - Besides littering, climate change is the main issue for plastic

- Aim for the highest plastic-to-plastic yield
  - More and more plastics are used in long-life products (cars, houses) so the amount of plastic waste available is 60% of the amount of new plastic required
  - For circular plastics you need efficient conversion of waste to recyclate

- More technologies for recyclate for food grade plastics (esp. PE and PP)
  - Food brands target recyclate in packaging, but mechanical recycling often does not meet food safety criteria

- A level playing field in the market
  - Stimulate both mechanical and chemical recycling based on CO_2 and yield
  - Don't forget re-use, re-fill and deposit

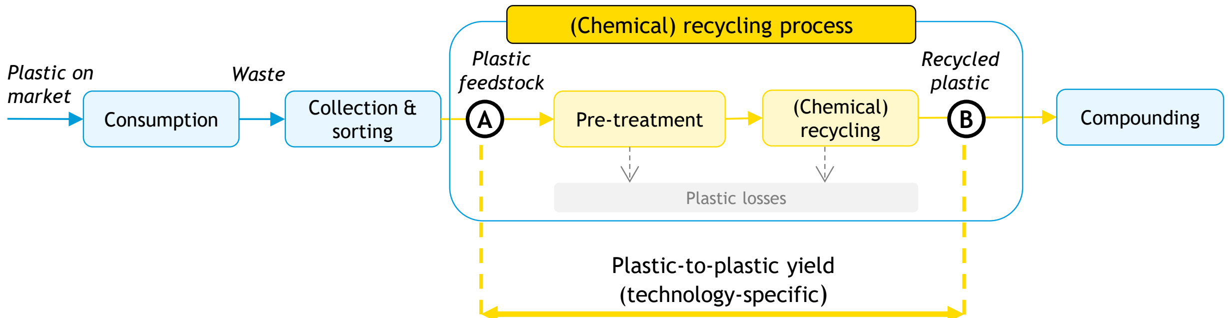
Main types of recycling with different environmental performance



* Dissolution often considered as 'chemical recycling', but the proces is physical so dissolution can also be viewed as a form of physical recycling.

Environmental indicators

- Different indicators and perspectives are used to assess the environmental performance of recycling technologies
  - Note: there is no 'perfect' indicator. A wide ranges of aspects (including different environmental impacts, feedstock flexibility, availability of waste streams, economics, etc.) should be considered when designing circular plastics systems.
- This analysis uses:
  - **Carbon footprint ('waste perspective'):** greenhouse gas emissions associated with treating 1 tonne of plastic waste, including the production of new valuable products
  - **Plastic-to-plastic yield:** amount of new plastic, ready for compounding, that can be produced from 1 tonne plastic in sorted plastic waste

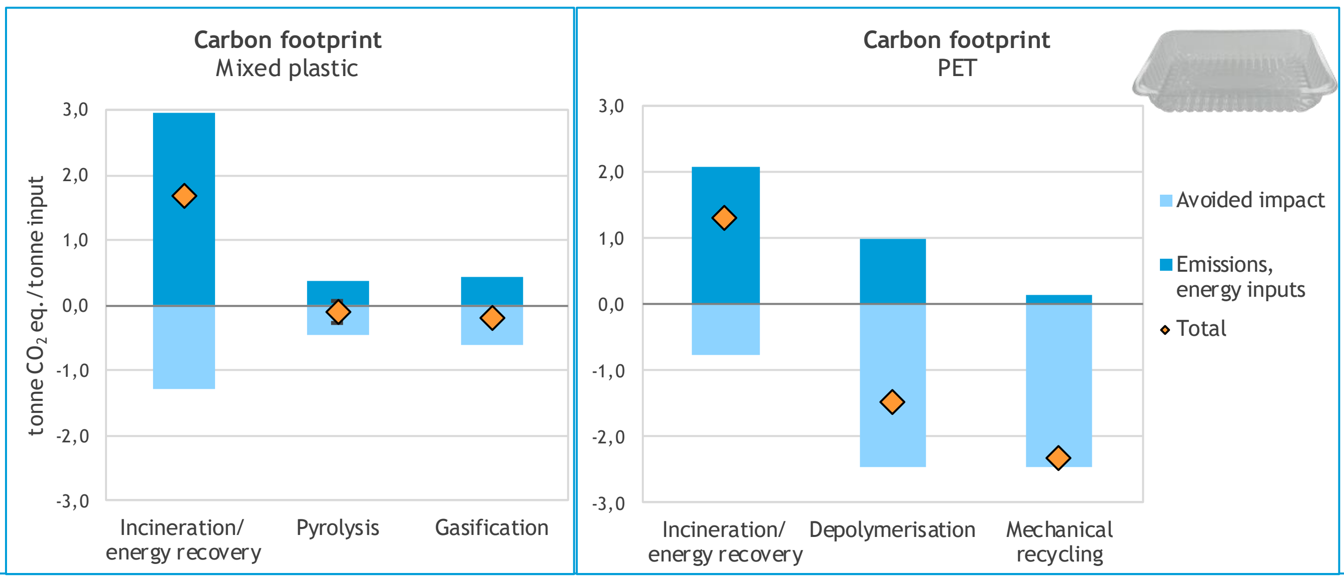


Note that the 'product perspective', i.e. the environmental impact of producing 1 tonne (recycled) plastic, is not used here. In this perspective, recycling processes are sometimes considered responsible for avoiding the incineration of plastic, if a waste stream is diverted from an MSWI. This can benefit processes with low plastic-to-plastic yields.

Carbon footprint of mechanical and chemical recycling (waste perspective)

Compared to incineration with energy recovery:

- GHG reductions of depolymerisation and dissolution are comparable to mechanical recycling
- GHG reductions of pyrolysis and gasification are about half that of mechanical recycling
- GHG reductions depend on energy recovery efficiency of incineration



Note: indicative results from screening LCAs representing environmental performance of technologies in development in the Netherlands. Carbon footprint results depend on specific technology, plastic waste composition and reference technology (e.g. energy recovery efficiency). Please refer to our Exploratory study on chemical recycling for details (CE Delft, 2019).
https://cedelft.eu/publications/exploratory-study-on-chemical-recycling-update-2019/

CO_2 emission reduction per kg of plastic waste

- Data from different studies[#] and different input materials

Recycling technology	CO_2 reduction compared with incineration in an average Dutch MSWI[*] (kg CO_2 per kg plastic waste)
Mechanical recycling	2.5 to 3.5
Dissolution (PS)	Circa 3
Depolymerisation (PET)	Circa 3
Pyrolysis (mix PE and PP)	Circa 1.5

Sources (non-confidential):

- Exploratory study on chemical recycling for details (CE Delft, 2019). https://cedelft.eu/publications/exploratory-study-on-chemical-recycling-update-2019/
- CO2 reduction with circular plastics in the Netherlands https://cedelft.eu/publications/co2-reduction-with-circular-plastics-in-the-netherlands-scenario-analysis-for-2030-and-several-case-studies/
- Summary of Ioniqa LCA. Screening carbon footprint analysis https://cedelft.eu/publications/summary-of-ioniqa-lca-screening-carbon-footprint-analysis/

* MSWI= Muncipal Solid Waste Incinerator

Plastic-to-plastic yields (efficiency)

- Target of 40% recyclate in new plastics implies that 97% of all waste plastics should be recycled in 2030[1]
- This means that plastic waste will become scarce: yield is important.

- Plastic-to-plastic yields from recent studies (different plastic waste input)

Technology	Input	Average plastic-to-plastic yield
Mechanical recycling	Monomaterial streams	95-100%
Dissolution	PS, PE, PP	100%
Depolymerisation	PET	95-100%
Pyrolysis	DKR350/DKR310	~50% (with mass balance allowed)

- Strong correlation between yield and CO_2 reduction per kg of waste

[1] Source: CE Delft, 2021. CO_2 reduction with circular plastics in the Netherlands. https://cedelft.eu/publications/co2-reduction-with-circular-plastics-in-the-netherlands-scenario-analysis-for-2030-and-several-case-studies/

Mass balance discussions

- Mechanical recycling, dissolution and depolymerisation (shorter recycling loops) can directly produce recycled plastics
  - One plastic product output
  - Recycled content can be traced easily
- Pyrolysis and gasification (longer recycling loops) produce recycled basic chemicals which are blended with virgin basic chemicals
  - Basic chemical sites produce a range of outputs (plastics, fuels, other chemicals)
  - Recycled content is difficult to physically trace
- **Mass balancing** is a bookkeeping method to keep track of recycled content when they are blended with non-recycled materials. In addition, it can be used to allocate recycled content to specific outputs.
  - For example, mass balancing may allow attributing recycled content from non-plastic output to plastic outputs, where there can be more market demand

Mass balance methods

Three main mass balance options have been suggested:

- **Free allocation**: Recycled content in all outputs (materials and fuels) can be freely allocated (except losses)
- **Fuels exempt**: Recycled content in all non-fuel outputs can be freely allocated (except losses)
- **Technical balance**: Recycled content is determined based on the amount theoretically present in the output product. All products receive a proportional share of the recycled content in the inputs.

Policy discussions on which form of mass balancing should be permitted are ongoing.

Regardless of the option selected, double counting of recycled content should be avoided and recycled content claims should be clearly indicated to avoid misleading consumers.

Free allocation mass balancing

- Attractive for pyrolysis/gasification developers, (most freedom):
  - Recycled content can be shifted e.g. from fuels to plastics if this is economically attractive
  - Prevents the allocation of recycled content to product categories (e.g. solvents) where there is no demand for recycled content

- Criticisms (e.g. by NGOs):
  - Greenwashing: selling products with minimal physical amount of recycled content as '100% recycled'
  - Creates a 'circularity mismatch':
    - Recycled content may be administratively present in the economy, but have physically been burnt for energy purposes
    - If all plastics from steam cracking are made 100% recycled with free allocation, crude oil inputs would still be required to produce them

Fuels exempt mass balancing

- Balance between very strict and very lenient rules:
  - Allows shifting recycled content from non-plastic products (e.g. solvents) to plastics
  - Does not allow allocating recycled content from fuel products to plastic outputs
- Recycled content that is physically removed from the economy (as fuels and process losses) is also administratively removed; less confusing for consumers
- Less freedom for technology developers, could affect economic viability of some routes
- Plastic-to-plastic yields of technologies derived using fuels exempt mass balancing correlate with carbon footprint results

Quality / recycle for all purposes

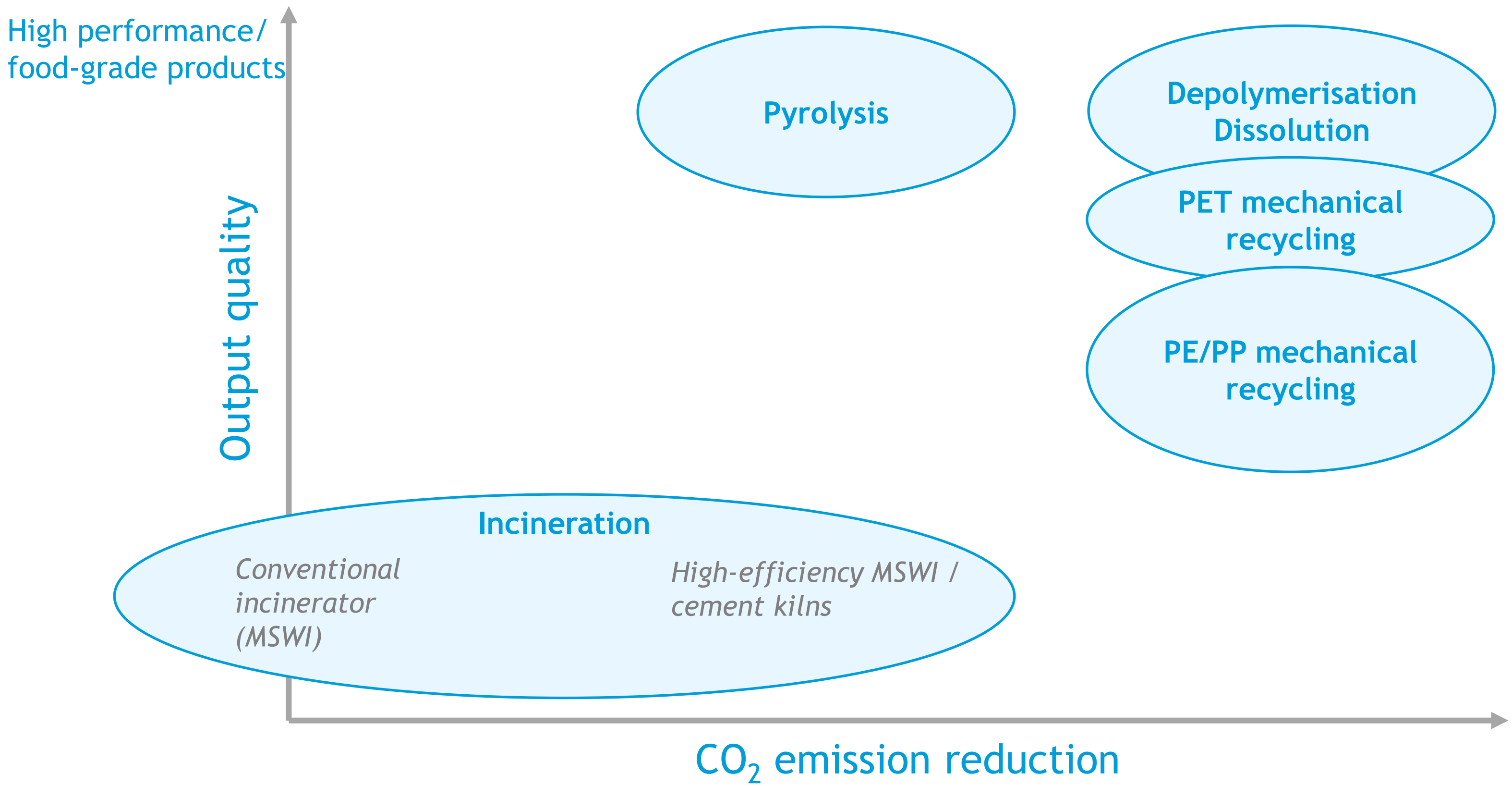
- The quality of mechanically recycled plastic varies
  - Most PE/PP is not applicable in food applications again
  - In some cases recycling of additives leads to problems
  - PET can in some cases be recycled for food applications

- Dissolution, depolymerisation and pyrolysis: Same quality as virgin

Combination CO_2 reduction and quality

	No CO_2 reduction	Medium CO_2 reduction	High CO2 reduction
Always applicable	MSWI (incinerator)	Cement kiln High efficiency MSWI	
Applicability non-food purposes			PE/PP mechanical recycling
Applicable for food and high performance purposes		Pyrolysis	Depolymerisation Dissolution PET mechanical recycling

Combination CO_2 reduction and quality

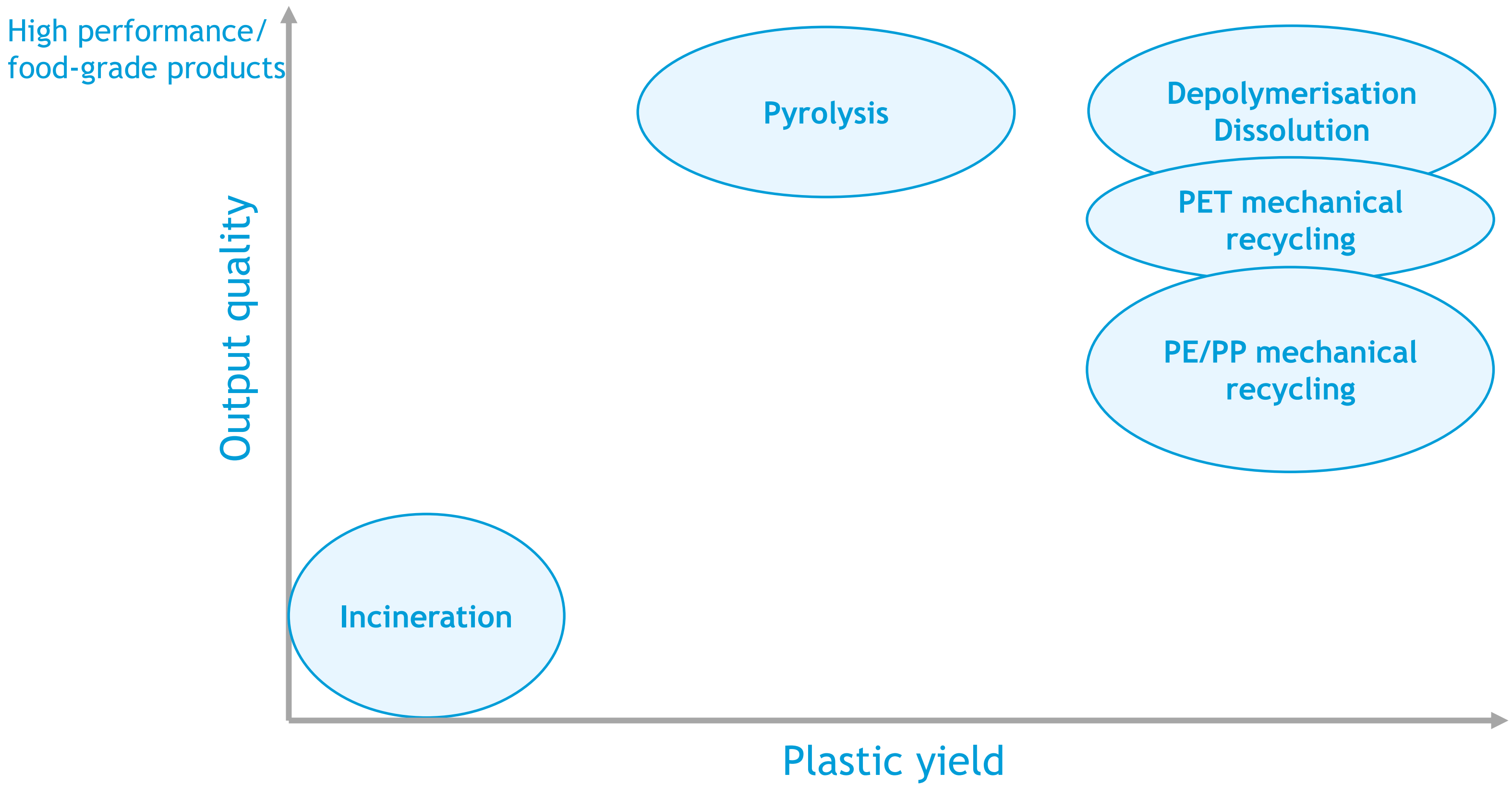


Combination plastic yield and quality

	Low yield	Medium yield	High yield
Applicability non-food purposes			PE/PP mechanical recycling
Applicable for food and high performance purposes	Pyrolysis (if mass balance is not accepted)	Pyrolysis (if mass balance allocation is accepted)	Depolymerisation (PET) Dissolution (PS, PE and PP) PET mechanical recycling

Combination plastic yield and quality

(With fuels exempt mass balancing for pyrolysis)



Chemical recycling in Dutch Waste law

Dutch waste law: LAP3: Landelijk Afvalbeheer Plan 2017-2029 na 2e wijziging

- Recycling is preferred above energy use of waste
- Two qualities of recycling (C1 preferred above C2)
  - C1 recycling for the same purpose as the first product or to another purpose with the same quality. This is part of mechanical recycling, dissolution and depolymerization (monomer chemical recycling).
  - C2 feedstock chemical recycling or mechanical recycling to a lower quality purpose. This is pyrolysis, gasification and mixed plastic use in thick building materials.

Dissolution (PS, PE, PP) or depolymerization (PET) or mechanical recycling (all plastics) are the preferred waste treatment options for plastic.

Recommendations 1: Recyclate supply

- As long as there is a growing use of plastic in long-life products, there is not enough plastic waste for a recyclate percentage higher than 30%.
  - Focus on technologies with high yield helps (depolymerization, dissolution and mechanical recycling)
  - More bio-based (e.g. up to 25%) could supplement this.

- If the plans go ahead for stimulating the use of plastic waste in fuel for airplanes and vehicles (SAF/RED), then more recycling will become increasingly difficult. Bring stimulus for product and energy in balance.

Recommendations 2: The role of government

- In order to realise the Transition Agenda, more regulation is required from the government.
  - E.g. manufacturer responsibility (collecting for recycling) for all applications of plastic (including design for recycling)
  - E.g. an obligation for an amount of recyclate and bio-based in new plastic
  - E.g. a focus on technologies with higher yield and CO_2 reduction (depolymerization, dissolution and mechanical recycling)

- Very interesting: In the Transition Agenda and other action plans, the plastics sector is indirectly asking for more government regulation.

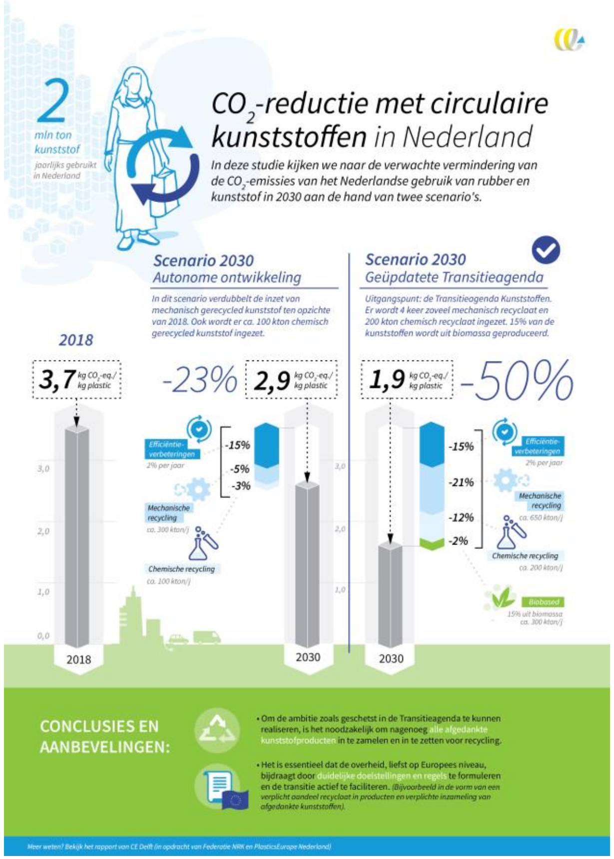
- A stimulating policy for plastic recycling is best carried out at a European level.

Conclusions

- Today plastic is a very linear material
- The Transition Agenda Circular Plastic 2030 is ambitious
- The CO_2 emissions per kg of plastic can be reduced by 50%
- We need all plastic waste for recycling to reach the targeted 40% recyclate in new plastics
- Technologies with high CO_2 reduction and high plastic-to-plastic yield have to be preferred:
  - Mechanical recycling,
  - Depolymerisation of PET and
  - Dissolution of PS, PE and PP

More information

- Contact Geert Bergsma: bergsma@ce.nl



- CO_2 reduction with circular plastics in the Netherlands
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- Exploratory study on chemical recycling
  https://www.cedelft.eu/en/publications/2173/exploratory-study-on-chemical-recycling
- CE Delft's department on raw material supply chains
  https://www.cedelft.eu/en/raw-material-chains