Modeling the transition towards sustainable plastic value chains

Lessons learnt from the ARRRA region

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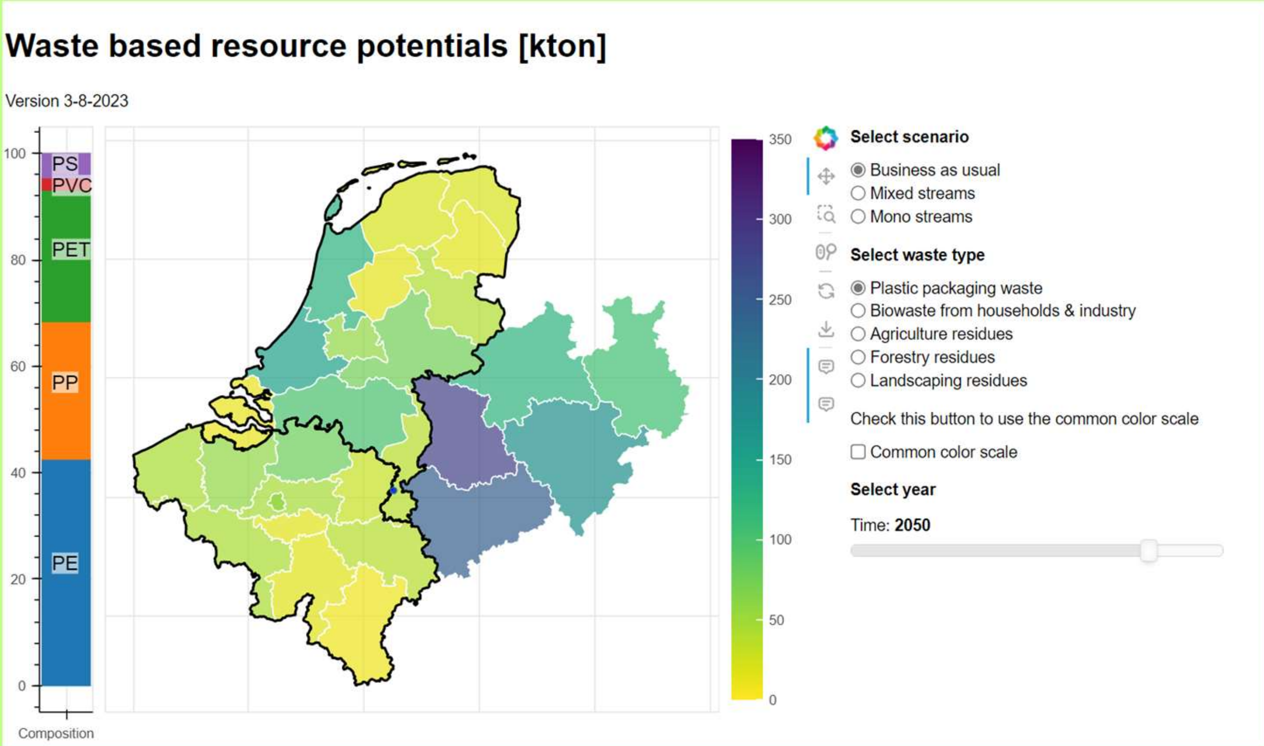
The project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement 101059909.

Scenario inputs

Geo tool for waste projections



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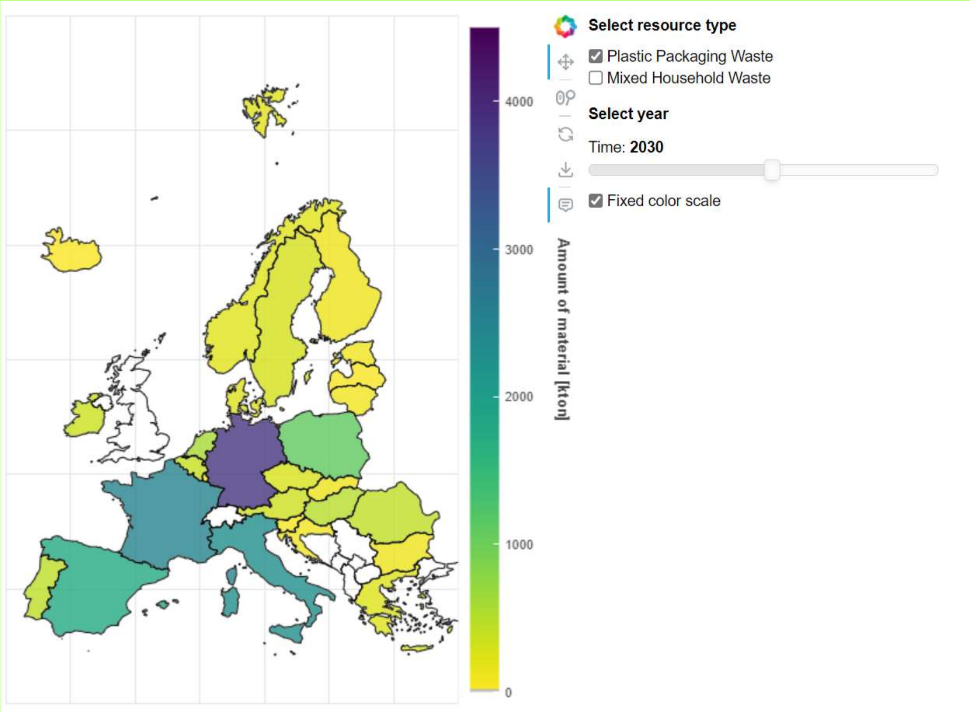
Geo waste tool for Europe



To be extended to NUTS2 regions, e.g., Lombardia

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Summarizing plastic and biowaste potentials in the ARRRA region

- **ARRRA** plastic packaging waste potential of 56 PJ equals 1/8 of **Dutch** chemical feedstock
- **ARRRA** biowaste potential of 141 PJ equals 3/8 of **Dutch** chemical feedstock

- So called **green carbon is scarce**

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Regional differences in potentials

- Regional waste differences are substantial, since plastic waste densities vary between NUTS2 regions with a factor 10 in the current situation and will increase to a factor 15 in 2060.
- For biowaste, these variations are even much larger.

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Background scenario & Foreground scenarios

Background: Energy mix & price; CO_2-price

Foreground: Polymer mix; Collection & sorting system

Foreground scenario / **Background scenario**	**Baseline / Current plastic mix**	**Mixed plastic policy** (in design & post consumer separation)	**Mono-plastic policy** (in design & separate collection)
Baseline 3.5 °C world, no CO_2 price	Baseline 3.5 °C - BAU		
1.5 °C world, green energy mix, CO_2 price	1.5 °C tax - BAU	1.5 °C tax - MIX	1.5 °C tax - MONO
1.5 °C world, green energy mix, optimized for CO_2 emission reduction	1.5 °C potential - BAU		

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The PRISM model

PRISM:

Plastic Recycling and Impact Scenario Model

Model to find the best* recycling technology system, for a given supply and composition of plastic waste streams varying over time

- Optimization for least costs and least environmental impacts
- Long-term scenario analysis (up to 2060), including changing energy system
- Includes 10 recycling technologies and 25 polymers
- System boundary: Waste collection, sorting & treatment; benefits of avoided primary plastics and energy are included.

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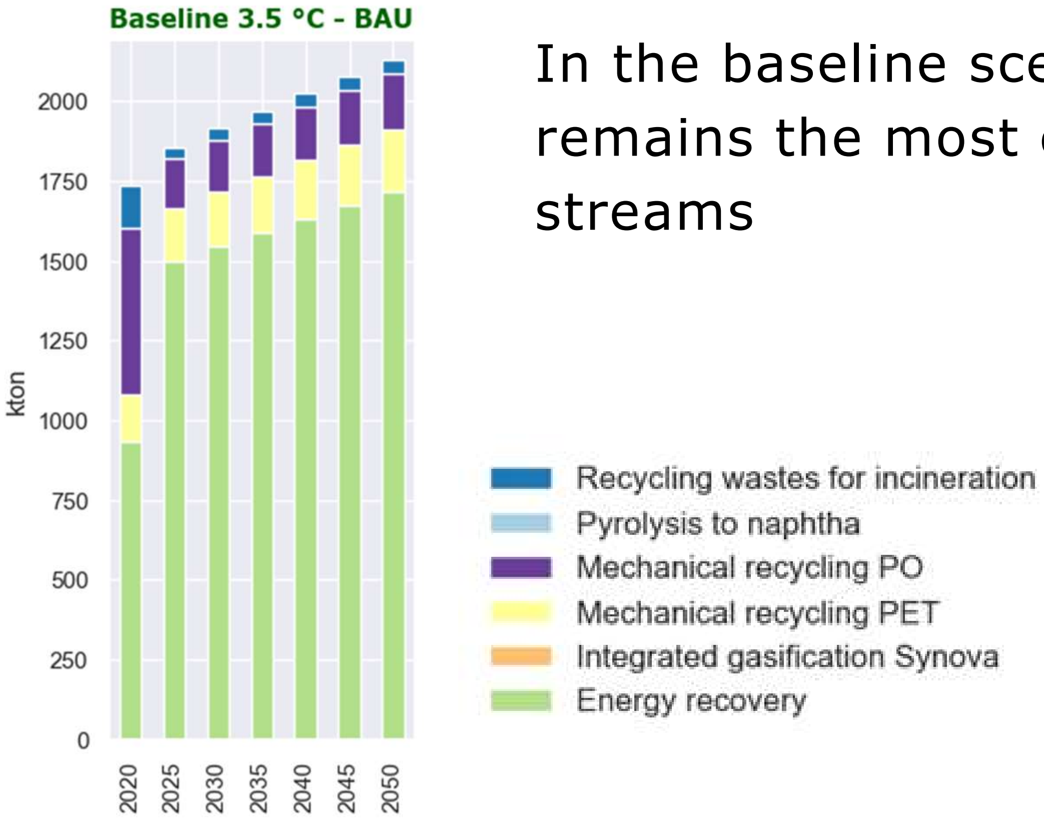
*Considering impacts and costs

Initial results: PRISM, the societal perspective

Plastic packaging waste allocation to waste treatment technologies



In the baseline scenario energy-recovery remains the most cost-effective for most waste streams

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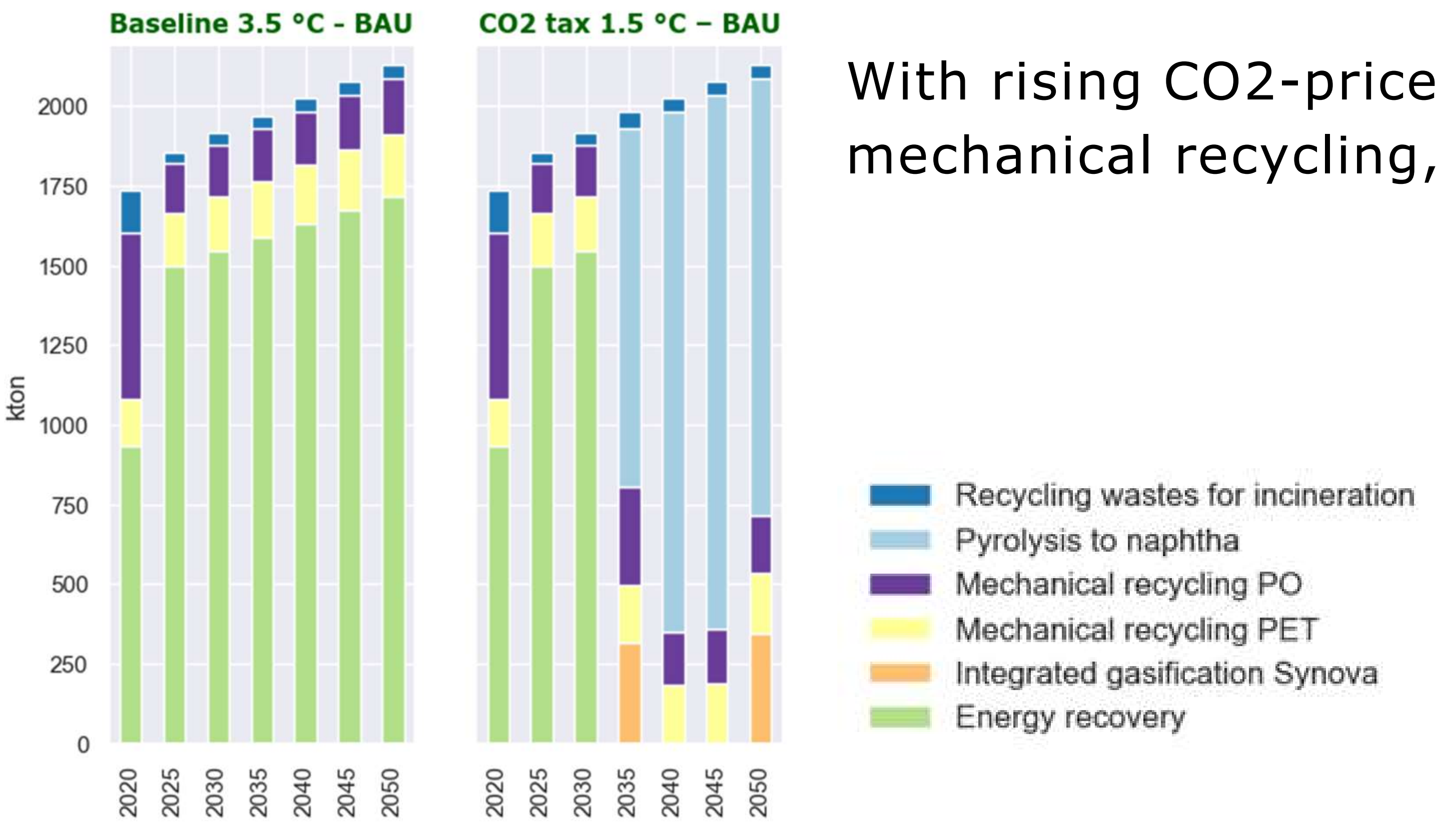
Plastic packaging waste allocation to waste treatment technologies



With rising CO2-price we see a shift to mechanical recycling, pyrolysis, & gasification.

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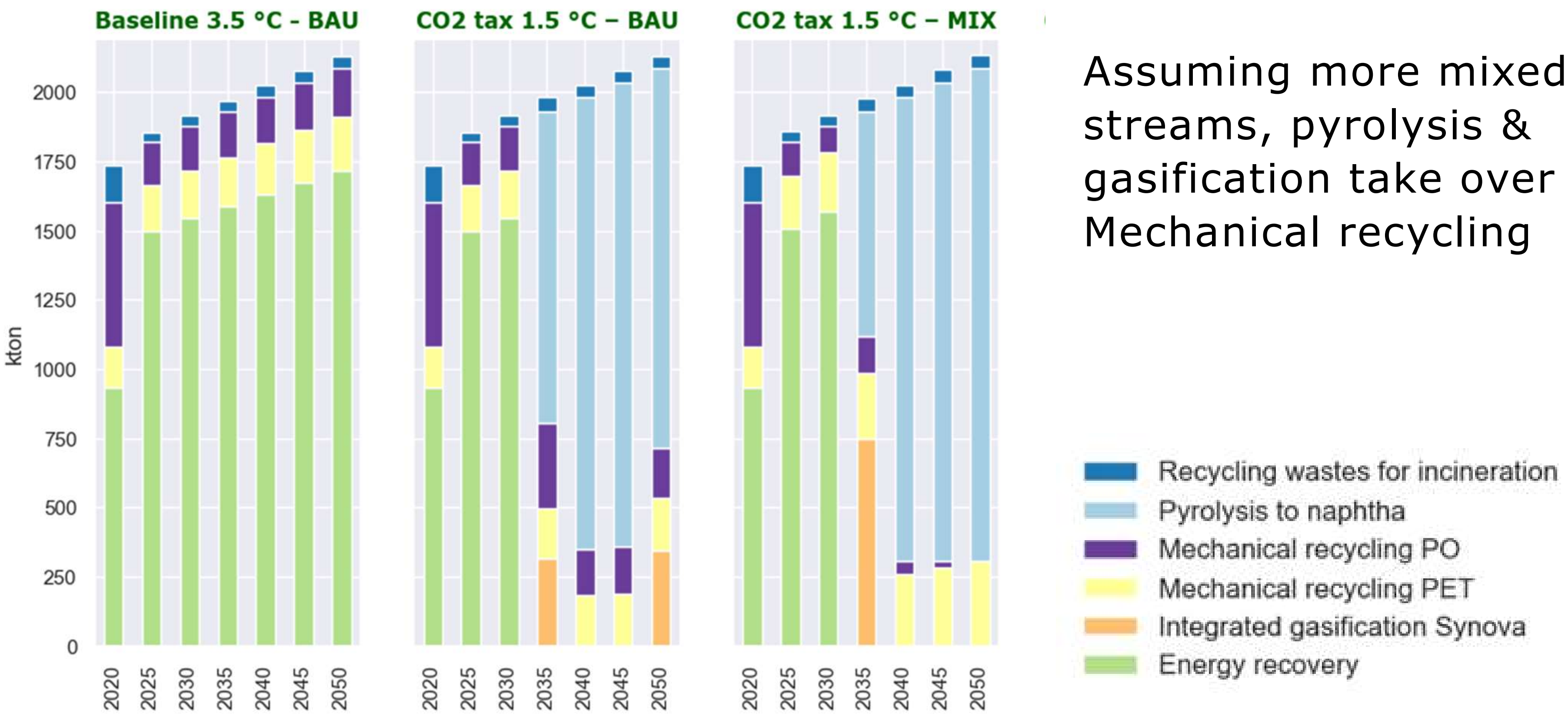
Plastic packaging waste allocation to waste treatment technologies



Assuming more mixed waste streams, pyrolysis & gasification take over from Mechanical recycling

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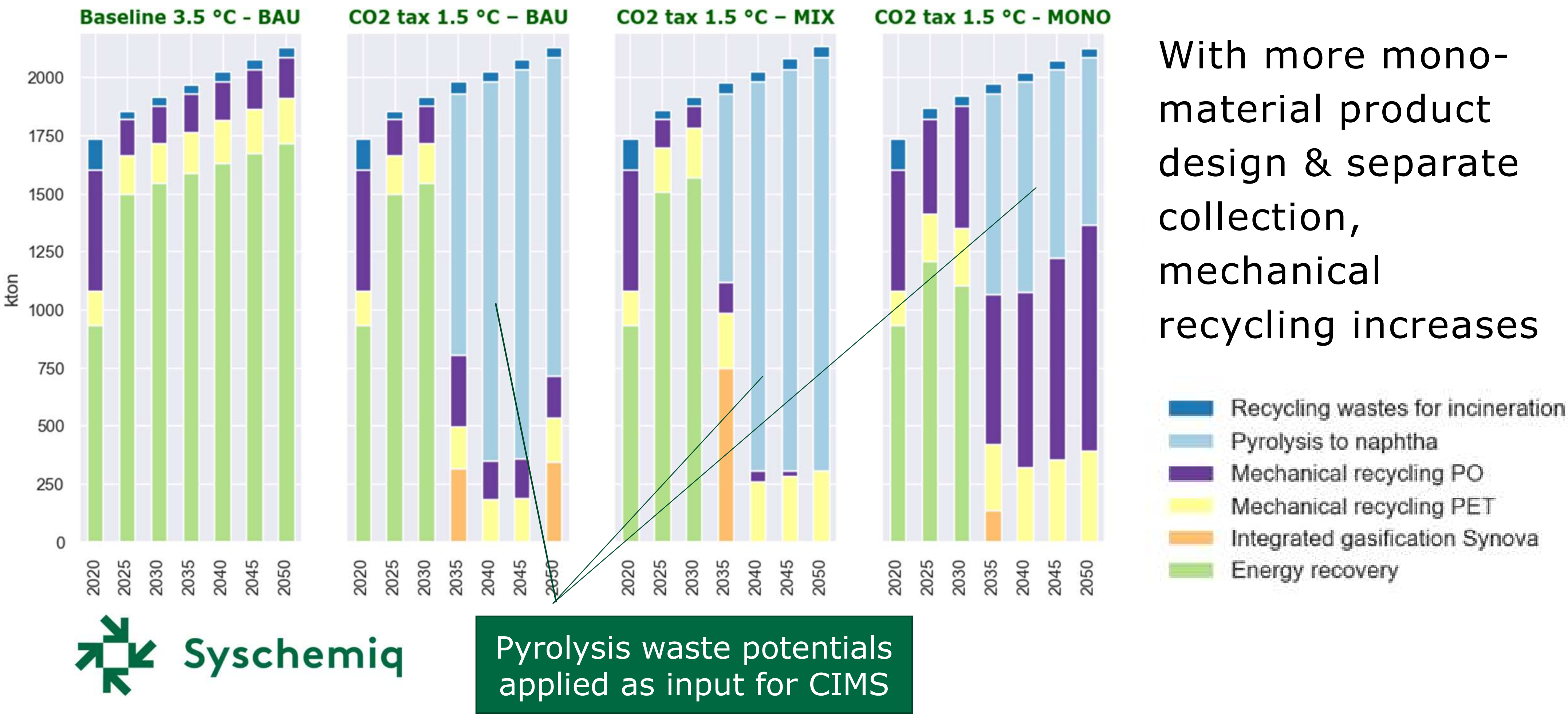
Plastic packaging waste allocation to waste treatment technologies



With more mono-material product design & separate collection, mechanical recycling increases

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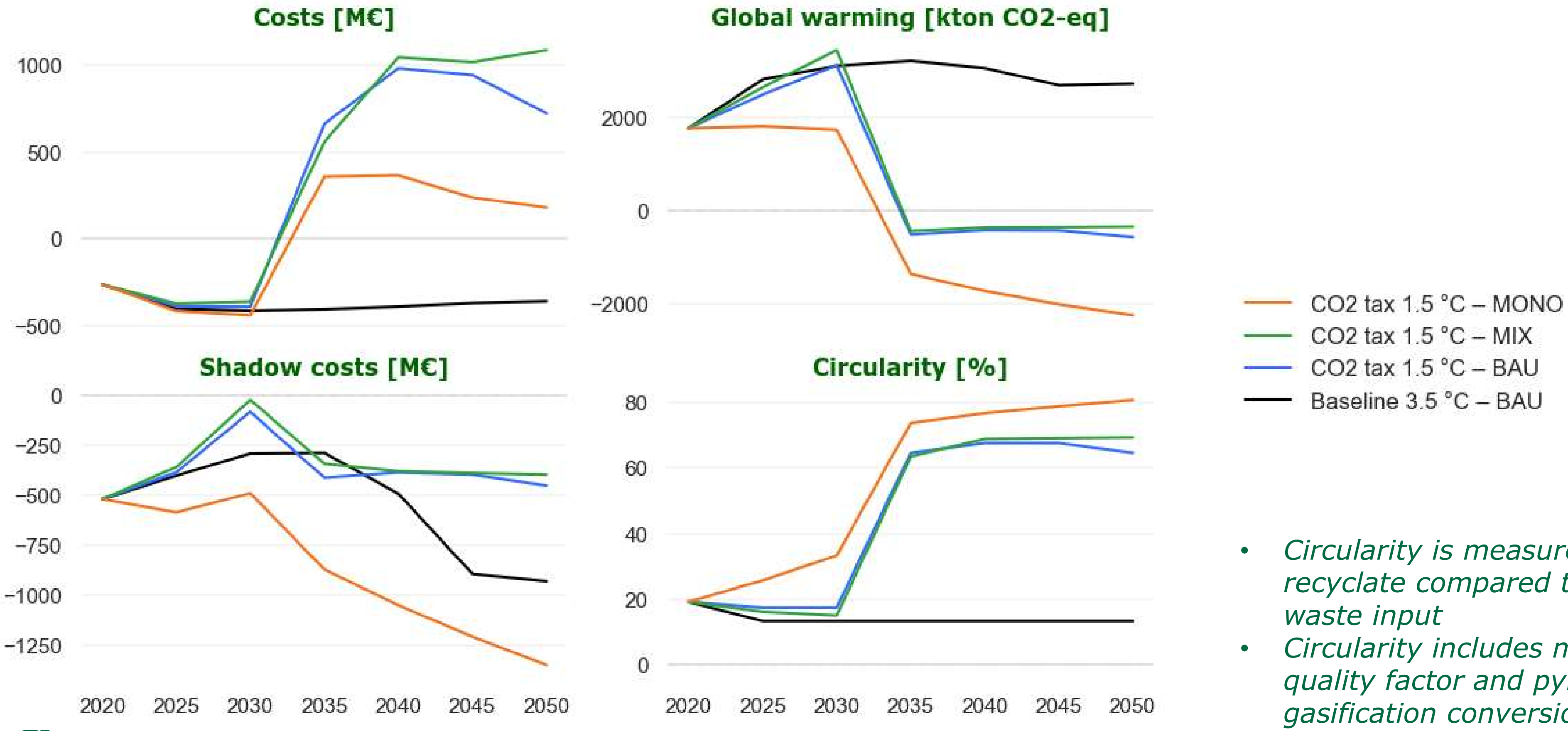
Scenario impacts



- *Circularity is measured as % if recyclate compared to total waste input*
- *Circularity includes material quality factor and pyrolysis and gasification conversion rates (polymer to polymer);*
- *Costs exclude CO_2 taxes*

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Conclusions from a societal perspective

1. Without any policy, energy recovery remains the cheapest solution
2. With CO_2 pricing, recycling takes over
3. Advanced recycling leads to overall lower societal costs / damage
4. Waste composition (current, mixed, or mono) favour attractiveness of different options

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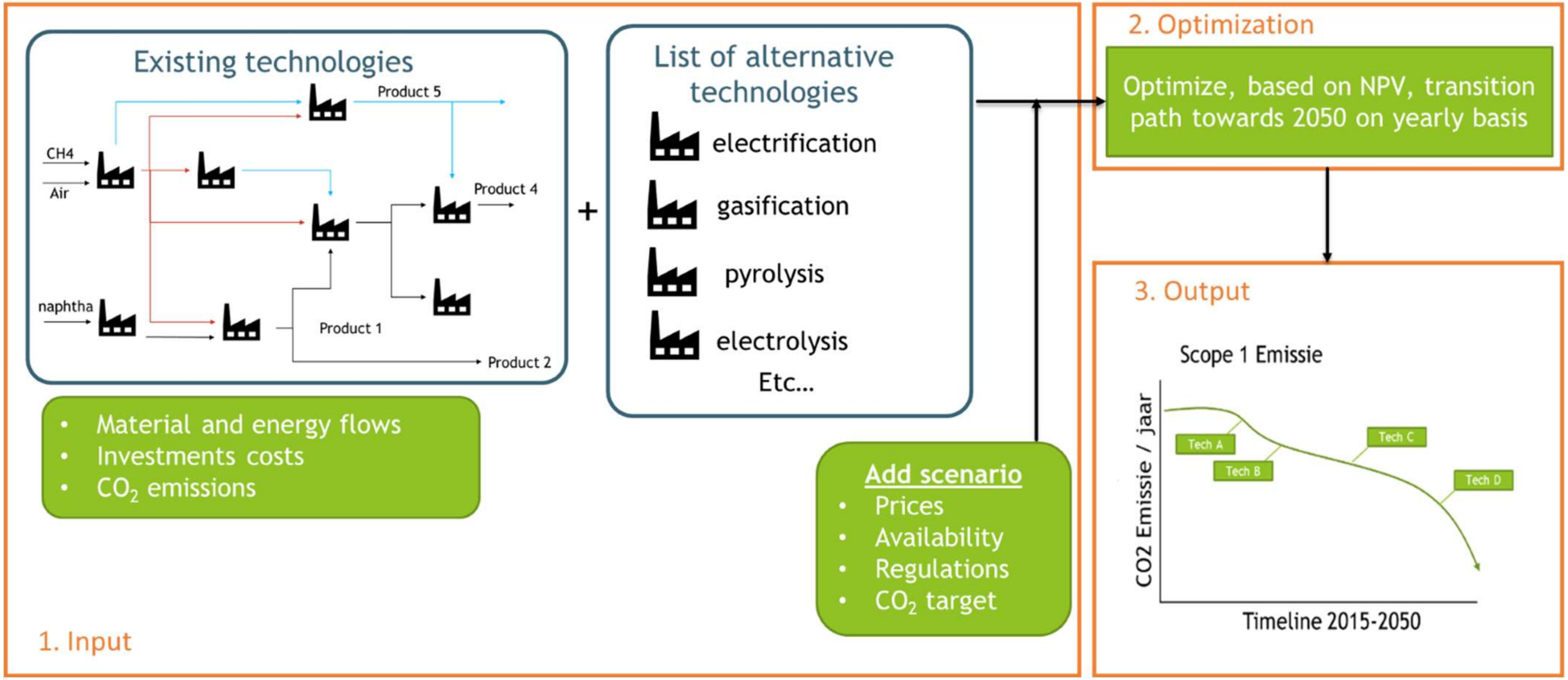
The CIMS model

The Chemelot Integrated Model System



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Scenarios modelled

2 additional foreground scenarios:

- **Front-runner**: Chemelot has a front runner position in chemical recycling and has access to all the EU27 plastic waste and municipal waste it needs
- **Fair share**: Chemelot has access to a fair share of waste, based on its current share of European cracker capacity (5%)

	FRONT-RUNNER	SHARE
Baseline-BAU	X	X
1.5C-BAU	X	X
1.5C-MONO		X
1.5C-MIX		X
1.5C-BAU-ZeroCO2	X	X

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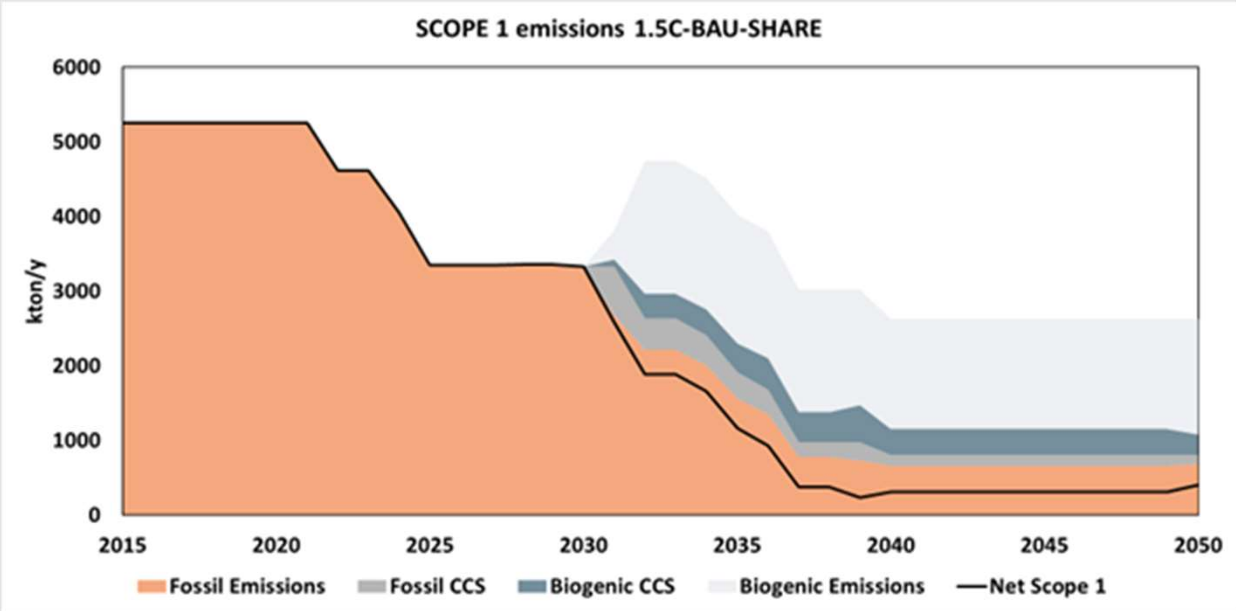
Initial results: CIMS, the business perspective

92% of scope 1 CO2 emission reduction



- In the 1.5 degree scenario, 92% of emission reduction achieved, both for Front-runner and Share scenario.
- As opposed to 34% reduction in baseline scenario (not shown).

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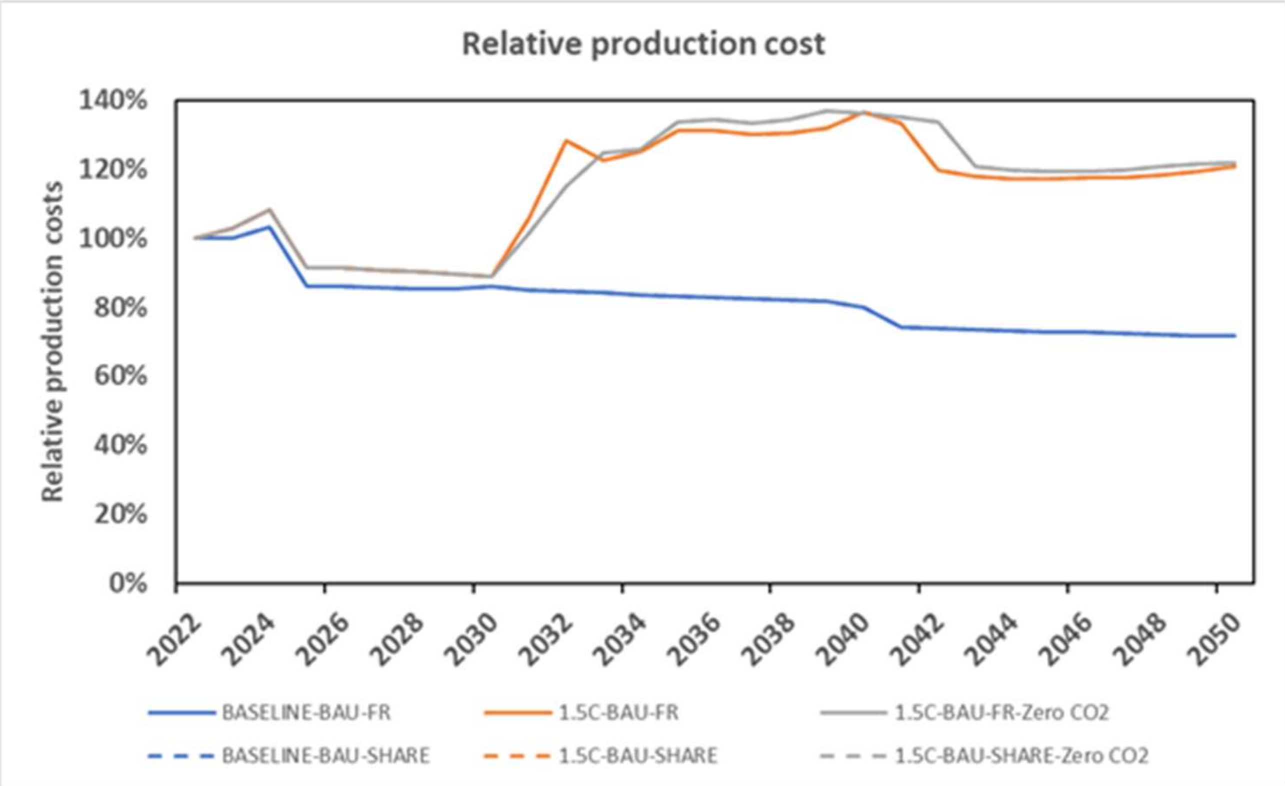
Significant increase in production costs



- 40% increase in production costs during the transition, 20% in 2050 in the 1.5 degree scenario.

- Productions costs is for the complete site (not only ethylene) and consist of feedstock costs, energy costs, ETS and CAPEX.

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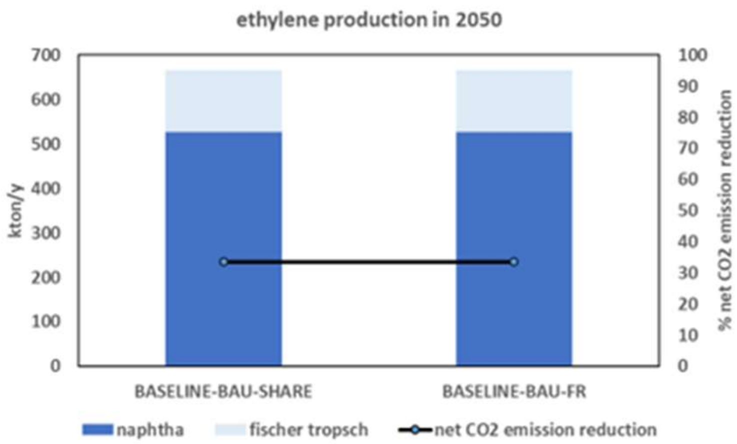
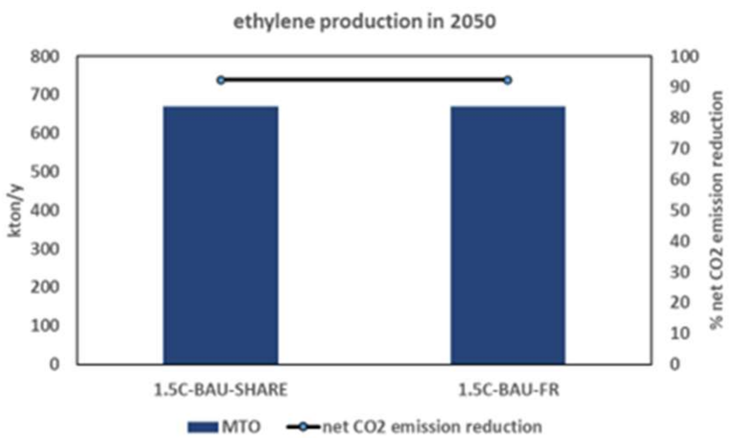
Technology choices





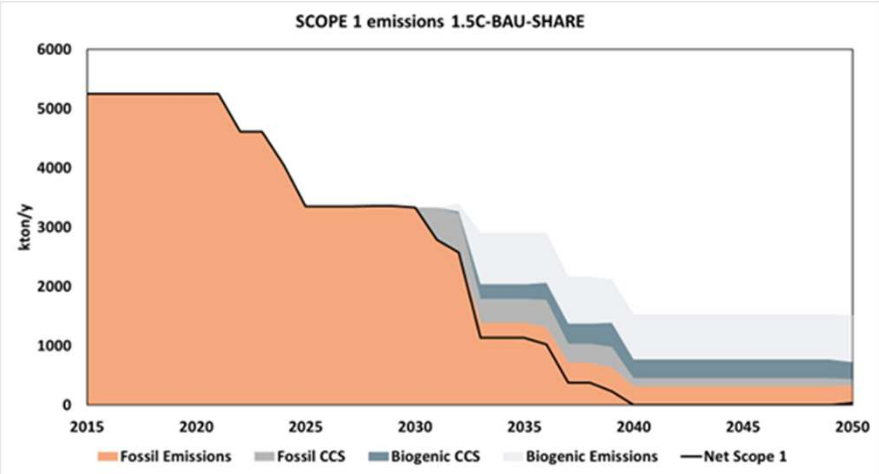
- In the baseline scenarios, naphtha remains the main feedstock for ethylene. Only partially replaced by gasification of mixed solid waste combined with conversion of the syngas to ethylene via the Fischer-Tropsch (FT) reaction and cracking of the FT-products.

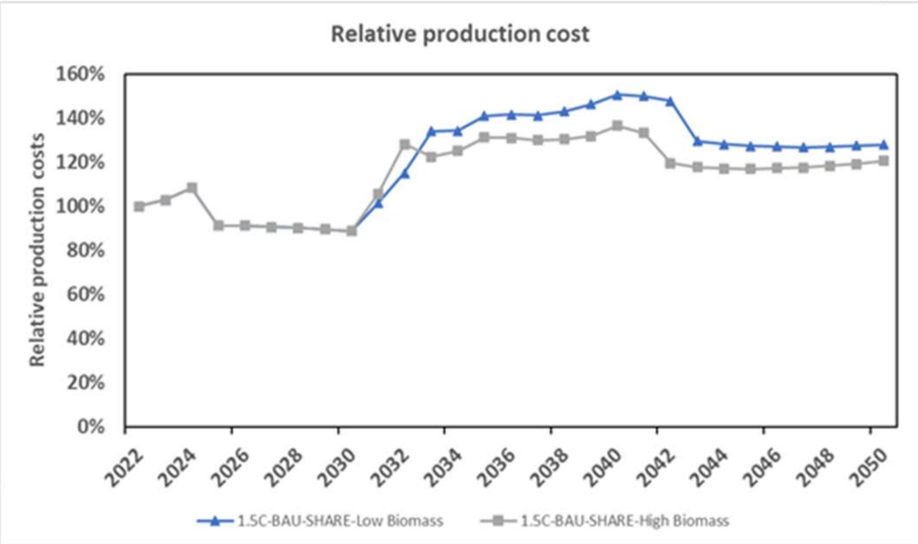
- In the 1.5 degree scenario, the cracker route is completed replaced by Methanol-to-Olefin, with syngas from biomass gasification. Additional hydrogen is coming partly from gasification (biomass and MSW) and from import (electrolysis).

- Pyrolysis of plastic waste is not chosen because of the CO2 emissions generated during the process, which are still considered fossil based as most of the plastic waste currently is of fossil origin (the same is valid for emissions from the steam cracker)

- No difference between foregrounds scenarios because availability not limiting.

Limiting also the availability of biomass





- Fair-share principle also applied to forestry waste availability for gasification.
- Cracker route still replaced by MTO, but syngas now from MSW gasification. Additional hydrogen from biomass gasification and import (electrolysis). Enough MSW available in the fair share scenario.
- 99% scope 1 CO2 emission reductions.
- Limited additional increase in production costs.

Conclusions from business perspective

- The modelling results did **not show a good business case for chemical recycling**, as gasification of biomass with further conversion to ethylene via methanol was the preferred option, above pyrolysis of plastic packaging waste and municipal waste gasification. When the biomass availability is limited, the gasification of municipal solid waste becomes the preferred route to ethylene.
- While Chemelot meets its climate targets in the model, **it barely contributes to the EU's circularity goals**. Solely providing incentives for reducing Scope-1 GHG emissions can lead to potentially non-desirable outcomes, such as hampering the implementation of circular technologies and even outsourcing chemical production.
- We urge policy makers **to stimulate the material transition** along the energy transition to create a more favorable business case for circular options such as pyrolysis of plastic waste or for MSW gasification, e.g. by having a temporary exemption of recycled based CO2 emissions, combined with a mandatory recycled content in plastic products.
- Disclaimer: There are many uncertainties related to the assumptions used for the modelling, in particular the price projections and even more so for waste and other renewable feedstocks. **The results should therefore be interpreted carefully.**

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