Sustainable industrial carbon cycles. A regional perspective.

Webinar

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Why did we pursue this study?

1. The province of South Holland is home to the largest port in Europe, including most of the petrochemical industry and greenhouse horticulture in the Netherlands.
2. Climate change urges the need for (this type of) industry to use alternative sources of carbon.
3. There is a need for science-based decision making:
   Which sustainable industrial carbon cycles have the biggest potential in terms of emission reduction and the transition towards a sustainable economy, and should thus be supported by regional authorities?

What research did we deliver?

Article 1: January 2022

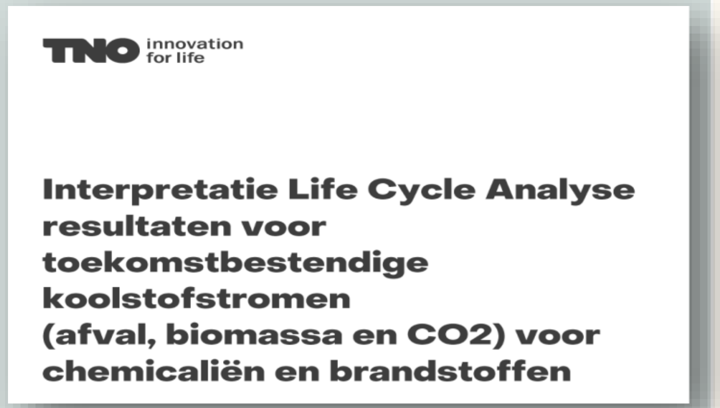
LCA of CCU product chains and policy recommendations for the province of South Holland

Article 2: July 2023

Sustainable carbon cycles. A regional perspective for the province of South Holland

Article 3: September 2023

Interpretation of LCA results for sustainable carbon cycles (waste, biomass and CO2) for fuels and chemicals



DISCLAIMER

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Introduction of the team

Petrus Postma (&flux) - Host

Nicole van Klaveren (&flux) - Moderator

Edwin Perdijk (PzH) - Moderator

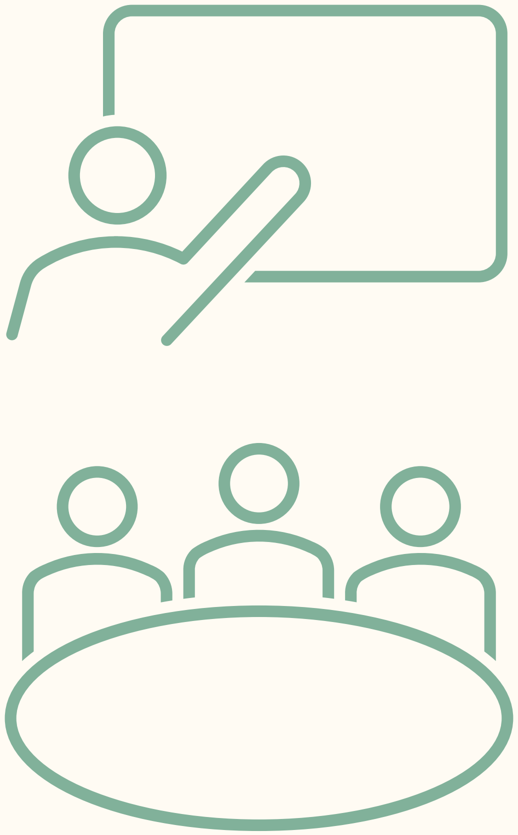
Geert Bergsma (CE Delft) - Expert

Yvette Veninga (TNO) - Expert

Rajat Bharadwaj (Power2X) - Expert

Topics

1. Research scope and methodology
2. Results and Q&A per product chain
    - Plastics
    - Fuels
    - Chemicals
3. Recommendations and call to action



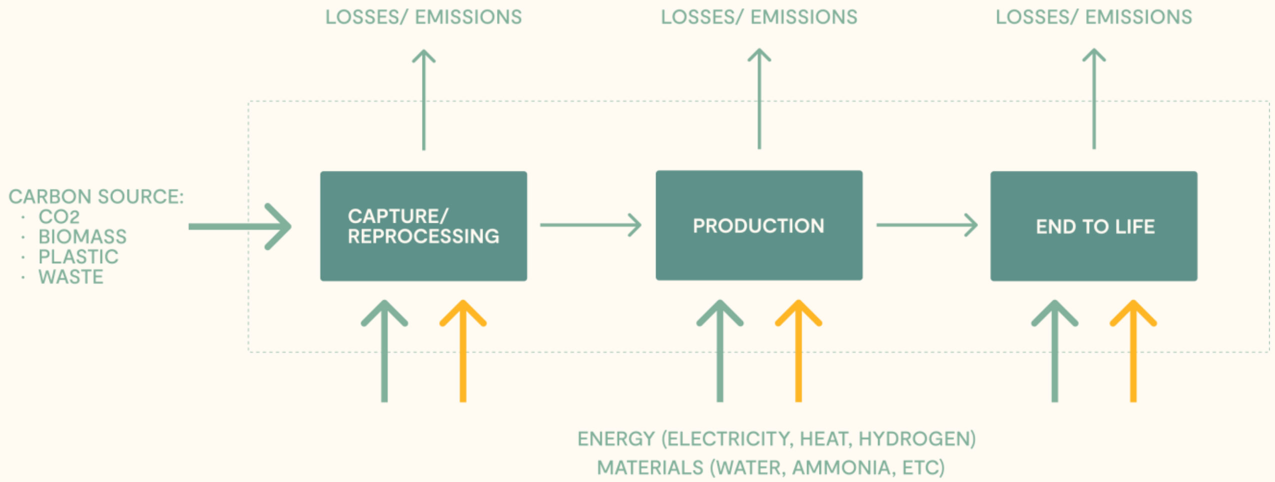
Presentation of research per product chain

- Key results
- General interpretation
- Scenario based long term outlook
- Policy analysis
- Expert reflection Q&A

Research scope and methodology

What methodology did we use?

System boundaries



Climate impact

- IPCC: only CO_2-equivalent emissions determine the methodology for Global Warming Potentials over a 100-year time horizon
- Reference is the *current case* fossil carbon source
- Functional unit: CO_2 eq. p kg product
- A mix of both literature and company data (e.g. Obbotec)
- Calculations based on utility inputs for the current case and for a future renewable case

Which cases did we calculate?

Objective of these cases is to show a band width of the CO_2-eq. emissions of a value chain: Current fossil based emissions versus the green option of future renewables.

Cases	Electricity	Heat	Hydrogen	End-of-life
Current	Current mix	Natural gas	Grey	Plastics and chemicals: incineration with energy recovery Fuels: emissions
Future renewables	Renewables	Biogenic	Green	Plastics and chemicals: maximum recycling Fuels: emissions

- Absolute perspective: quantification of net emissions
- Total CO_2 emissions across the entire product chain. No distinction made between scope 1,2,and 3

How did we select the product chains?

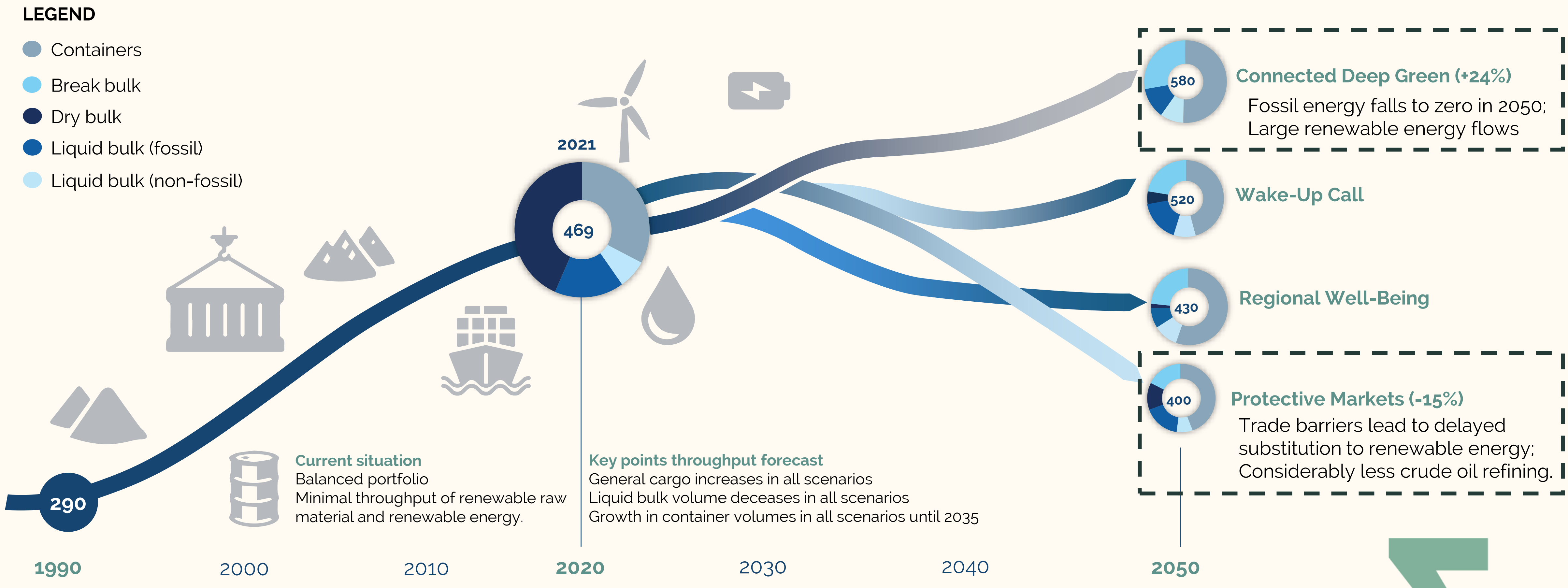
Plastics	
PE	Used for packaging (i.e. foils), cables and tubes
PP	Used in electronics, automotive, and vials
PET	Used for bottles, trays, and textiles
PLA	New type of bioplastic suited to replace PS plastic. After BioPE and BioPET the most widely used in the market

Fuels	
MeOH	Methanol, expected to become an important maritime fuel in the future
Kerosine	Aviation fuel
Methane	Various (industrial) applications for high temperature heating
Ethanol	Feedstock for aviation fuels
DME	Fuel to replace propane in LPG or diesel

Chemicals	
MeOH	Methanol, basic raw material for several chemicals, including plastics
Nafta	Raw material for plastics
Ethanol	Solvent, potential raw material for proteins
BTX	Intermediate product for plastics and solvents
Ethylene	Raw material for plastics

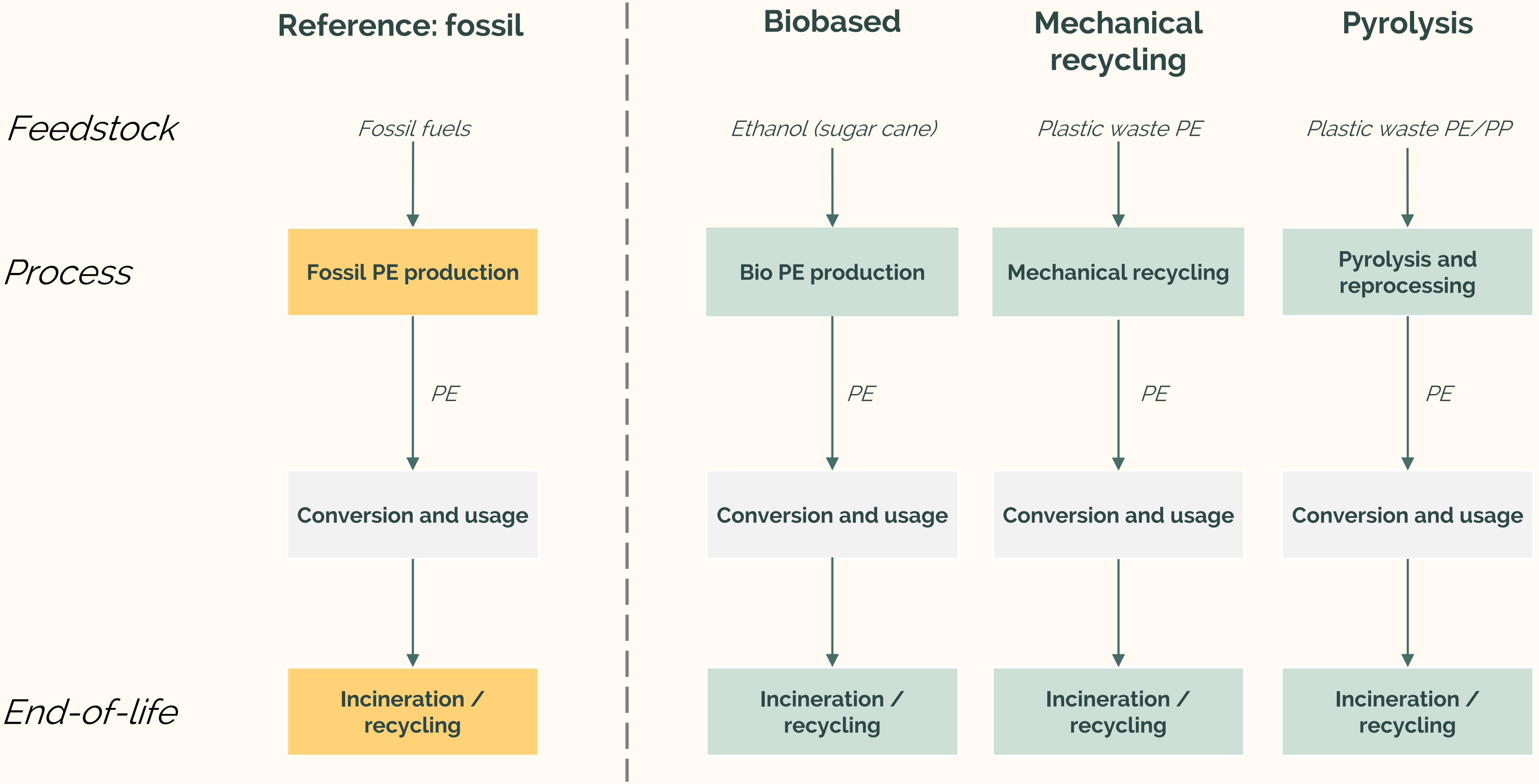
The methodology of future outlook is based on 4 different scenarios investigated by the POR which results in 4 different flows for 2050[1]

Throughput per Scenario towards 2050, in Millions of Tonnes



1. PoR – link 1 & link 2

Example PE (LCA): 3 alternative routes vs. fossil



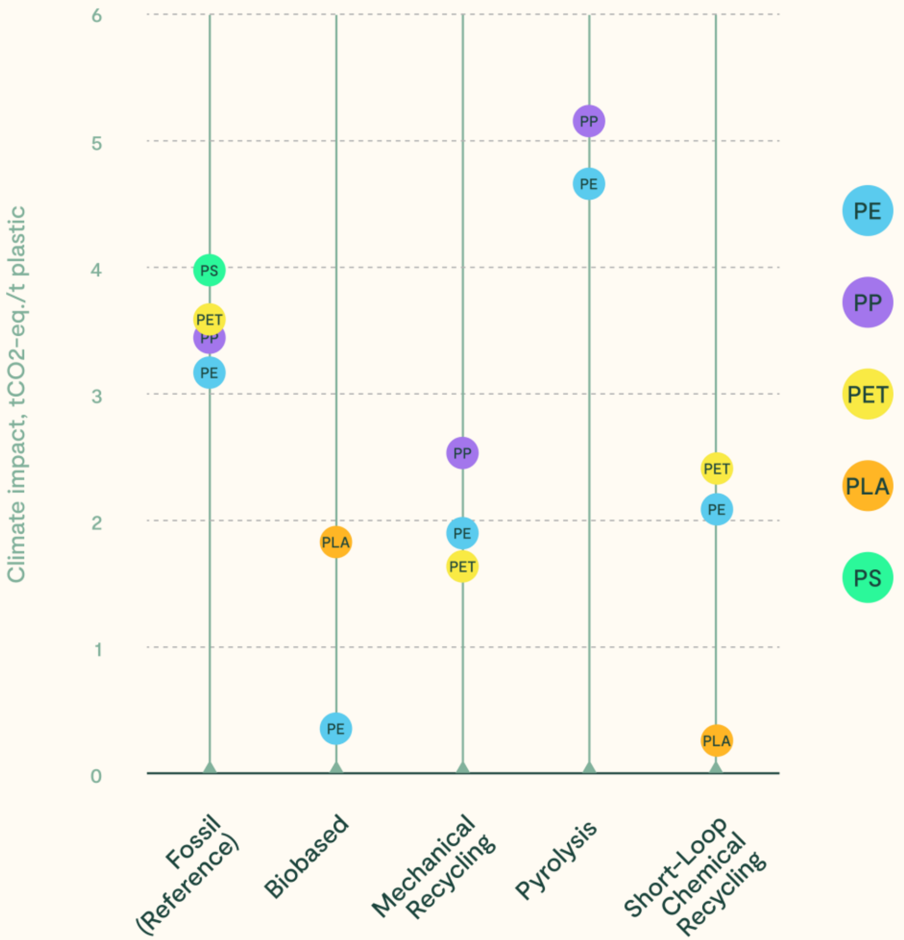
Results for plastics

Plastics – LCA value chains (10)

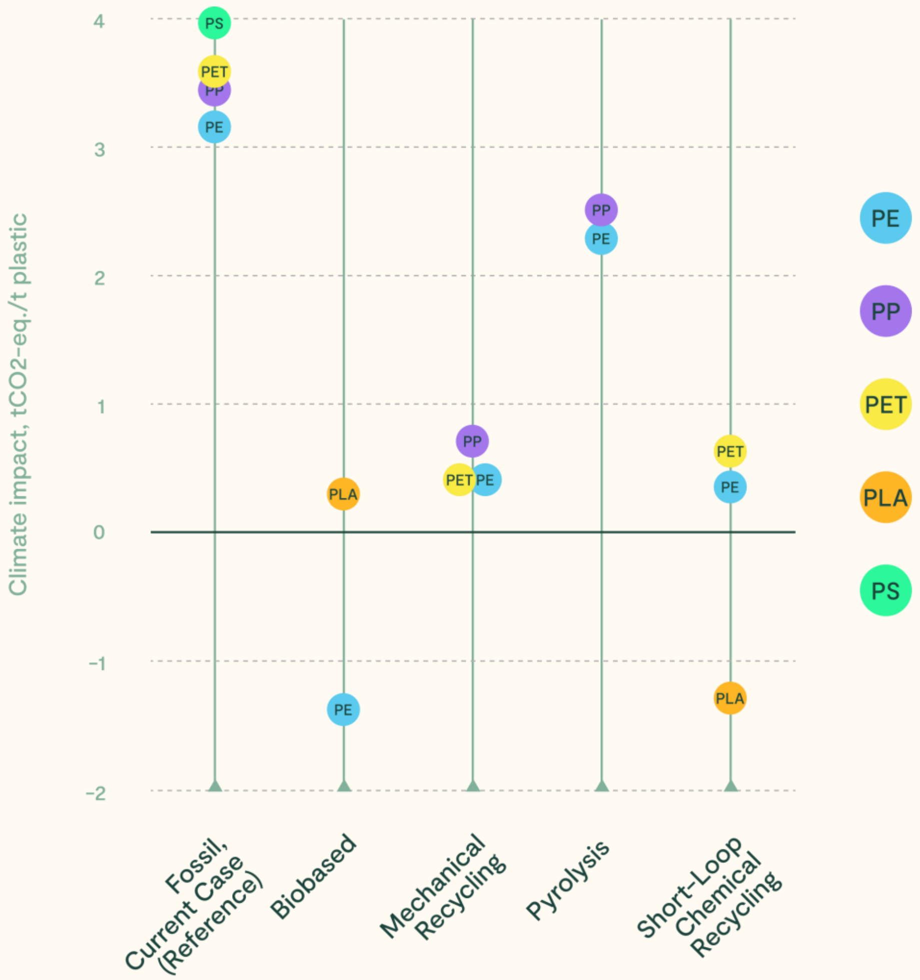
	PE				PP		PET		PLA	
Feedstock	Plastic waste PE	Plastic waste PE/PP	Ethanol (sugar cane)	Plastic waste PE	Plastic waste PP	Plastic waste PP/PE	Plastic waste PET	Plastic waste PET	Sugar	Plastic waste PLA
Process	Mechanical recycling	Pyrolysis & reprocessing	Bio PE production	Dissolution	Mechanical recycling	Pyrolysis	Mechanical recycling	Depoly-merisation	PLA-production	Depoly-merisation
Product	PE				PP		PET		PLA	

Climate impact results for plastics
(ton CO2-eq./t plastic)

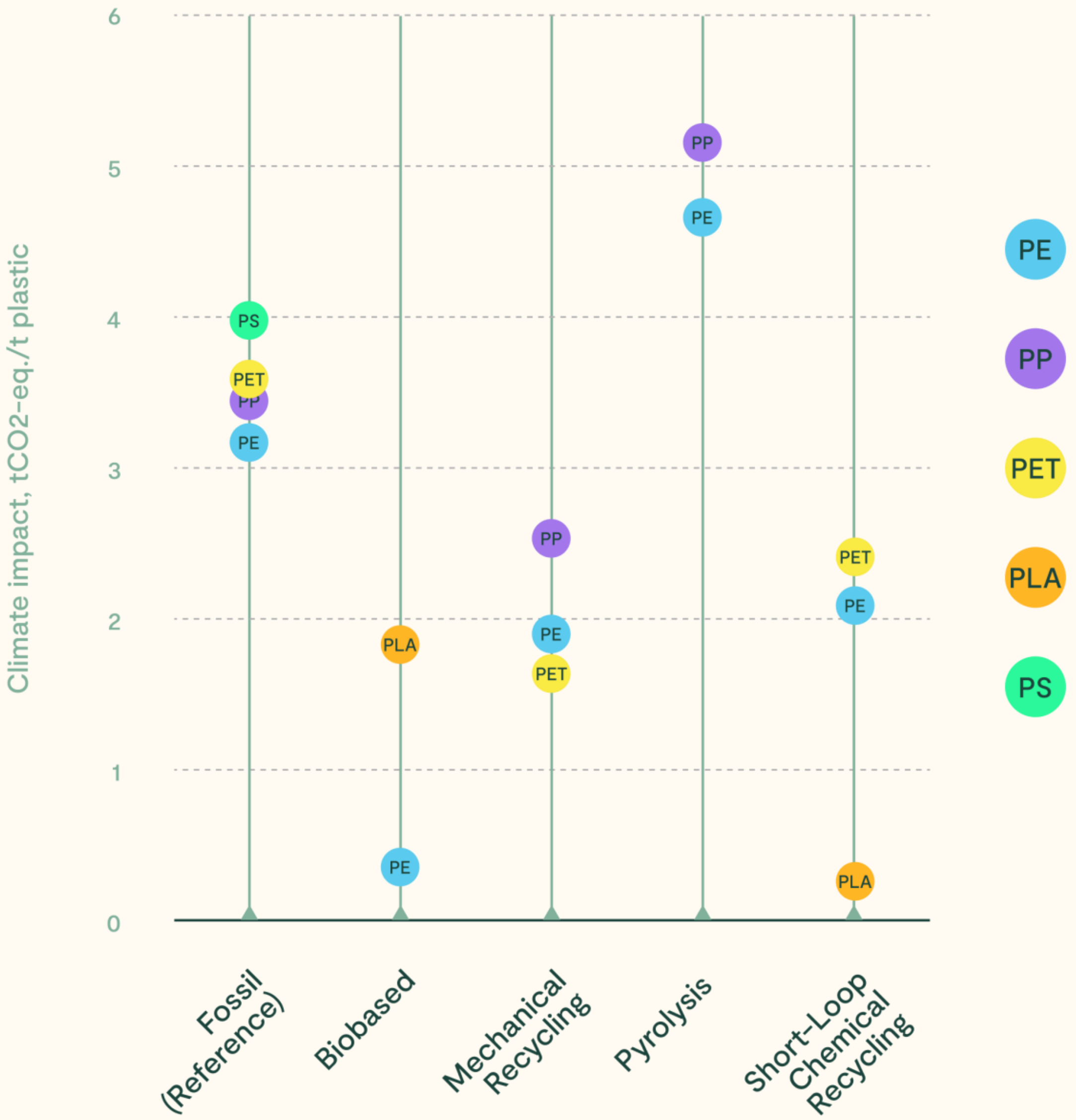
Current case



Future renewable case



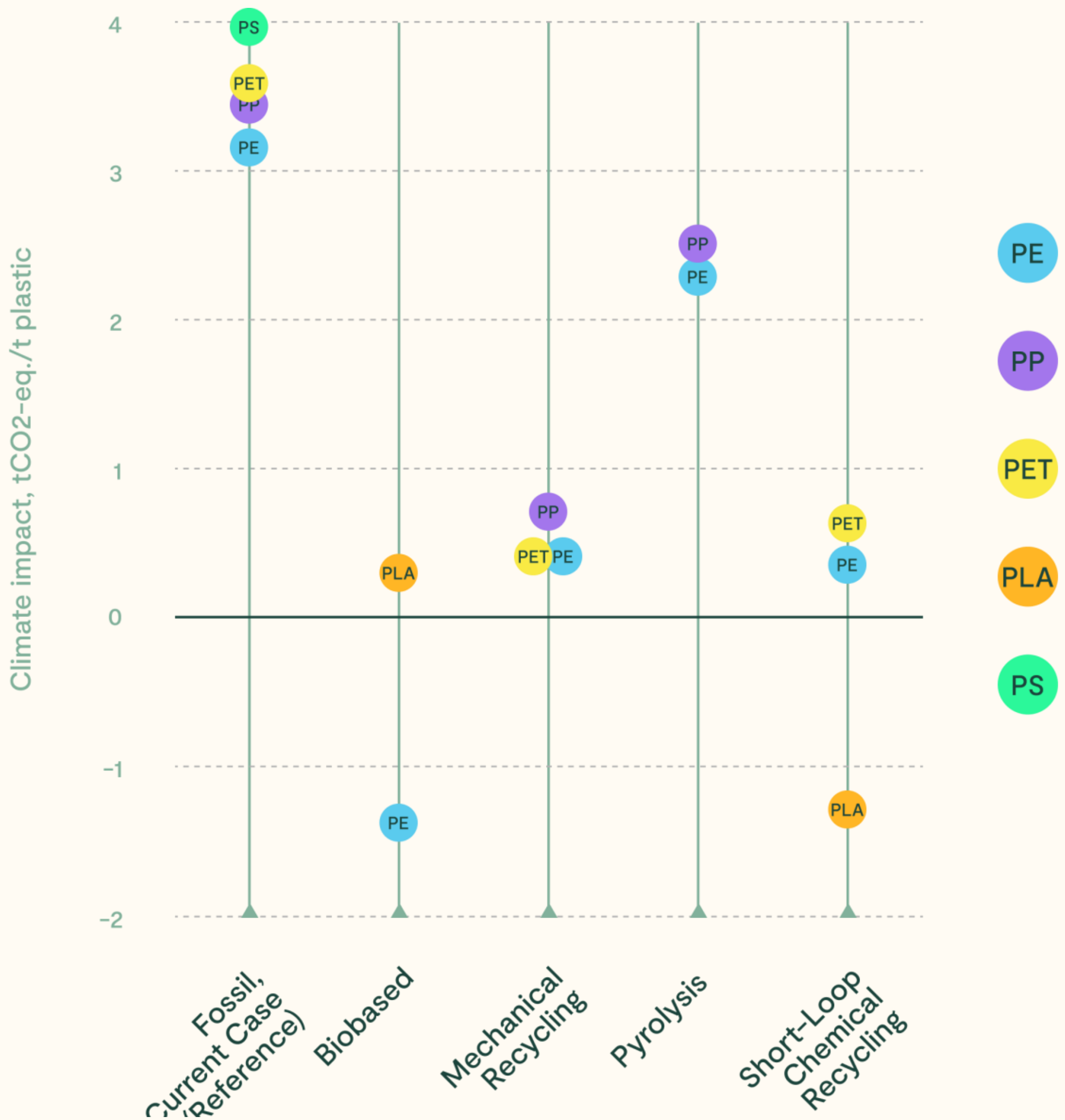
Plastics key results – current case



- PE: biobased, mechanical recycling, and dissolution (i.e. Obbotec) all perform well in achieving CO2 emission reductions
- PP: mechanical recycling is the most interesting technology for emission reduction
- PET: mechanical recycling and depolymerisation are both interesting technologies for emission reduction
- PLA: Biobased and short-loop chemical recycling are interesting options to reduce emissions
- Pyrolysis has higher emissions than fossil because prevention of incineration is not included in this analysis.

If prevention of incineration is included, the performance of pyrolysis will improve with 3 kg CO2. Mechanical and short-loop chemical recycling technologies will also have a better performance of 1,5 kg CO2

Plastics key results – future renewable case



Adjustments compared to current case

- Process energy is based on renewable energy sources (electricity, heat, and hydrogen)
- 90% recycling End-of-life

Findings

- All routes in the renewable case perform better than in the current case
- Pyrolysis has a lower climate impact than current fossil-based plastics
- Biobased sometimes even has a negative climate impact score because CO2 is absorbed and not emitted at the end-of-life phase

Plastics – General interpretation

- Non-circular fossil-based plastics produce a CO_2-eq emission of 3 to 4 kg CO_2 / kg plastic
- Some biobased plastics (i.e. bio PE and bio PLA) can lower the CO_2 emission with 50% up to 90%
- Mechanical recycling can lower the CO_2 emissions for a part of the plastic waste with 30% up to 50%

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Plastics – General interpretation (continued)

- Short-loop chemical recycling (dissolution or depolymerisation) performs the same as mechanical recycling
- Long-loop chemical recycling options like pyrolysis lead to more CO_2 emissions if no extra waste is turned away from incineration. In the short term some long-loop chemical recycling may be interesting, however in the long run this becomes less interesting
- With an increasing renewable energy capacity, the CO_2 emissions between the options will decrease, yet the sequence stays the same. Except for mechanical recycling

Note: The Obbotec dissolution technology was analysed for this study. All chemical recycling routes are still being developed

Plastics – Scenario based long term outlook

- Demand for plastics in the future is rather certain
- The flow of renewable and circular plastics are expected to increase in all cases
- An increase of demand (24%) is estimated for connected deep green scenario[1], based on overall flows in the port, all of which is renewable
- Slight decrease in demand (-15%) is estimated for protective market scenario[1], based on overall flows in the port. Of which
  - Renewable/ circular flows is estimated to be ~60%
  - And fossil based are estimated to be ~40%

  based on the same ratio of non-fossil flows and fossil flows in described in the methodology slide of scenarios[1]

1. PoR – link 1 & link 2

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Plastics – Policy analysis

Key policy developments

- EU taxation for plastic under discussion (800 euro/ton, CO_2 tax, incineration tax, etc.)

- Extra EU targets for plastic packaging (recycling and recycled content)

- The Dutch government announced a mandatory recycled content target of 25% biobased or circular plastics in 2027 and 30% in 2030

- Feedstock competition: plastics for recycling or plastics for energy (E.g. Aviation fuel)

Plastics – Policy analysis

Other policy issues influencing circular plastics

EU

- Inclusion of the chemical industry in EU ETS and CBAM
- European discussion on mass balancing for chemical recycling

The Netherlands

- Extension of the SDE++ subsidy with circular categories
- Target for municipalities of 30 kg non recycled waste (VANG)

To seize the opportunities stimulated by public policies, the the supply of feedstock plastics for recycling should increase. As well as more biobased in origin, however this is currently less stimulated by policy.

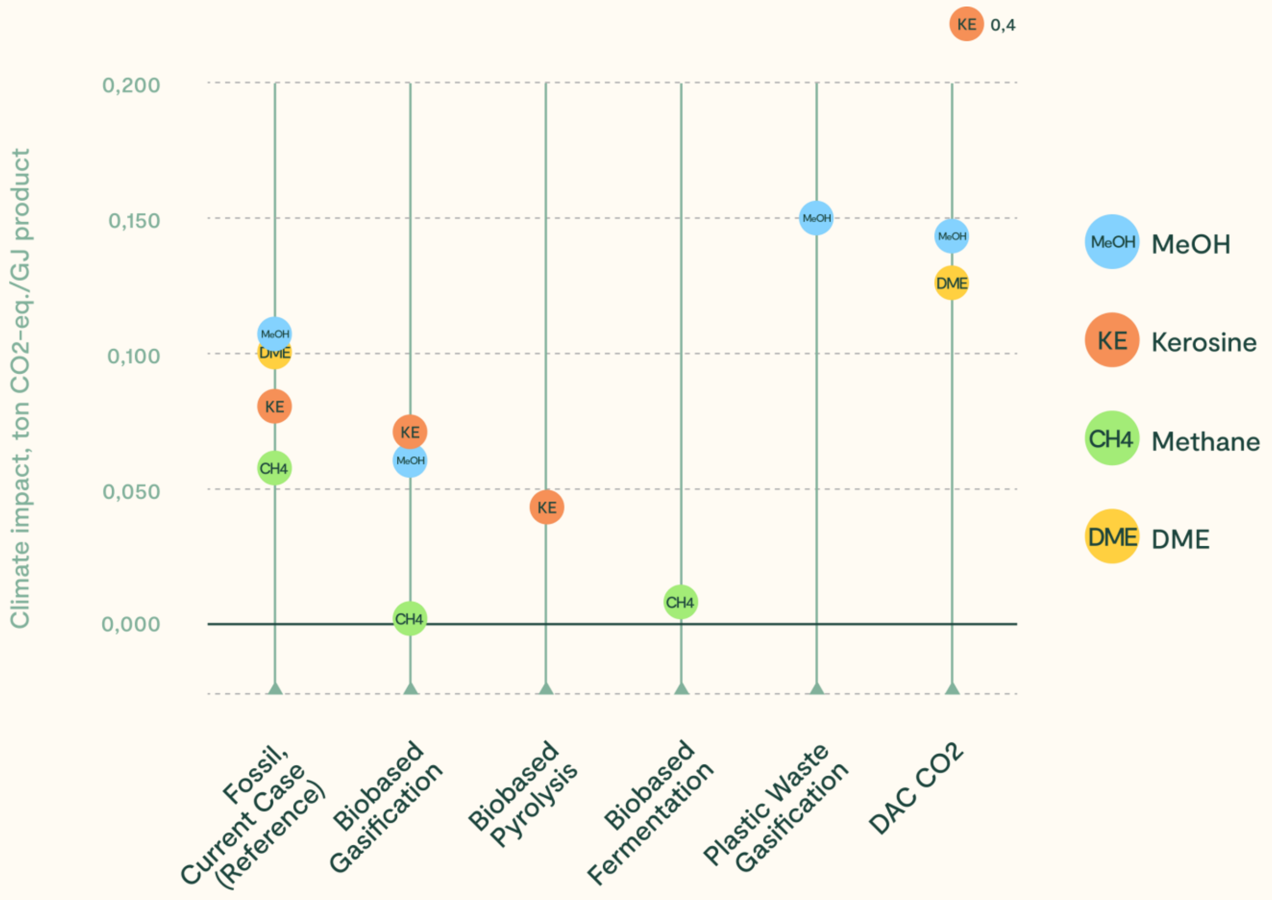
Plastics – Expert reflection Q&A

Results for fuels

Fuels LCA value chains (9)

	MeOH			Kerosine			Methane		DME
Feedstock	Primary biomass	Plastic waste	CO_2	Biomass - general		CO_2	Biomass low-quality	Sewage sludge	CO_2
Process	Gasification (via syngas)	Gasification (via syngas)	CCU	Gasification & Fischer Tropsch	Pyrolysis	CCU	Biodigester	Gasification	CCU
Product	MeOH			Kerosine			Methane		DME

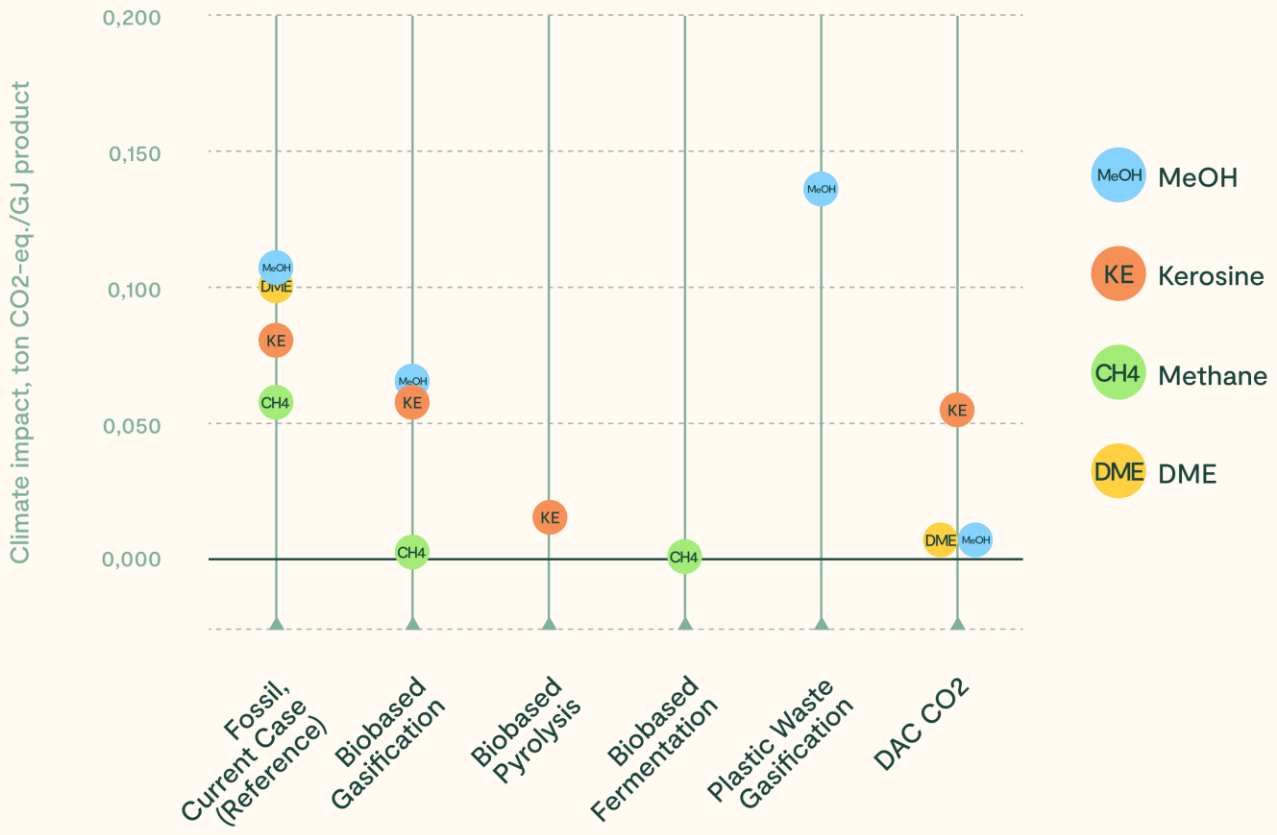
Fuels key results - current case
(ton CO2-eq./GJ product)



Current case

- Methanol: biomass gasification reduces the climate impact by 40%
- Kerosine: Pyrolysis of biomass reduces climate impact by 40%
- Methane: both biomass gasification or fermentation reduce the CO2-eq. emissions significantly (~90%).
- DME: CO2 conversion has a larger climate impact than the fossil reference case

Fuels key results – future renewable case
(ton CO2-eq./GJ product)



Future renewable case

- Methanol: CO2 conversion becomes most favorable (~90% reduction), under the assumption that sufficient green energy is available. Biomass gasification also reduces the climate impact (~40%)
- Kerosine: Pyrolysis of biomass has the lowest impact (~75% less)
- Methane: both biomass gasification or fermentation perform very well on CO2-eq. emission reduction.
- DME: Climate impact can be reduced by 90%, under the assumption that sufficient green energy is available.

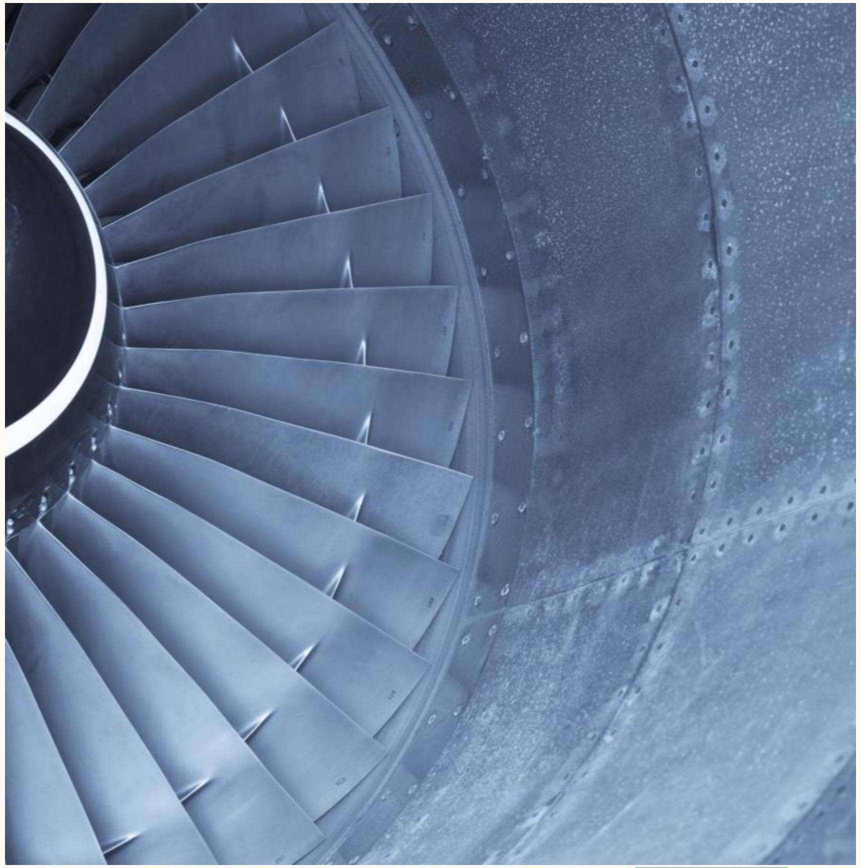
Fuels – General interpretation

- Using biomass as feedstock for fuels already reduces the climate impact with ~40% for the current case
- Also for the future, biomass is a favorable feedstock for fuels to reduce CO_2 emissions
- Renewable energy will have limited availability and an economic impact, especially for the value chains with CO_2 as feedstock
- Fuels will have a (reduced) climate impact in the future. This will depend on the type of fuel and value chain (reduction 40-90%)

Fuels – Scenario based long term outlook

In all scenarios the volume of liquid bulk decreases[1] - the extent to which depends on the pace of the energy transition determined by scenarios[1]

- For the protective market scenario, demand follows overall flow in the region (-15%) and the total demand of renewable fuels is driven by regulations
  a) For aviation – ReFuelEU[2] aviation proposes >63% SAF in EU aviation fuel mix in 2050
  b) For Maritime: the share is derived from FuelEU Maritime[2] which prescribes an 80% Carbon Intensity reduction by 2050 in annual energy consumption
- For connected deep green[1] scenario, demand follows overall flow in the region (24%) for both maritime and aviation fuels which are totally renewable



1. PoR – link,, 2. EU Commission | ReFuelEU aviation proposal – link, EU Commission | FuelEU Martime – link
Notes: For Aviation: Regulations not yet adopted, mandatory minimum targets for 2050 differ between 63% (proposed by EU Commission and Council) and 85% (proposed by Parliament) for the share of SAF in the total aviation fuel mix; For Maritime: Adopted regulations state that in 2050 the carbon intensity of energy used in shipping will be -80% compared to 2020

Fuels – Policy analysis

- Policy, mandates and the ambition of Europe to become self sufficient will have a strong influence on the market for sustainable fuels.

- European and Dutch policy for biofuels has been developing since 2003. The goal of policy implementation is to reduce CO2 emissions by using more renewable energy as a feedstock.

- EU Taxonomy is the main driver of increasing demand from industry for renewable energy and Renewable Fuels of Non-Biological Origin (RFNBO).
  a) Renewable Energy Directive III
  b) Alternative Fuel Infrastructure Regulation,
  c) REFuelEU Aviation including Sustainable Aviation Fuels and FuelEU Maritime
  d) Mandatory adoption of biogas by households.

Fuels – Expert reflection Q&A

Results for chemicals

Chemicals – LCA value chains (8)

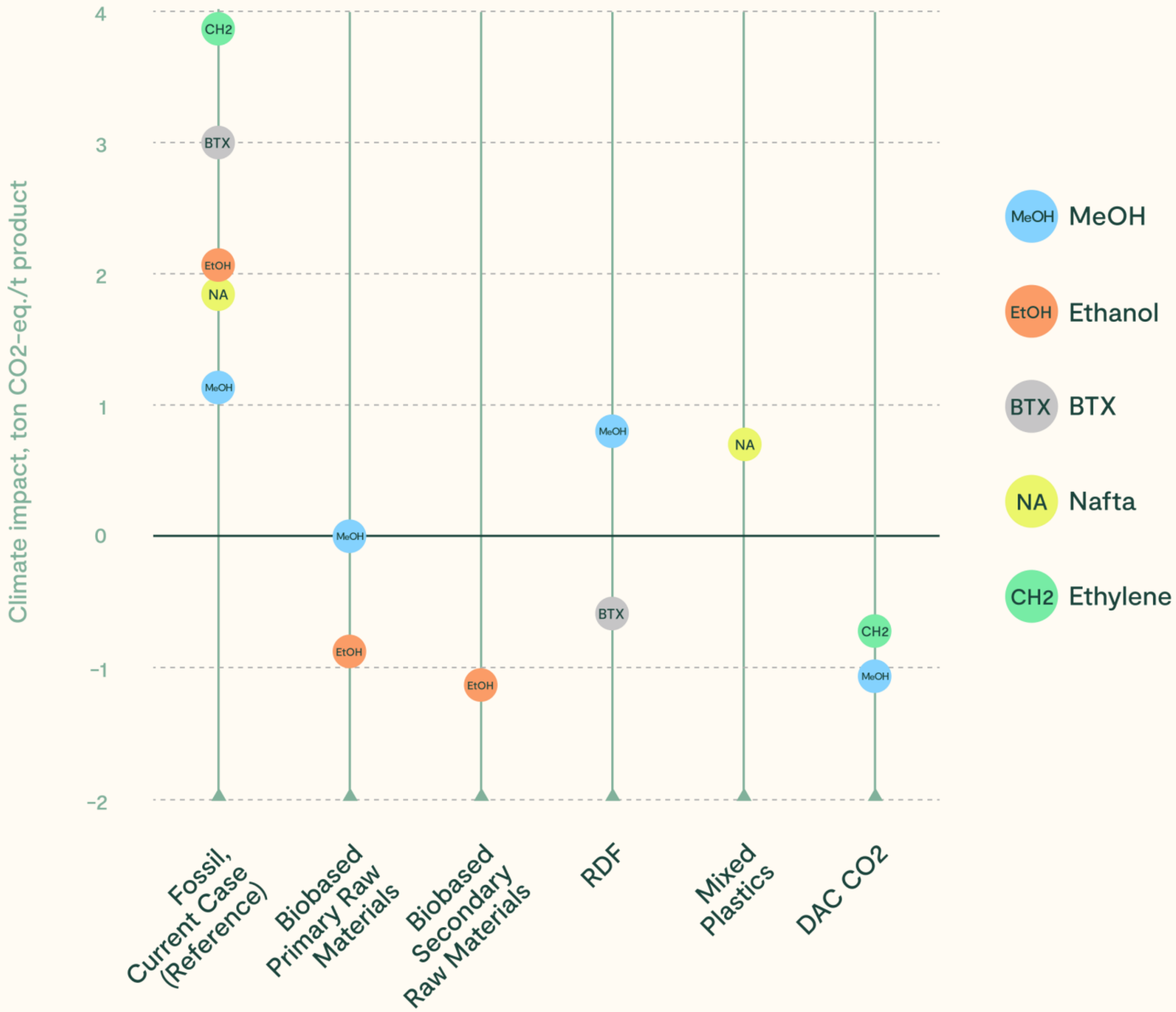
	MeOH			Nafta	Ethanol		BTX	Ethylene
Feedstock	Primary biomass	Plastic waste (RDF)	CO_2	Plastic waste	Biomass - corn	Secundary biomass - Ligno-cellulose	Plastic waste (RDF)	CO_2
Process	Gasification (via syngas)	Gasification (via syngas)	CCU	Pyrolysis & reprocessing	Fermentation & Distillation	Fermentation & Distillation	High temperature pyrolysis	CCU
Product	MeOH			Nafta	BioEtOH		BTX	Ethylene

Chemicals key results – current case

Current Case

- Methanol: Gasification of biomass reduces climate impact by 60%
- Ethanol: Fermentation of secondary biomass has a negative climate impact
- BTX: Climate impact of BTX by RDF-pyrolysis is reduced by ~50%
- Naphtha: Pyrolysis of mixed plastic waste has a significant higher climate impact than fossil reference
- Ethylene: Climate impact of CO_2 conversion much higher than fossil reference

Chemicals key results – future renewable case



Future renewable case

- Methanol: Biomass value chain will become climate neutral and CO2 value chain will become climate negative (~180% reduction)
- Ethanol: Fermentation of biomass has a negative climate impact
- BTX: The climate impact is reduced by almost 120% and becomes negative
- Naphtha: The climate impact reduces significantly with ~65%
- Ethylene: Climate impact of CO2 conversion becomes negative

Adjustments compared to current case

Process energy is based on renewable energy sources (electricity, heat, and hydrogen)

90% recycling End-of-life

Chemicals - General interpretation

- Sustainable production of chemicals reduces the climate impact significantly and when End-of-Life is circular, the climate impact can become negative.
- For the current case, biomass gasification or fermentation are already interesting value chains to reduce climate impact for methanol and ethanol production.
- CO_2 conversion into chemicals can have a negative climate impact if sufficient green energy is available and the products are circular.
- Please note: renewable energy will have limited availability and an economic impact, especially for the value chains with CO_2 as feedstock.

Chemicals – Scenario based long term outlook

- Scenario based analyses show that the demand for chemicals in the future is rather certain.
- The flow of renewable and circular chemicals are expected to increase in all cases
- An increase of demand is estimated (24%) for connected deep green scenario[1], based on overall flows in the port (all renewable).
- Slight decrease in demand is estimated (-15%) is estimated for protective market scenario[1], based on overall flows in the port. Of which
  - Renewable/ circular flows is estimated to be ~60%
  - And fossil based are estimated to be ~40%

  based on the same ratio of non-fossil flows and fossil flows in described in the methodology slide of scenarios[1]

Source: Agro&Chemie

1. PoR – link 1 & link 2

Chemicals – Policy analysis

- Biobased materials are not stimulated yet by public policies.
- Most financial incentives and subsidy schemes are tailored to renewable energy, less to green chemistry process.
- However, a mandatory recycled content target of 25% biobased or circular plastics was announced last year.
- Moreover, in recent years chemical recycling has been recognised as an important track next to mechanical recycling.

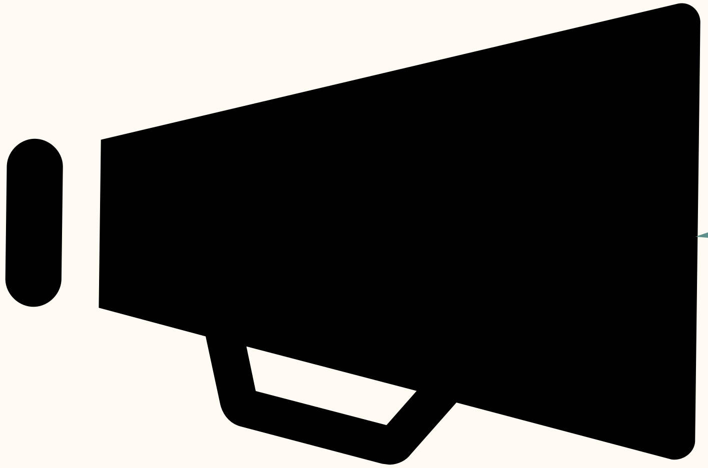
Chemicals – Expert reflection Q&A

Recommendations

Recommendations

1. Prioritise biomass import and valorisation, as well as secondary feedstocks
2. Scarcity of renewable energy limits the amount of realistic new product chains
3. Priority: Base products or high end products?
4. Mandates dictate the market
5. Lobby to accelerate future proof strategies, especially on chemicals (NL and EU)
6. Regional public entities to facilitate innovation
7. Need for spatial planning strategy

Call to action



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