Life cycle and experimental assessment of sustainable thermal processing of waste plastics

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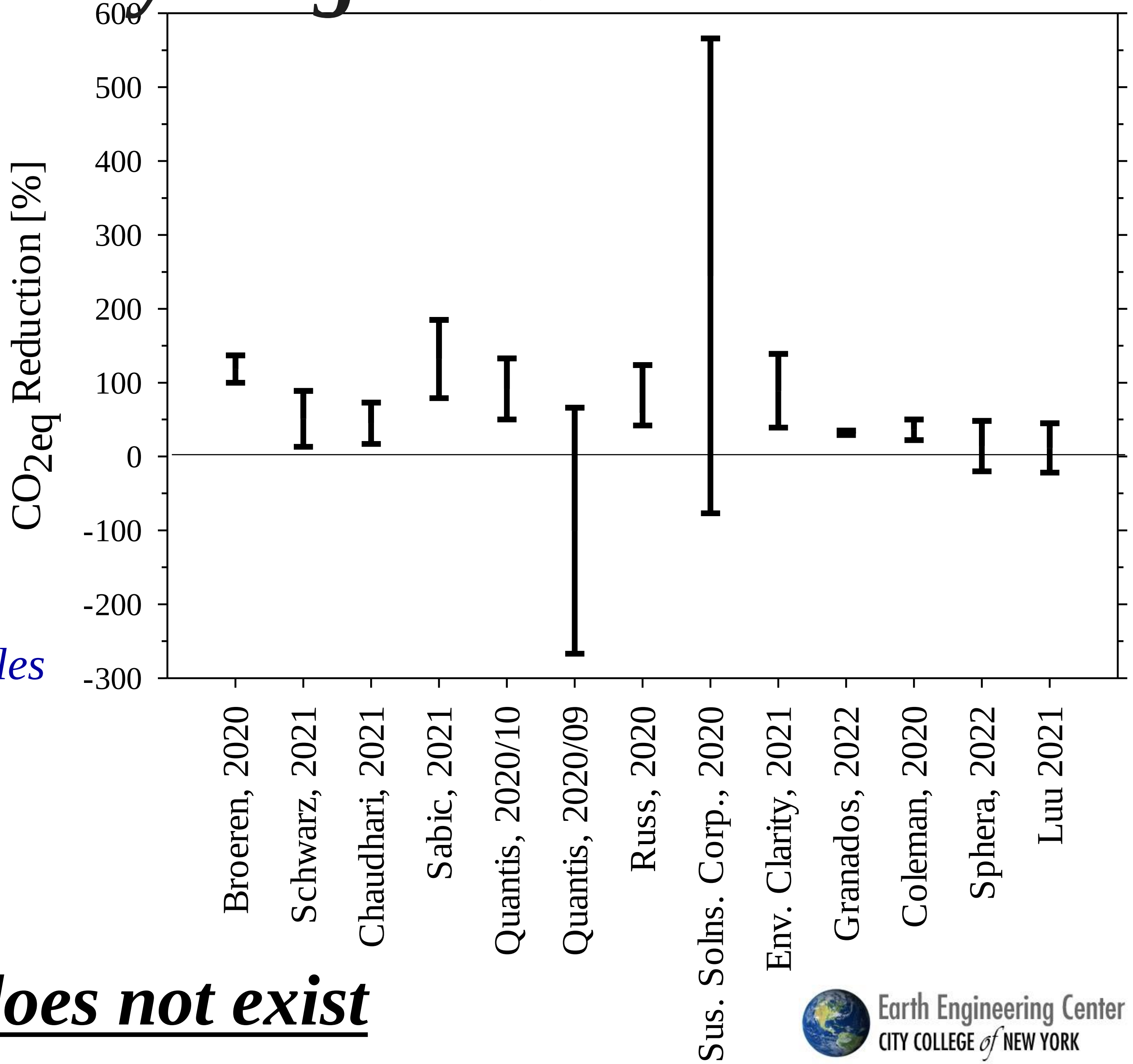
LCA BLUF: Advanced Recycling Reduces GHGs

- *Wide range of possible outcomes*
  - *Ranges capture results of boundaries and benchmarks assumed*
- *Majority of scenarios show GHG reduction*
  - *Some show increases in GHG emissions*
- *Details of each LCA are important*
  - *Scenario comparisons contain multiple variables*



<u>Average or representative value does not exist</u>

Methodologies used for the LCA review

- 13 LCAs from Jan. 2020 to May 2022

  focused on recent LCAs → encompasses most recent data

- Incorporated a professional standard

  e.g. ISO or European equivalent

- LCAs had to contain broadly applicable results

  large regions with representative energy and used materials processing systems

- Pilot or commercial plants with input processing capacity

  ~216,000 Mtpy – glycolysis)

  ~22,000 Mtpy – co-gasification/reforming)

  ~100,000 Mtpy – methanolysis)

  ~200,000 Mtpy – pyrolysis

- Primary boundaries

  cradle-to-gate (i.e., resource extraction to factory gate)

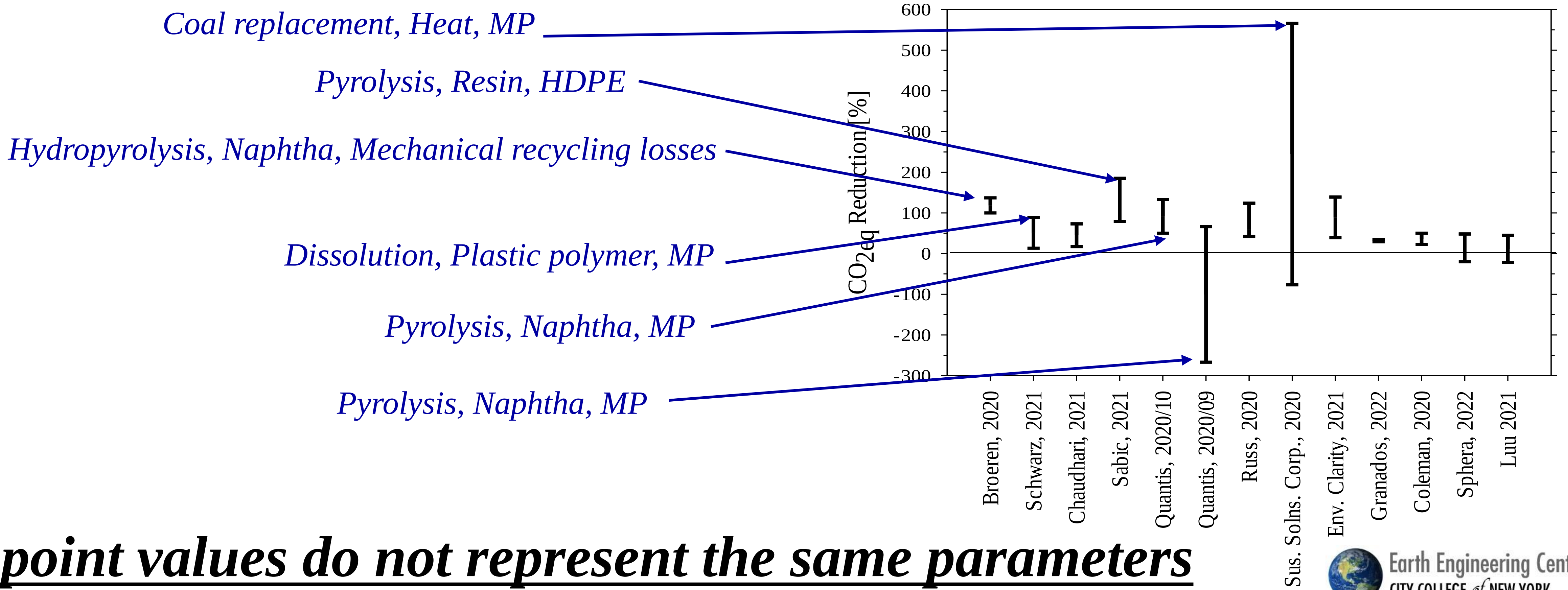
  cradle-to-grave (i.e., ending with product disposal)

  focus on utilization of AR technology to produce products not fuels or energy

<u>Selection criteria anticipated short time to technology maturity</u>

Some Detail of the GHG Reduction Findings

LCA	1	2	3	4	5	6	7	8	9	10	11	12	13
CO_2eq reduction min, max	100, 137	13, 89	17, 73	79, 185	50, 133	-267, 66	42, 124	-77, 566	39, 139	29, 35	22, 50	-20, 48	-22, 45



<u>End-point values do not represent the same parameters</u>

Analysis Example: One material, different AR

Figure 2 - Carbon footprint of treating recycling losses with various technologies, tonne CO_2 eq./tonne input

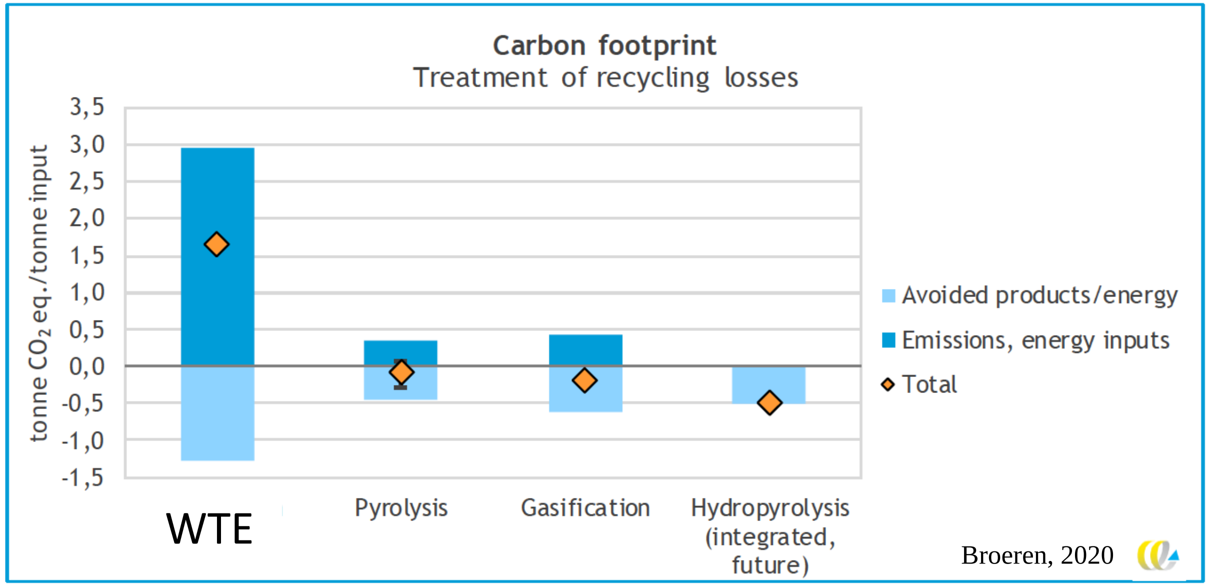
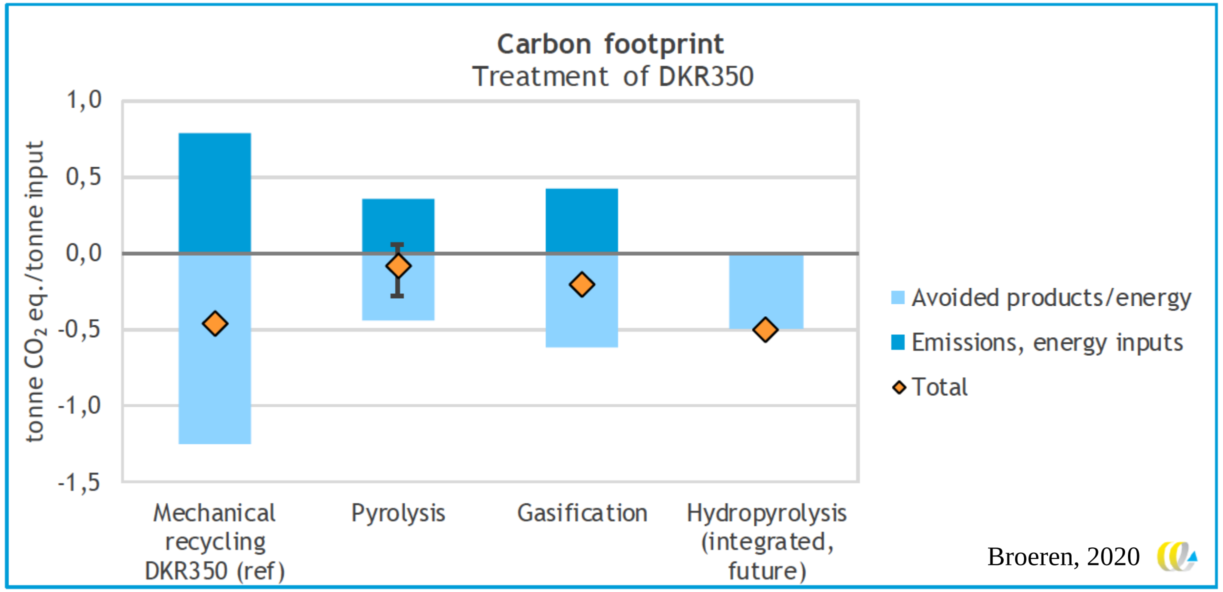


Figure 4 - Carbon footprint of treating DKR 350 with various technologies, tonne CO_2 eq./tonne input



- Mechanical recycling would be best, but practically very difficult for mixed plastic (MP) (i.e. multilayer)
- Three evaluated AR technologies outperform WTE in terms of CO_{2eq} emissions for MP that cannot currently be mechanically recycled.
- Pyrolysis performs similarly to gasification (within its range of error). Integration of projected future process efficiency gains further reduces CO_{2eq} emissions,

Mixed plastics processed with AR technologies are preferred

Analysis Example: One AR, different material

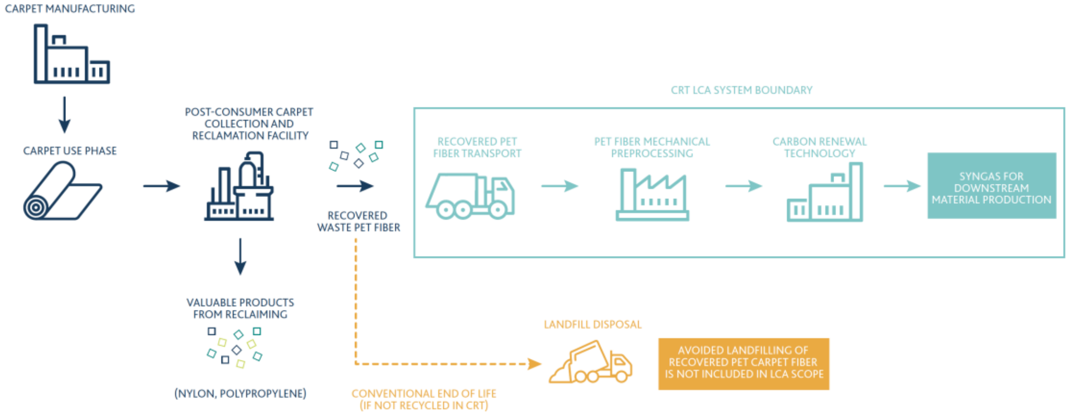
Co-gasification technology (plastic + coal)

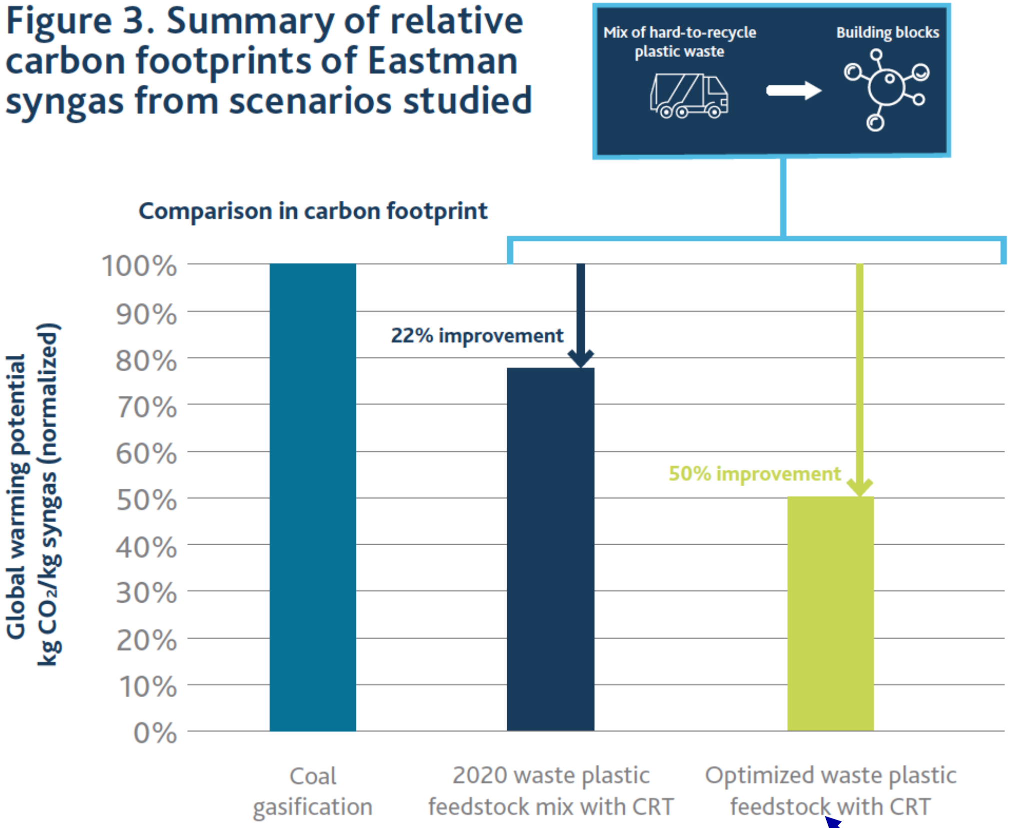
<u>Many input feedstocks:</u>

- Post-consumer polyester carpet fiber
- Pre-consumer cross-linked polyethylene scrap
- Postindustrial cellulose acetate plastic scrap

<u>All produce the same output intermediates:</u>

- Syngas (→ further intermediates and products)





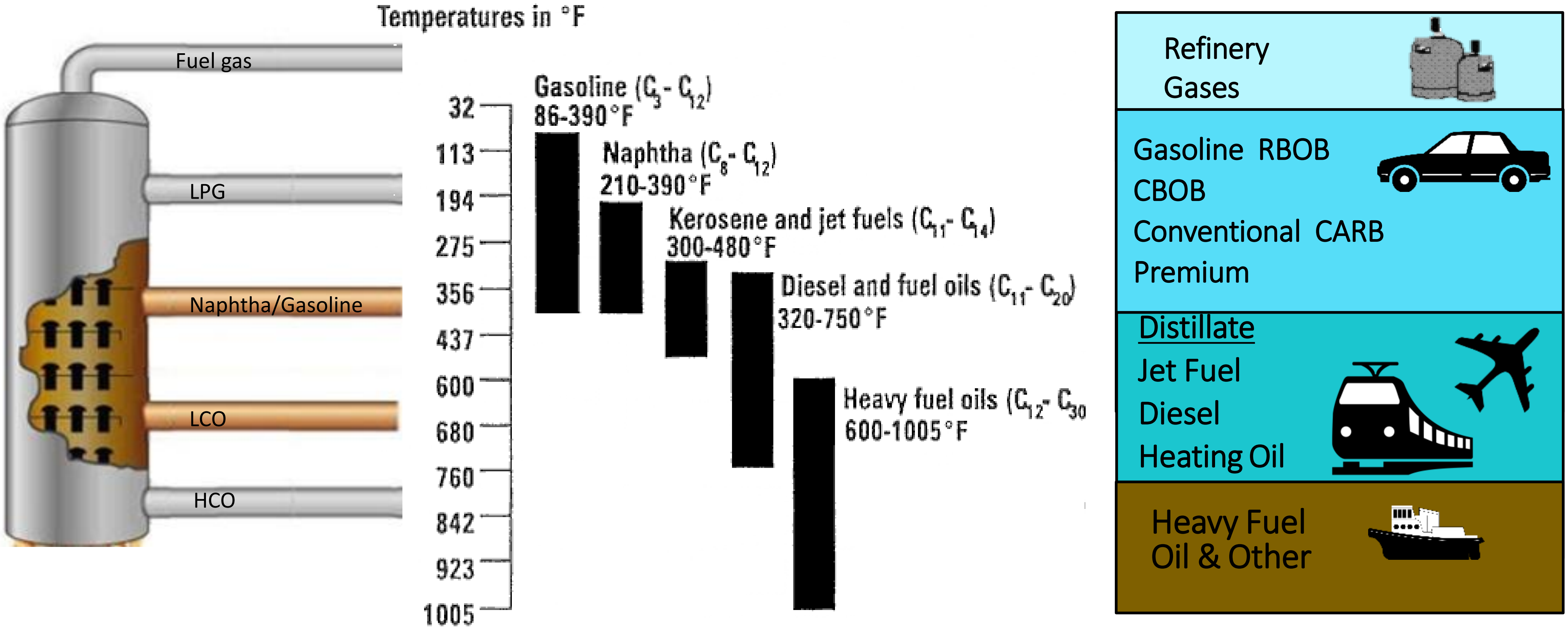
Coleman, 2020

Commercial weighted avg of CRT feedstocks for 2020 operating plan

*Optimized supply chain of feedstock sourced within **500 miles***

<u>The 'best' material is closest proximity to technology</u>

Integration with Current Infrastructure Exists

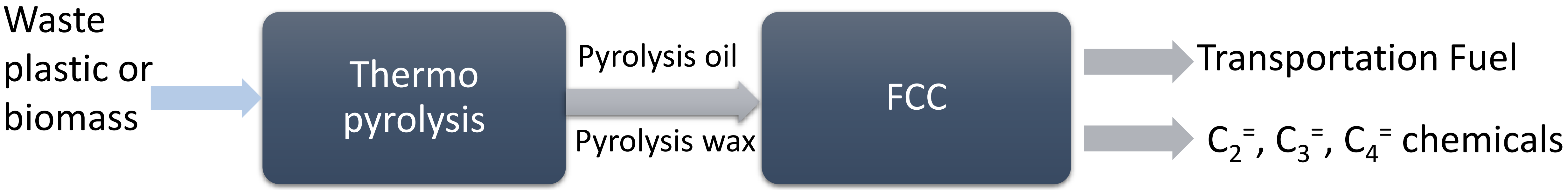


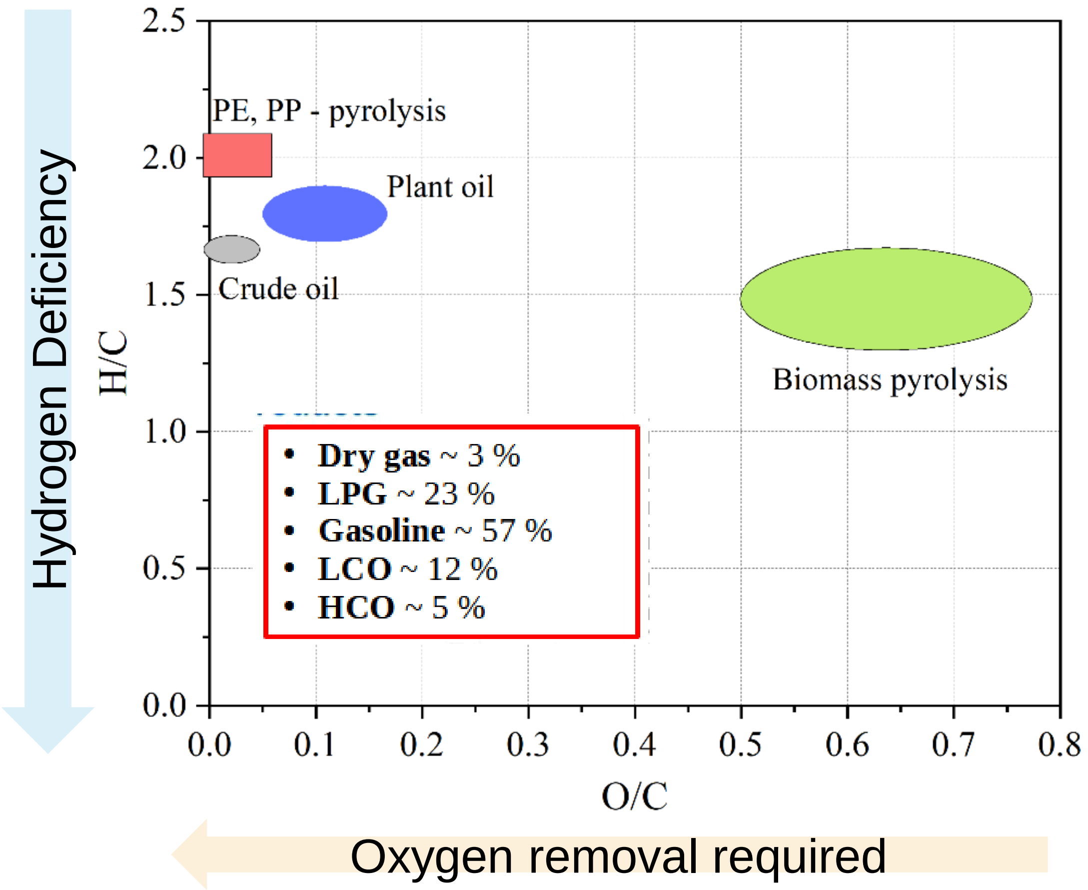
Refining industry is essential for providing the world's platform chemicals and transportation fuel.

Refiners are exploring waste plastic pyrolysis-oil (py-oil) & biogenic feeds for co-processing in FCC.

Catalytic cracking (FCC) can process pyrolysis oils from plastics

Infrastructure Integration Challenges Exist



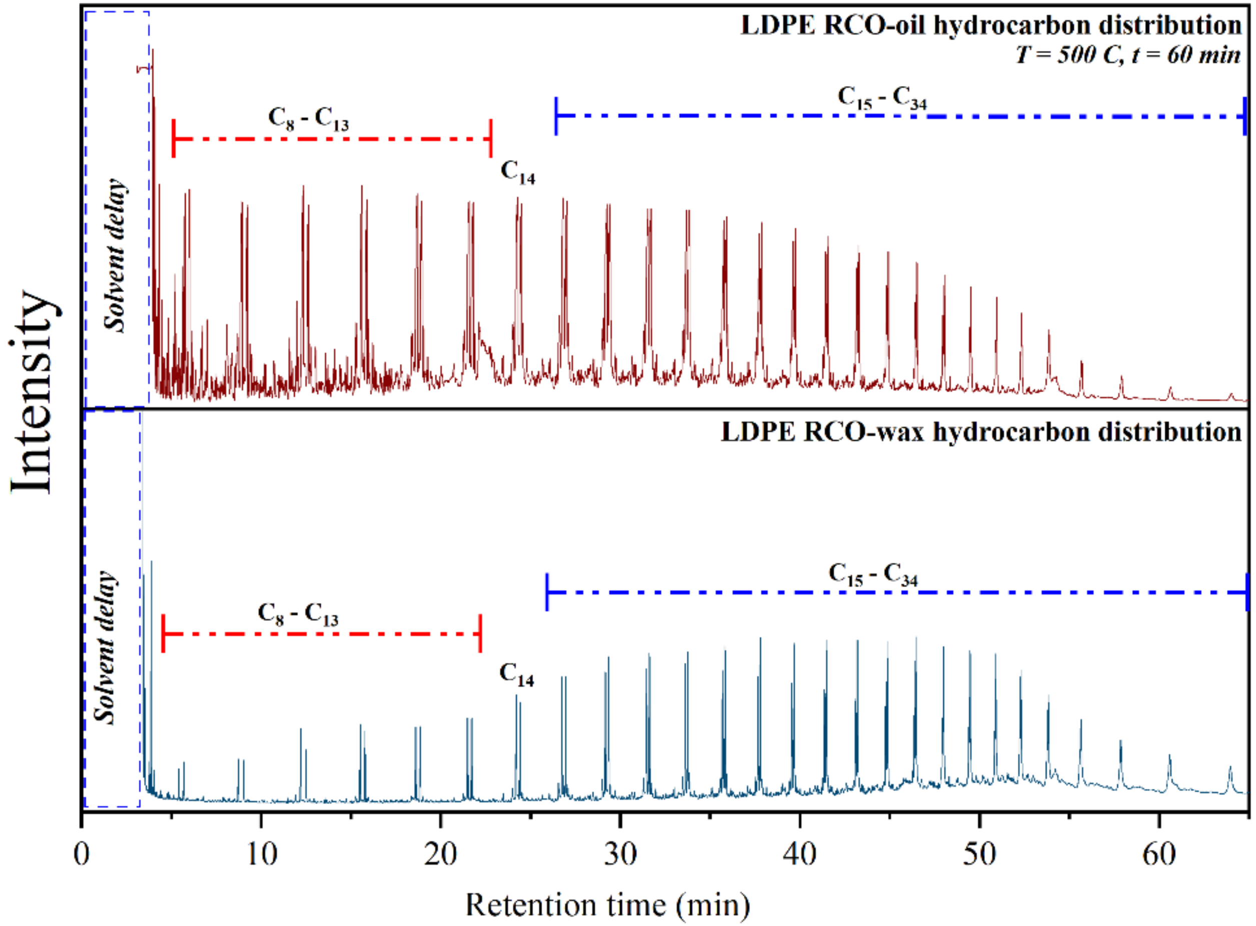


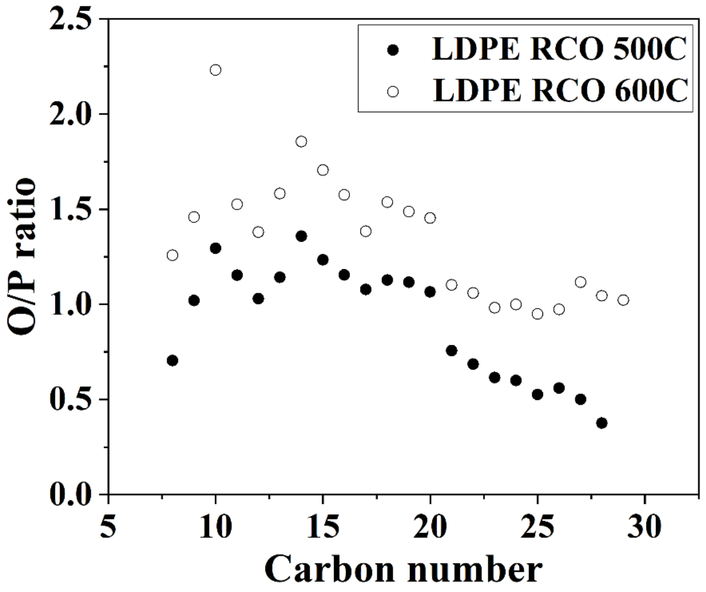
- FCC → production of transportation fuels and commodity chemicals
- FCC units process a variety of gasoil feedstock with varying contaminant levels
- As a result, the use of **renewable and recyclable py- or crude oils (PYOIL/RCO)** such as the pyrolysis oil obtained from waste biomass and plastics is explored

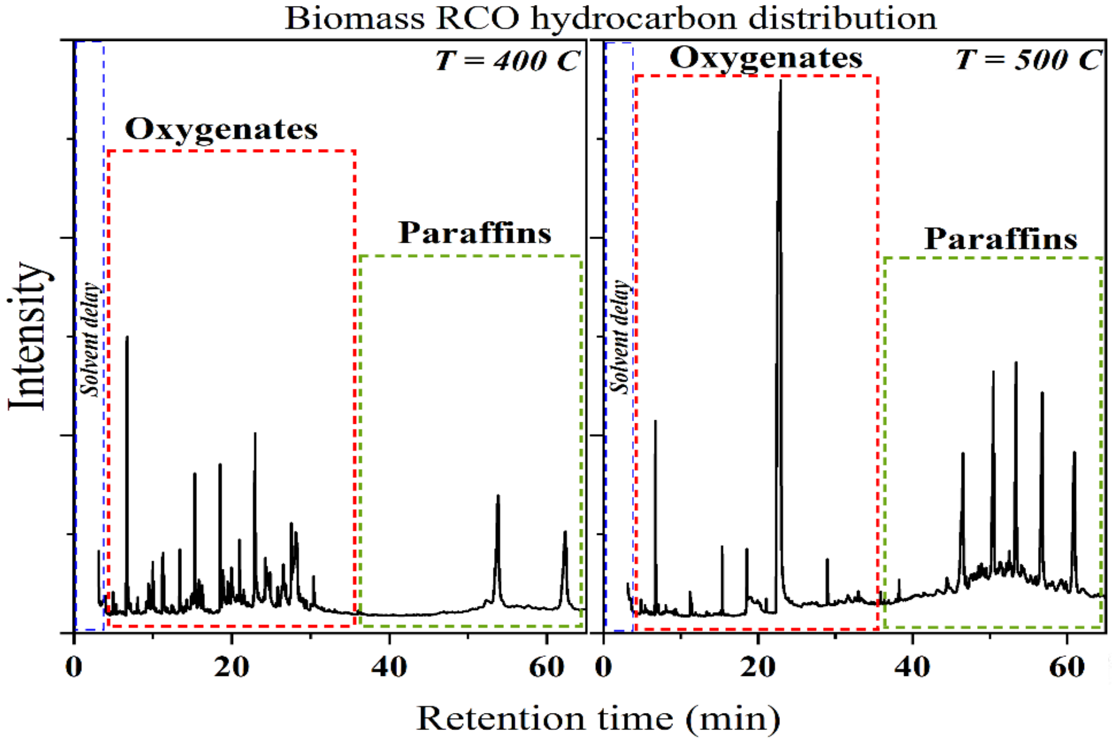
<u>Bio-based pyrolysis oils present challenges:</u>

- ***High oxygen content***
- ***Metals → catalyst fouling***

Pyrolysis product characterization







Plastics:

- Olefin/Parrafin ratio increases with increasing temperature

Biomass:

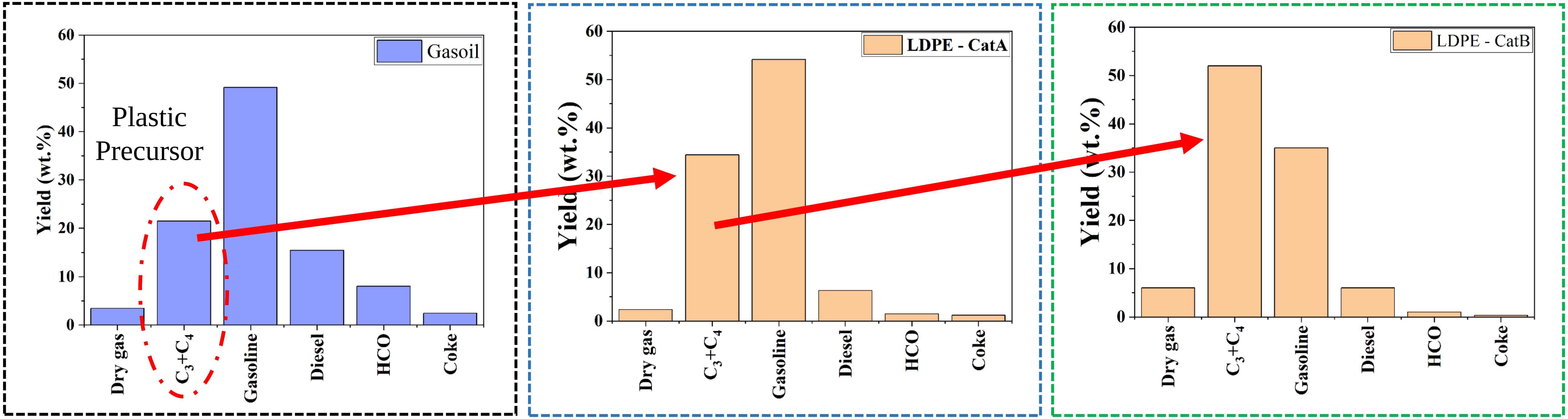
- Increasing temperature, decreases variety of oxygenated compounds.

FCC catalyst selection determines product mix

Catalyst A yields for conventional gasoil

BASF catalyst designed for transportation fuel production – Catalyst A

BASF catalyst designed for C_3-C_4 chemicals production – Catalyst B



<u>Catalyst formulation can be tailored to provide desired products</u>

- Cracking of polyethylene derived pyoil = higher yields of C_3-C_4 species, compared to the conventional gasoil cracking
- Catalyst A yields increased fuel; Catalyst B yields increased olefins

Can achieve ~50% of plastic recycling with existing technology!

Summary

- Advance Recycling (AR) technologies and processes must be evaluated on a specific “use-case”

    A single value does not accurately reflect the wide range of results

    Ranges within a given study may not have the same parameters for the maximum & minimum

- Choice of end-point is important (waste, produce, fuel, etc)

    Other environmental impact areas are dominated by beneficial results but are quite uneven

- Goal of AR must be chemical precursors to truly be considered recycling

    Fuel production is OK, but fossil CO_2 is eventually emitted

- Current infrastructure exists for large commercial scale deployment now

    Feedstock consistency and supply must be robust

<u>Focus now must be on capturing plastic to supply technologies</u>

<u>A specific LCA must be done for the system of interest</u>

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