Economic performance of thermochemical recycling of mixed plastic waste: Open-loop vs closed loop

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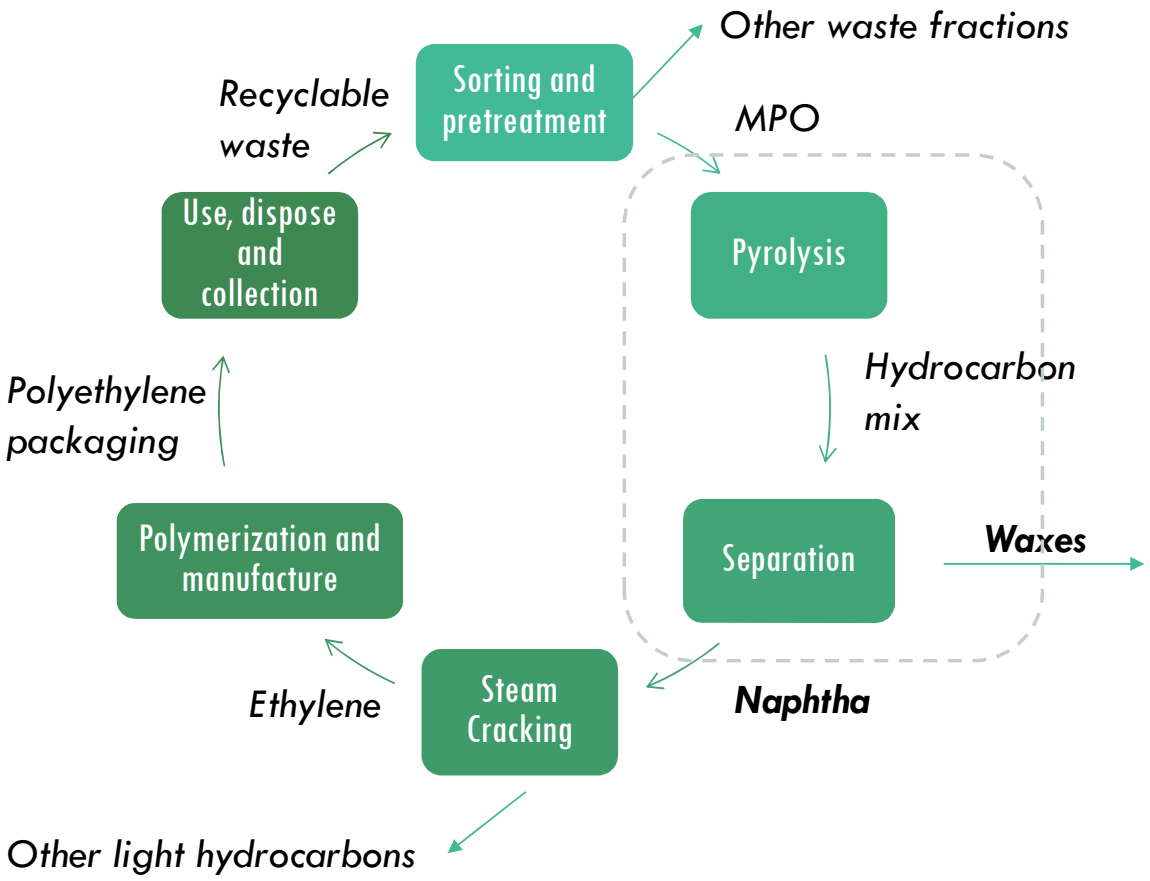
PLASTIC PACKAGING RECYCLING: OPEN VS "CLOSED LOOP"

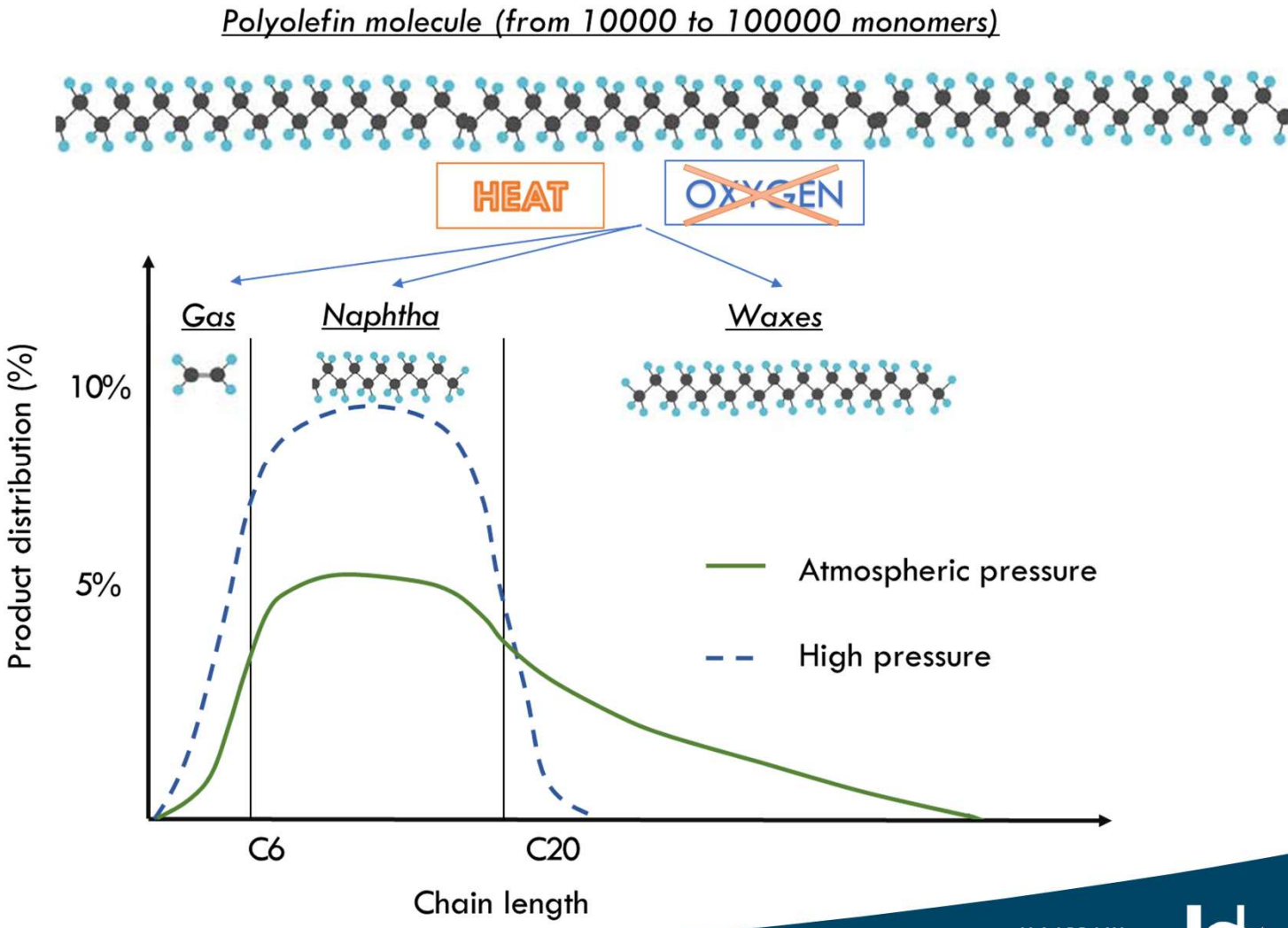


Objective:

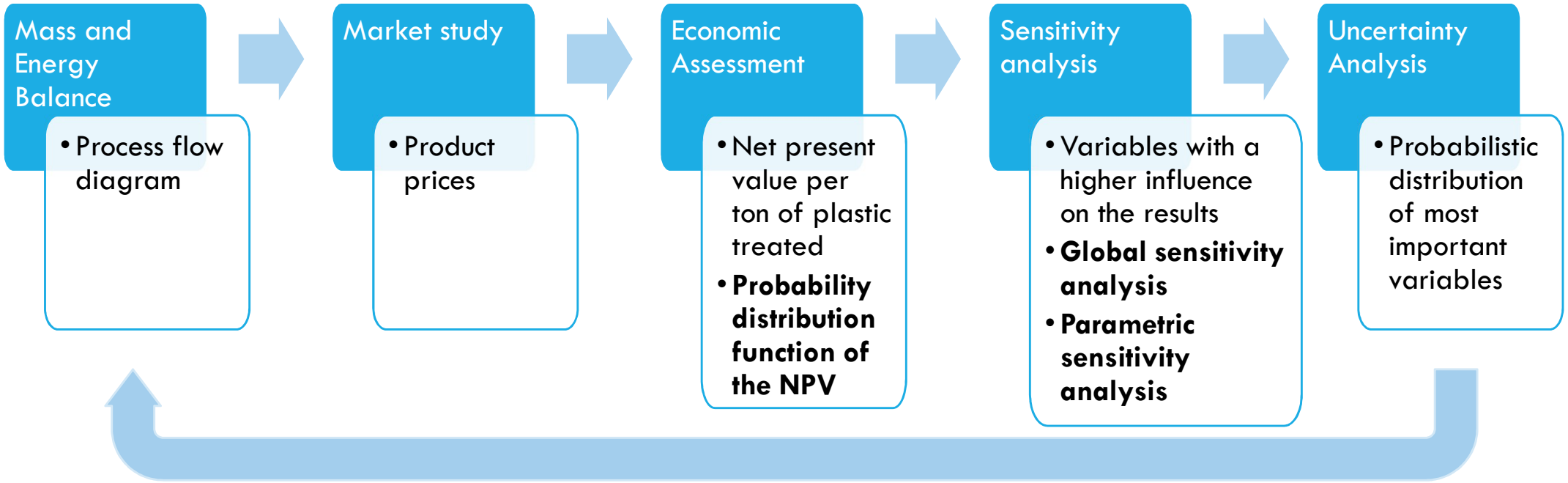
Compare the **economic performance** of closed-loop versus open-loop recycling of polyolefin waste.

PYROLYSIS

- Break the polymer molecules into smaller hydrocarbon chains
- Product distribution depends on the pressure:
  - Higher pressure → smaller molecules
  - Higher temperature → smaller molecules

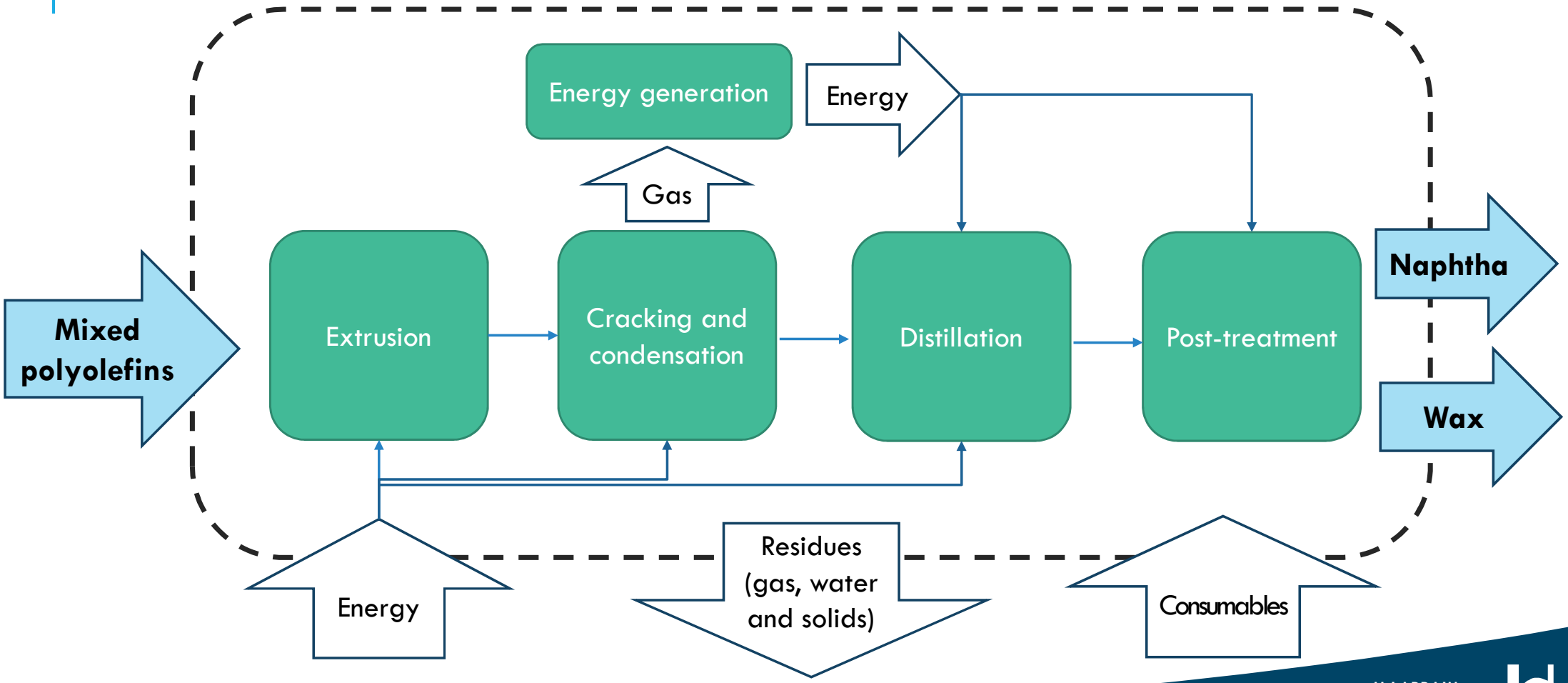


METHODOLOGY

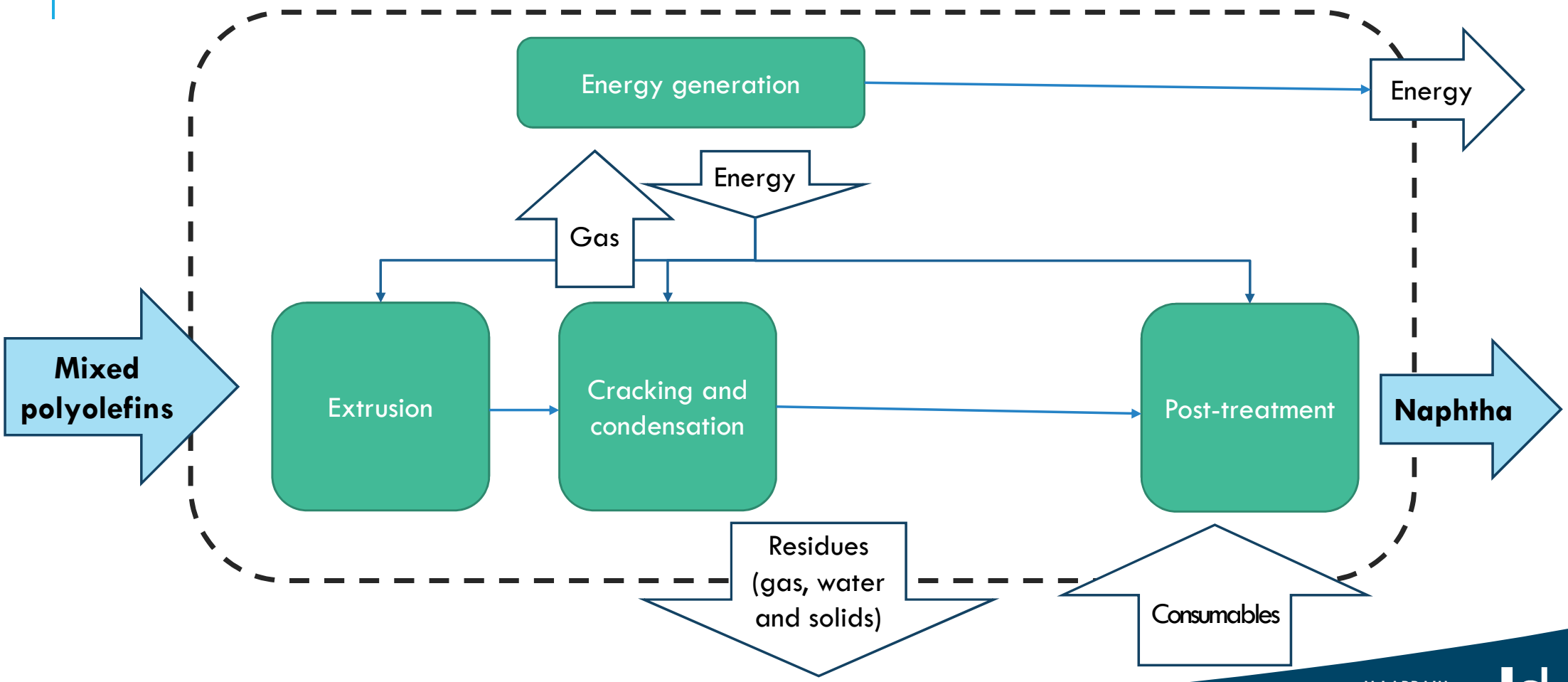


- 1st : deterministic analysis
- 2nd: Stochastic analysis

PROCESS FLOW DIAGRAM – CASE 1: NAPHTHA AND WAXES

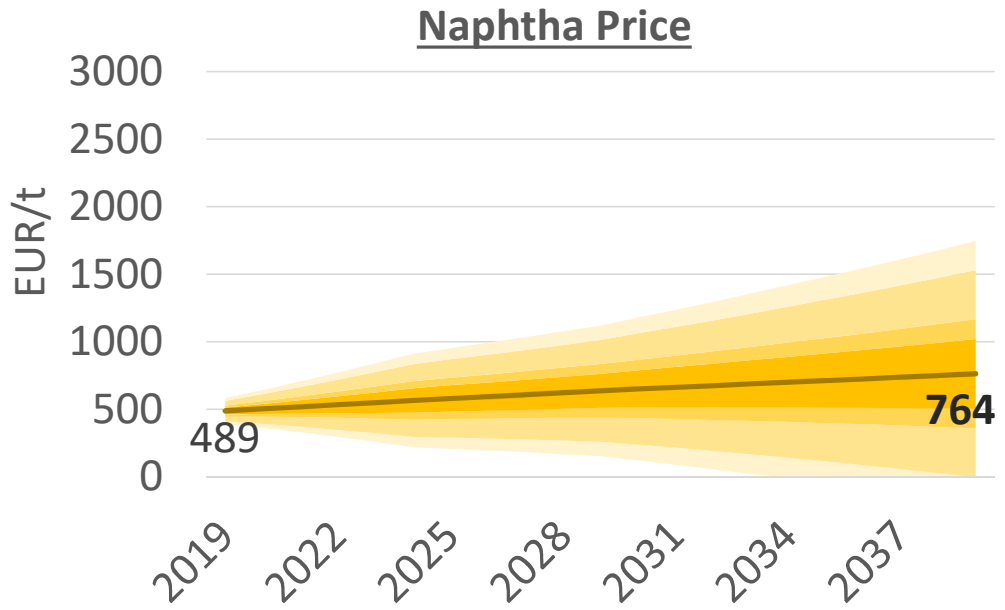


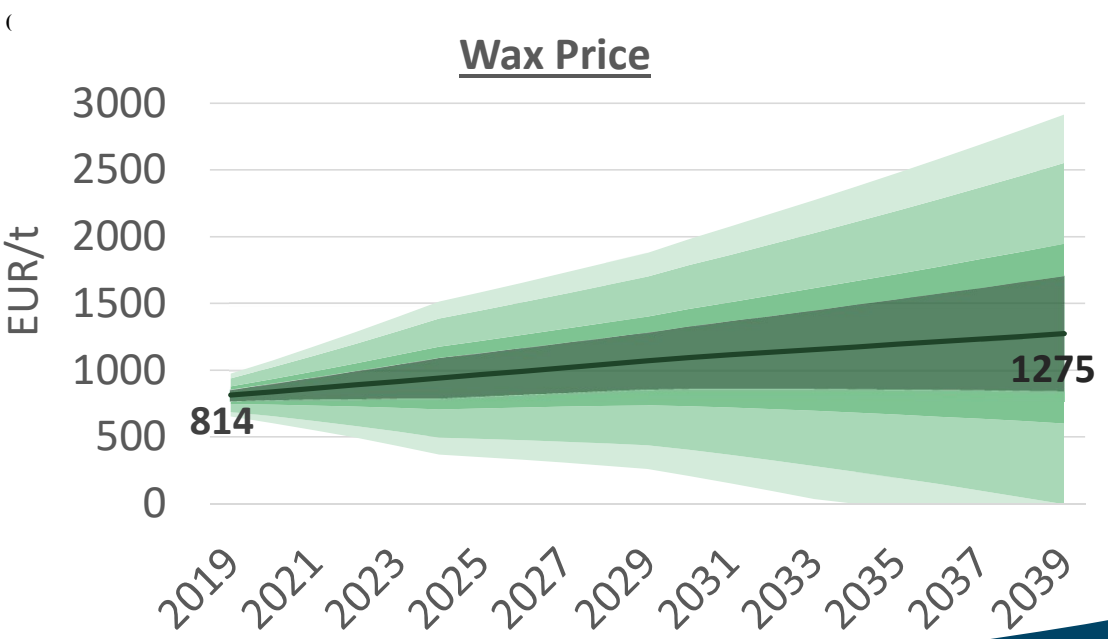
PROCESS FLOW DIAGRAM – CASE 2: ONLY NAPHTHA



MARKET STUDY: PRODUCT PRICE

- Normal distribution for every year price.
- Variance according to **observed projection errors** of past world energy outlook estimations. More future → higher uncertainty, higher error.



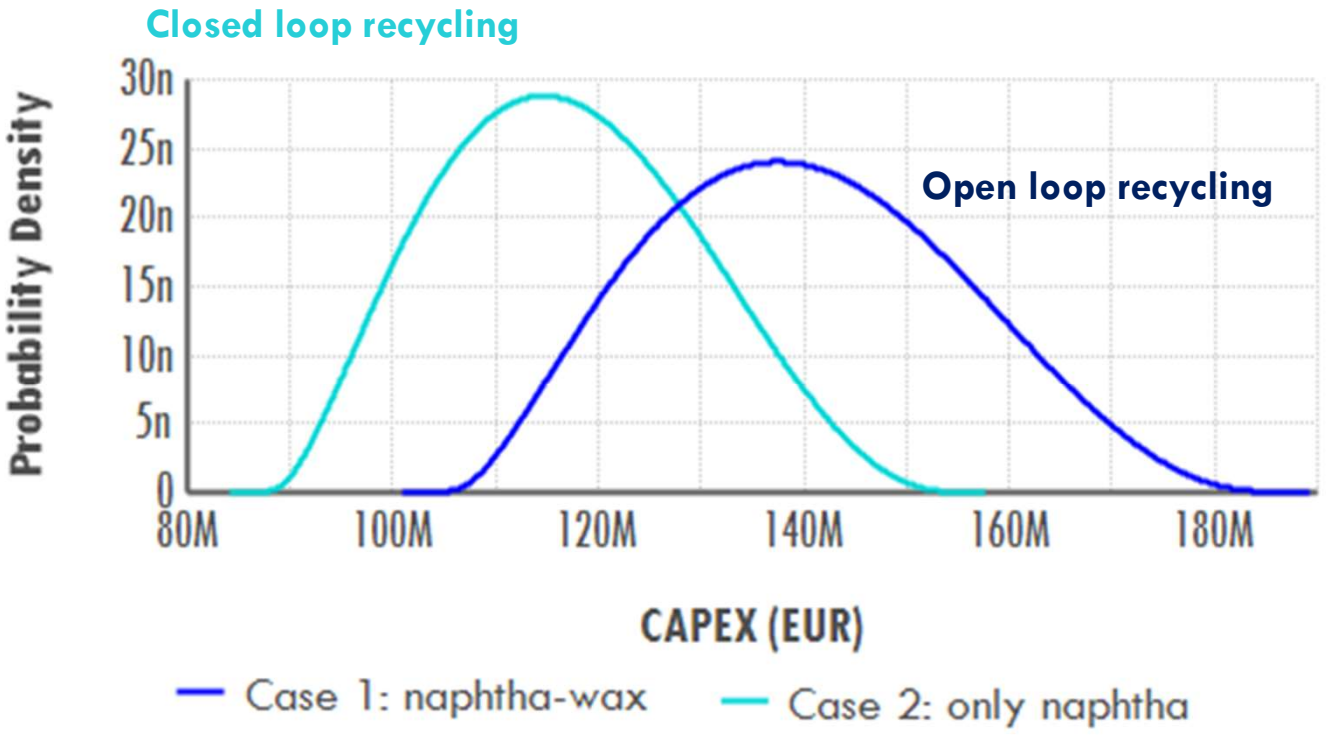


ECONOMIC ASSESSMENT: CAPITAL EXPENDITURE

- **Mid (most likely) value:**
  - Project design
  - + 10% project
  - +15% of contingency

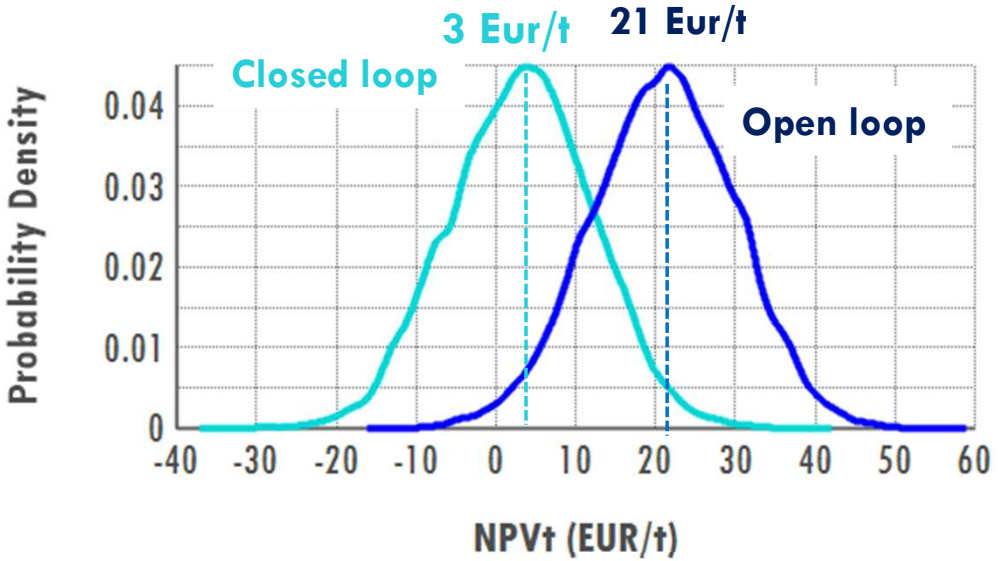
- **Uncertainty analysis:**
  - Negatively skewed pert distribution with uncertainty range for TRL 6:
    - Low -22.5%
    - High +35%

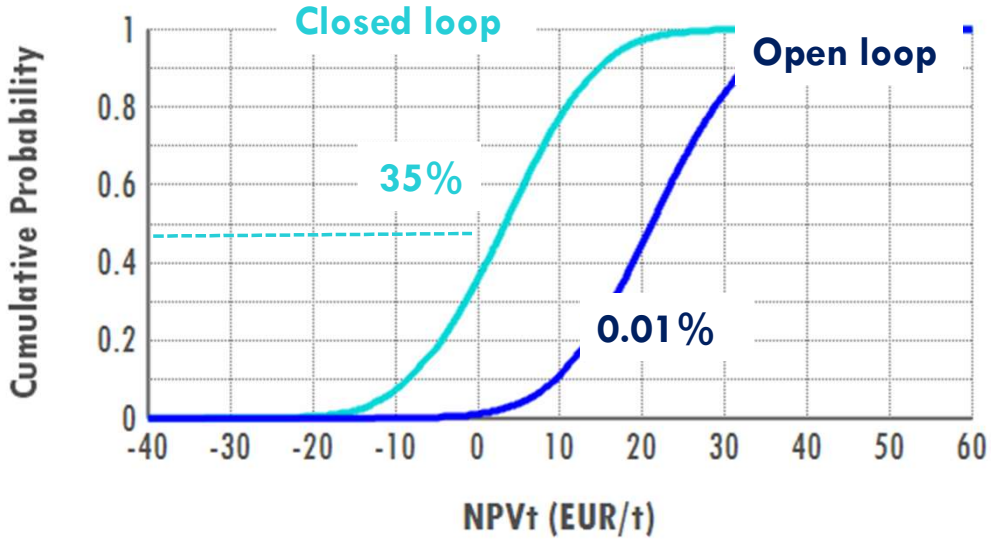
- **Working capital:** 15% of capex on year 1 and -15% of capex on year 20.



RESULTS – COMBINED MONTE-CARLO SIMULATION:

- **General assumptions:** Discount rate: 15%, Tax rate: 25%, evaluation period: 20 years.
- **Probabilistic variables:** wax price, CAPEX, naphtha price, hydrogen price and feedstock price.



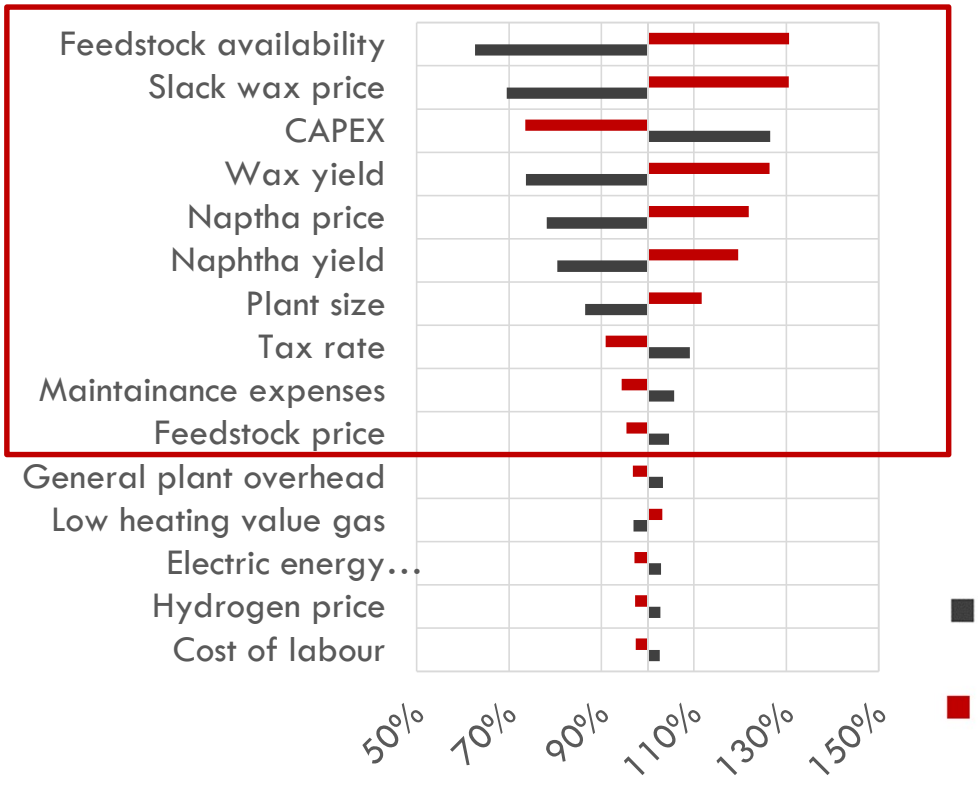


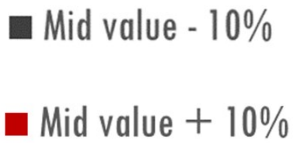
Case 1: naphtha-wax Case 2: only naphtha

Main message: open loop outranks closed loop recycling.

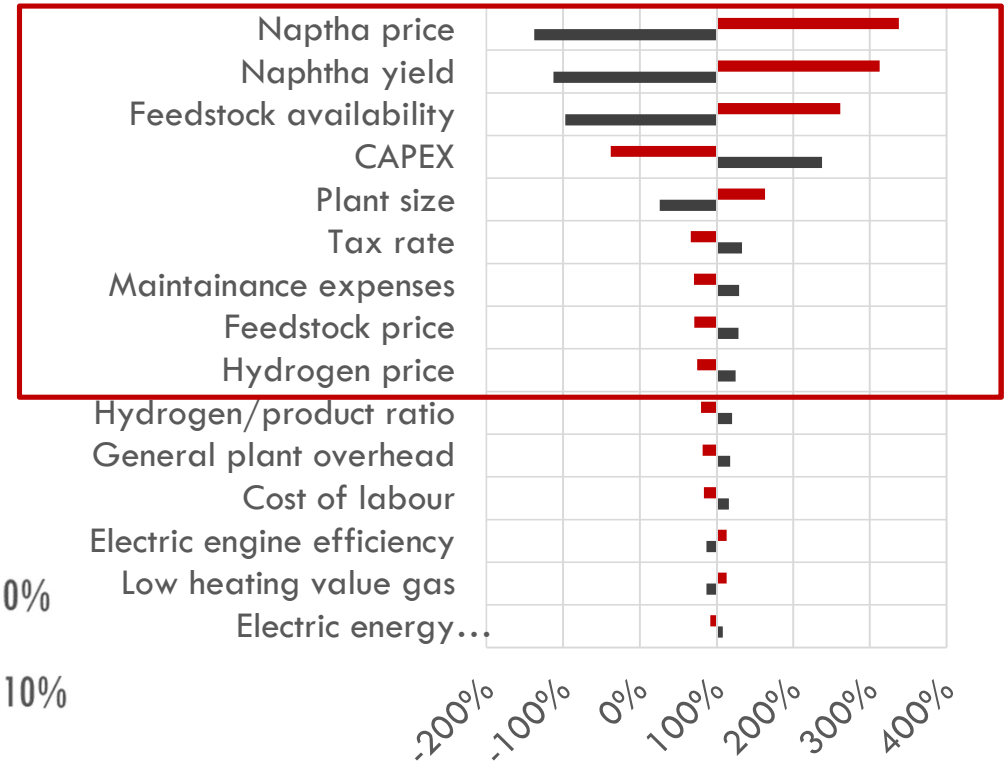
SENSITIVITY ANALYSIS: ONE-AT-THE-TIME

Case 1: naphtha-wax





Case 2:only naphtha



-**Probabilistic variables:** Prices and CAPEX

-**Parametric sensitivity analysis:** Discount rate, plant size, feedstock availability and tax rate.

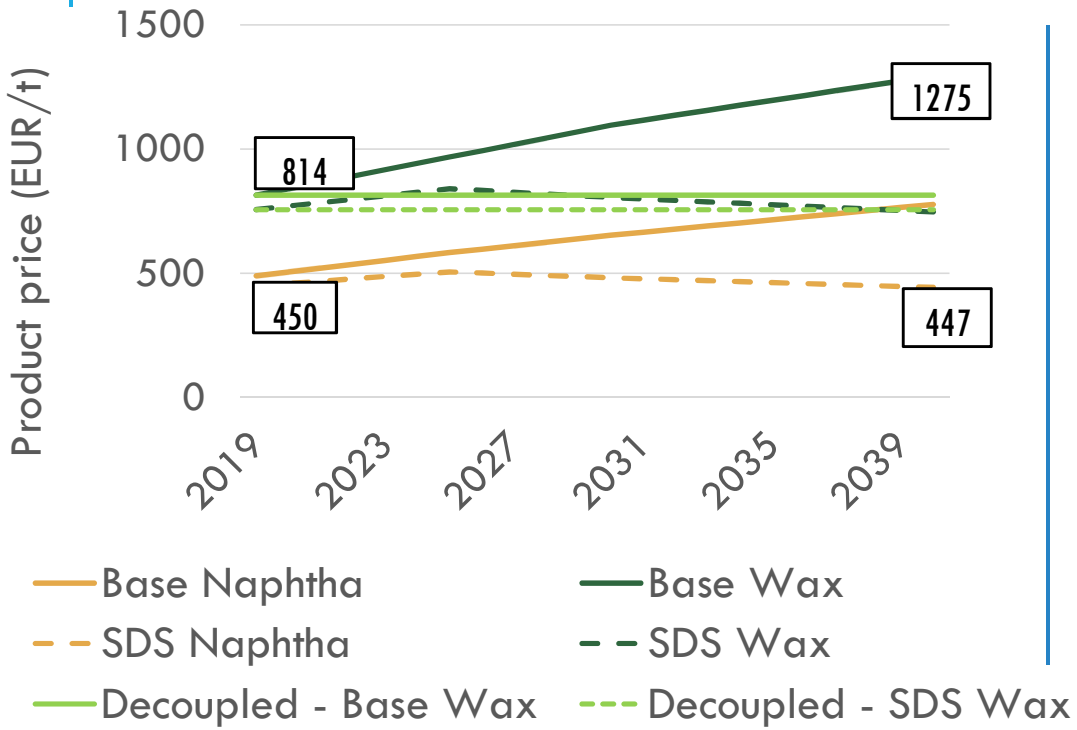
SENSITIVITY ANALYSIS: GLOBAL

- How the variance of each variable is related to the variance of the results.
- Spearman's rank coefficient: correlation of the ranking of the variable to the ranking of the results.

Variable	Case 1: naphtha-wax	Case 2: only naphtha
CAPEX	**49.3%**	**37.8%**
Hydrogen price	3.4%	5%
Feedstock price	6.1%	6.5%
Naphtha price	**52.6%**	**90.1%**
Wax price	**73.9%**	0%

Main message: Result uncertainty depend mainly on the uncertainty of CAPEX and product prices.

SCENARIO ANALYSIS: PRODUCT PRICE SCENARIOS

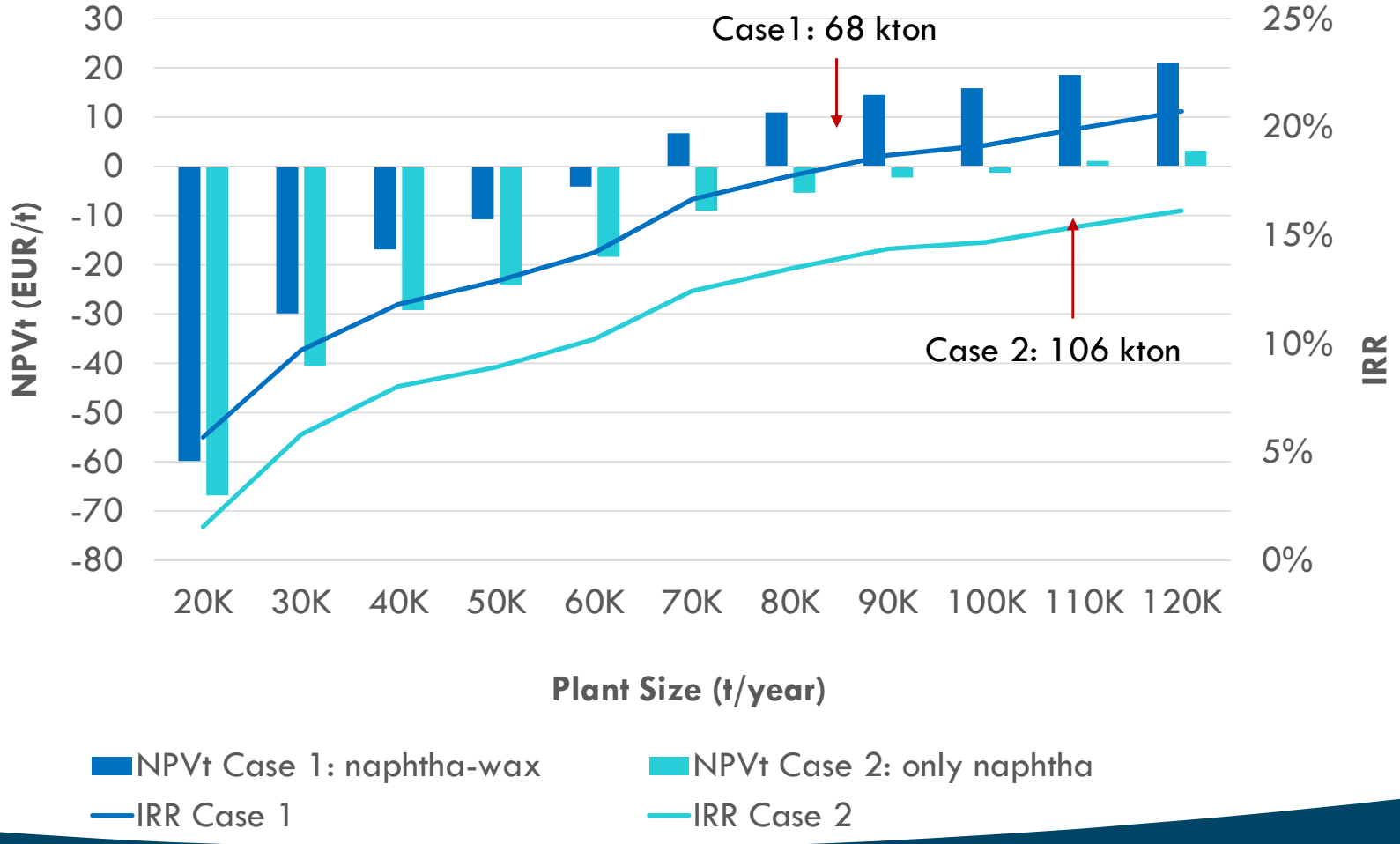


Expected value and probability of negative results of net present value per ton of plastic treated (EUR/t)

		Coupled	Decoupled
Base	Case 1:naphtha and wax	21 (0%)	10 (14%)
	Case 2:only naphtha	3 (35%)	
Sustainable Development	Case 1:naphtha and wax	1(47%)	-2(60%)
	Case 2:only naphtha	-12 (93%)	

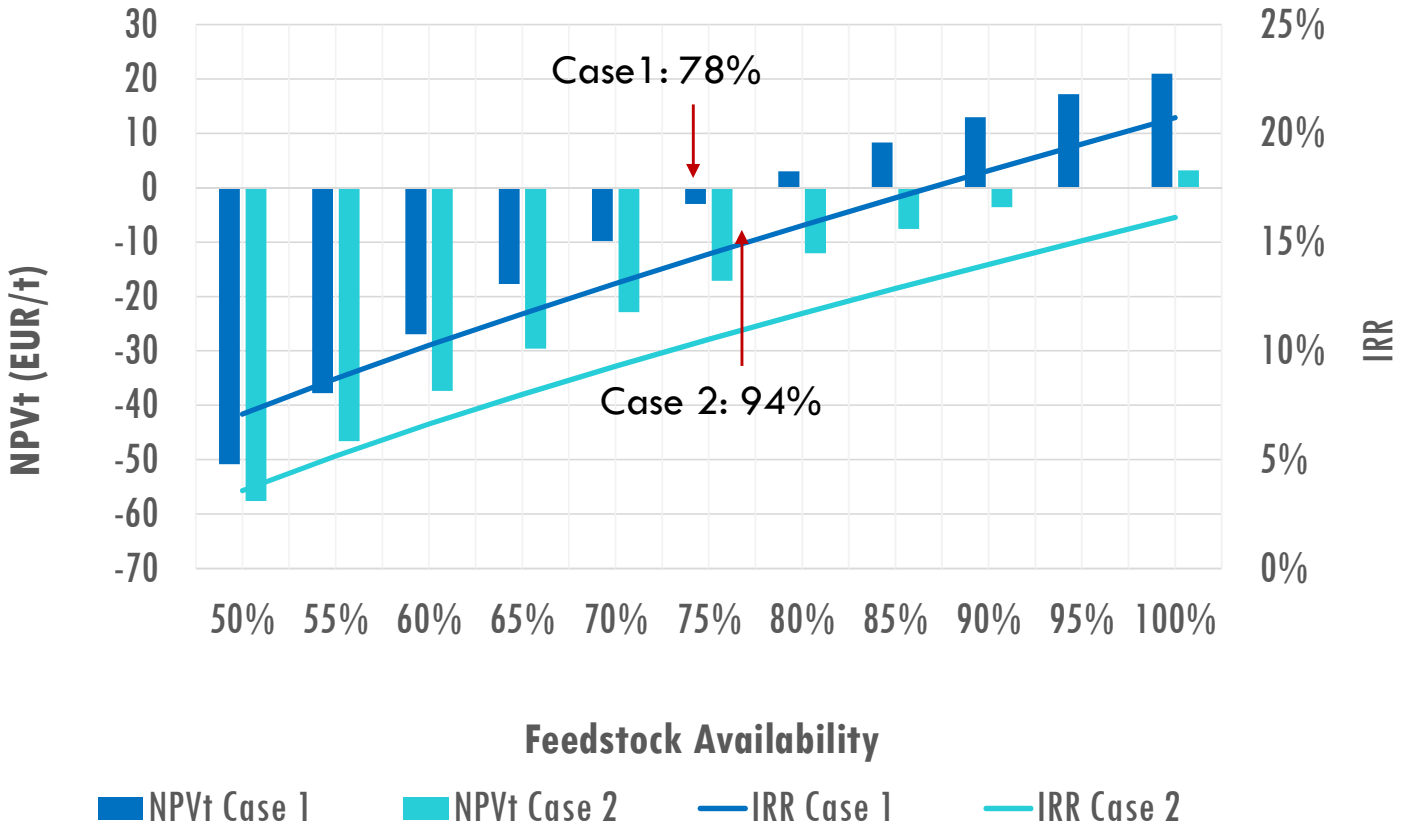
Negative results observed in sustainable development scenario
Worse results in case wax prices are decoupled from oil prices

SCENARIO ANALYSIS: SMALLER PLANT SIZE



Main message: Min size 68 kton/year for open loop and 106 kton/year for closed loop

SCENARIO ANALYSIS: FEEDSTOCK SHORTAGE



Main message: Min availability is is 78% for open loop and 94% for open loop.

CONCLUSIONS

- Open-loop recycling outranks closed loop recycling under a range of possible scenarios.
- Main drivers: feedstock availability, product price and investment cost.
- To ensure the economics benefits from chemical recycling it is important:
  - Ensure the provision of plastic waste feedstock to chemical recycling (at least 70,000 ton/year).
  - Enable a decoupling of plastics value chain from oil values.

- Future research:
  - Environmental assessment of both cases and comparison with other recycling and end-of-life treatments.

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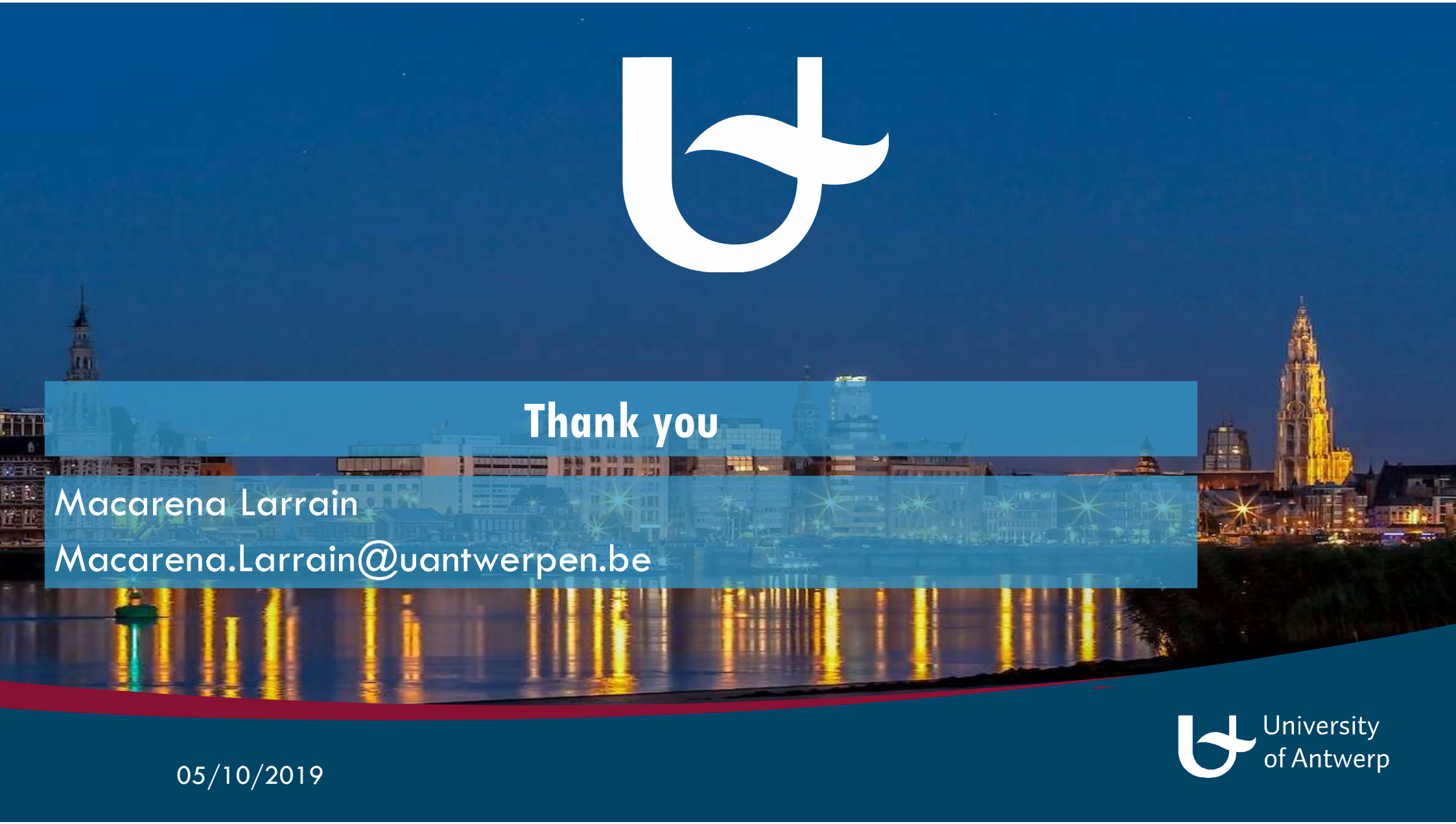

Thank you

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