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Thermal cracking for recycling of plastics and contaminated pyrolysis oils

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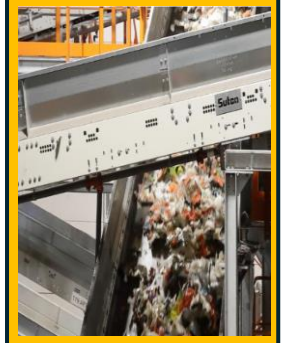
Chalmers University of Technology

The steam cracking step is the feedstock limiting

Plastic Waste

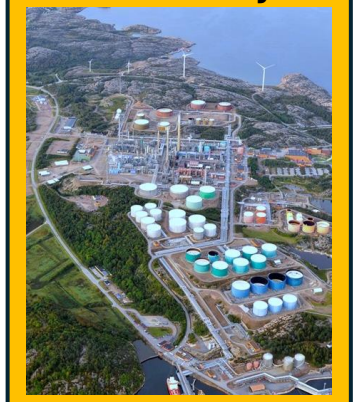
Advanced Sorting



Pyrolysis

Hydrogenation

Refinery



Steam Cracking

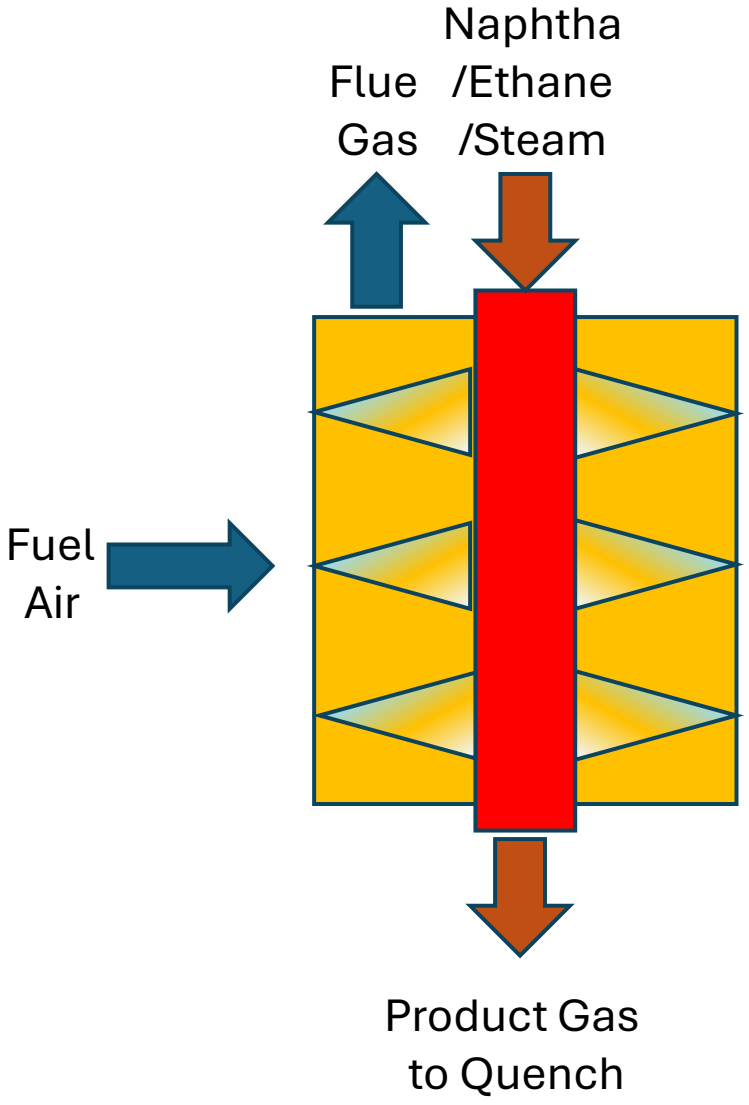
Fractionation

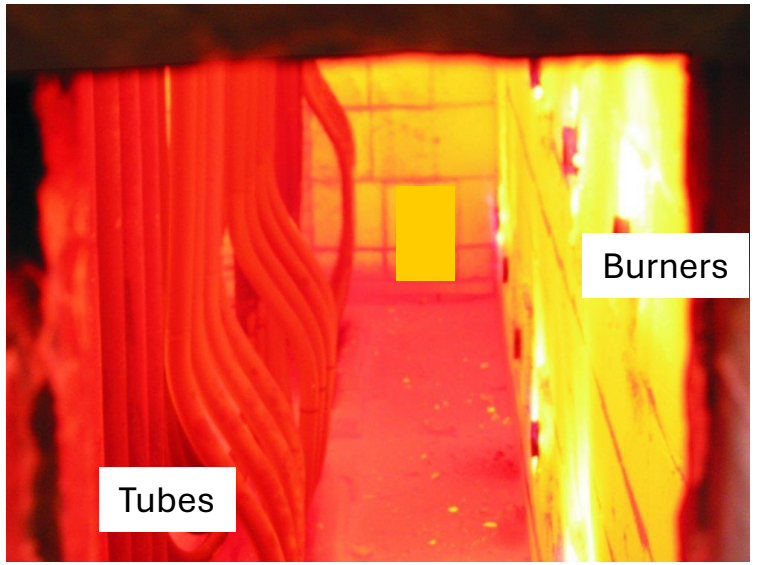
Olefins and other concentrated gases

Petro Chemical Cluster

Is it possible to design a steam cracker process that can handle **contaminated, charring, and ash-containing materials**, and produce a gas that can be sent to the fractionation unit?

Tubular Steam Cracker





How can I create a **moving heat transfer surface** that is continuously reheated, regenerates and is capable of transporting away ashes?

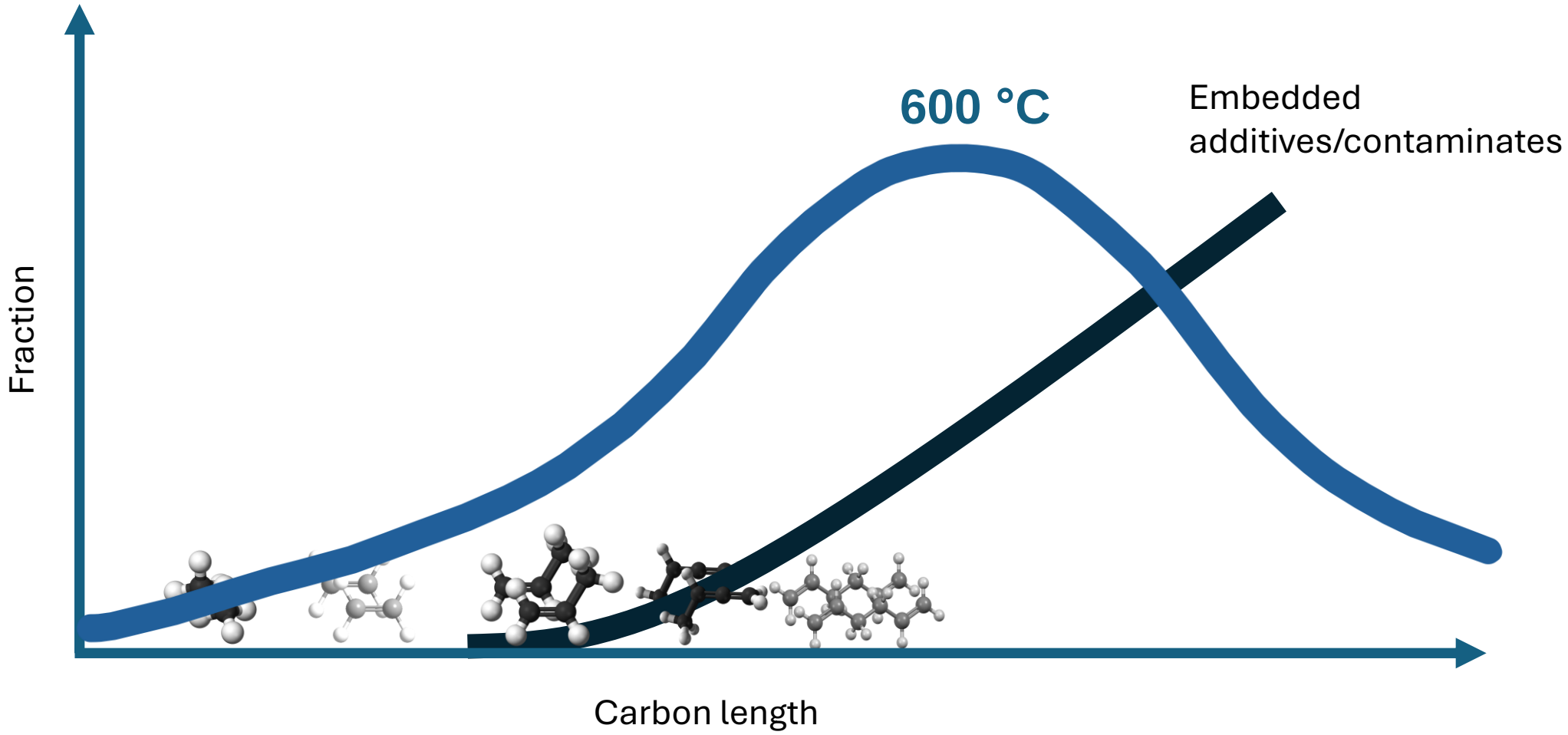
How can I create a wall that is continuously reheated, regenerates and is capable of transporting away ashes?

Regenerated and heated bed material

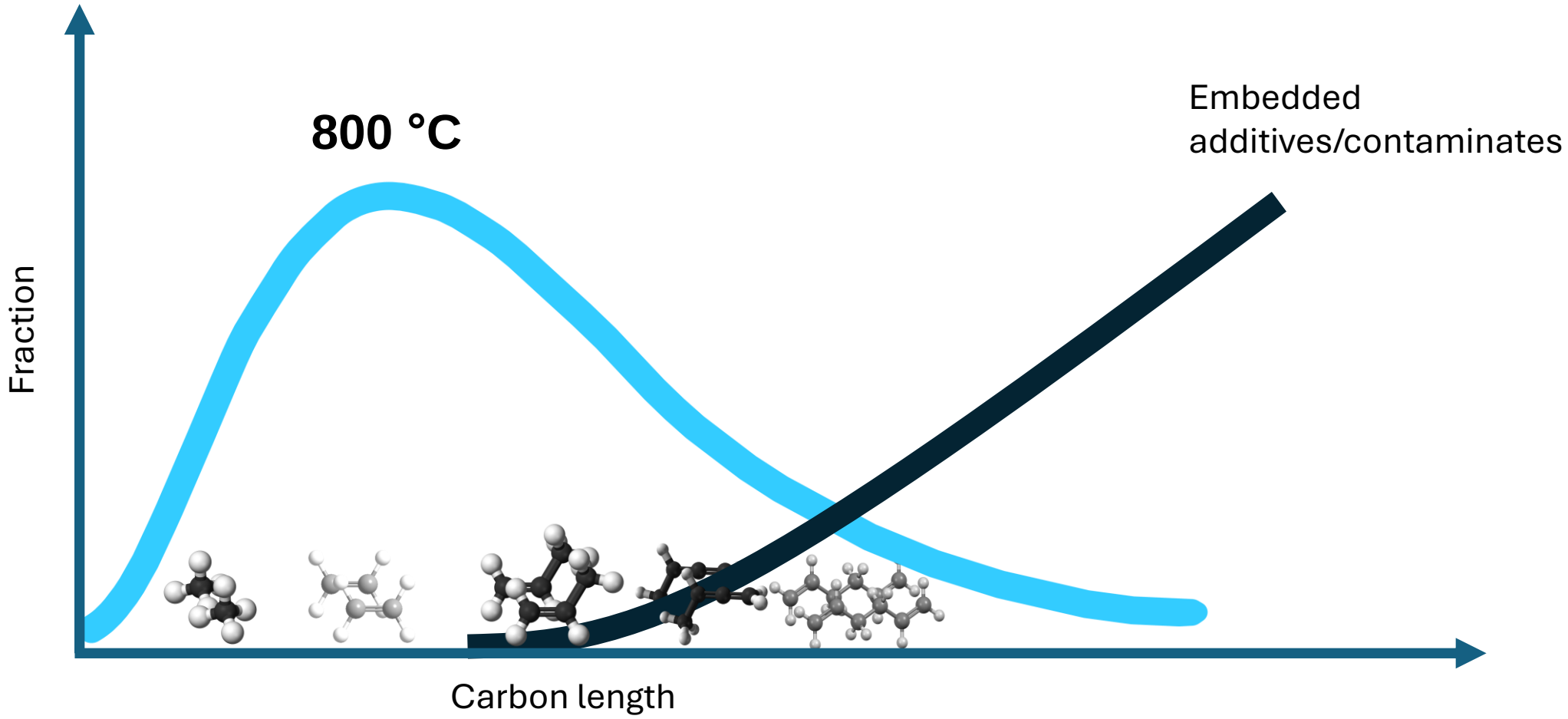
Contaminated, cooled down bed material

Moving heat transfer surface

Gaseous contaminates

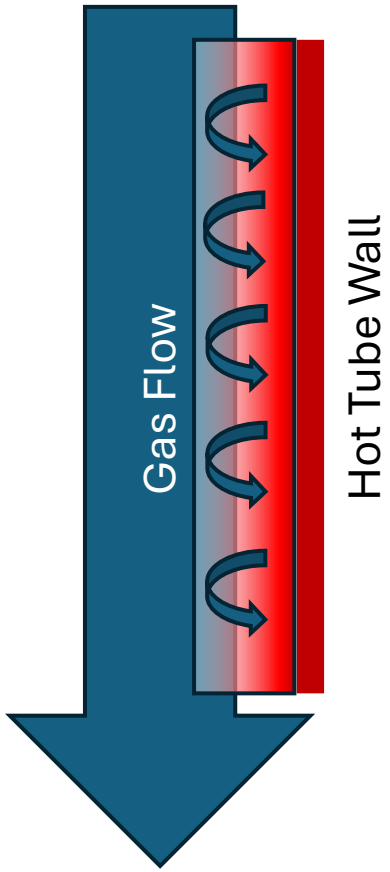


Gaseous contaminates



Residence time

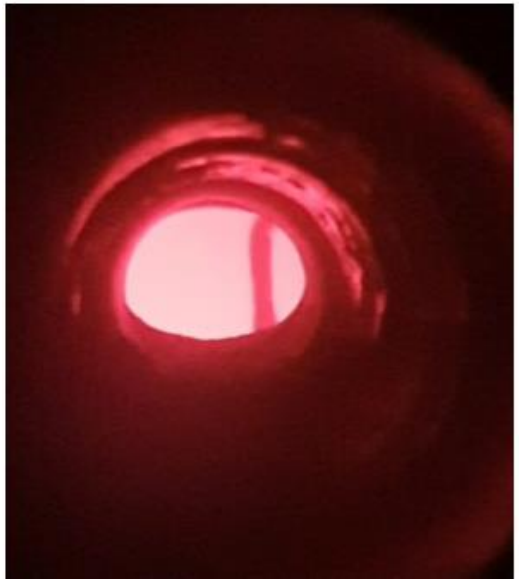
Traditional Tubular Steam Cracking

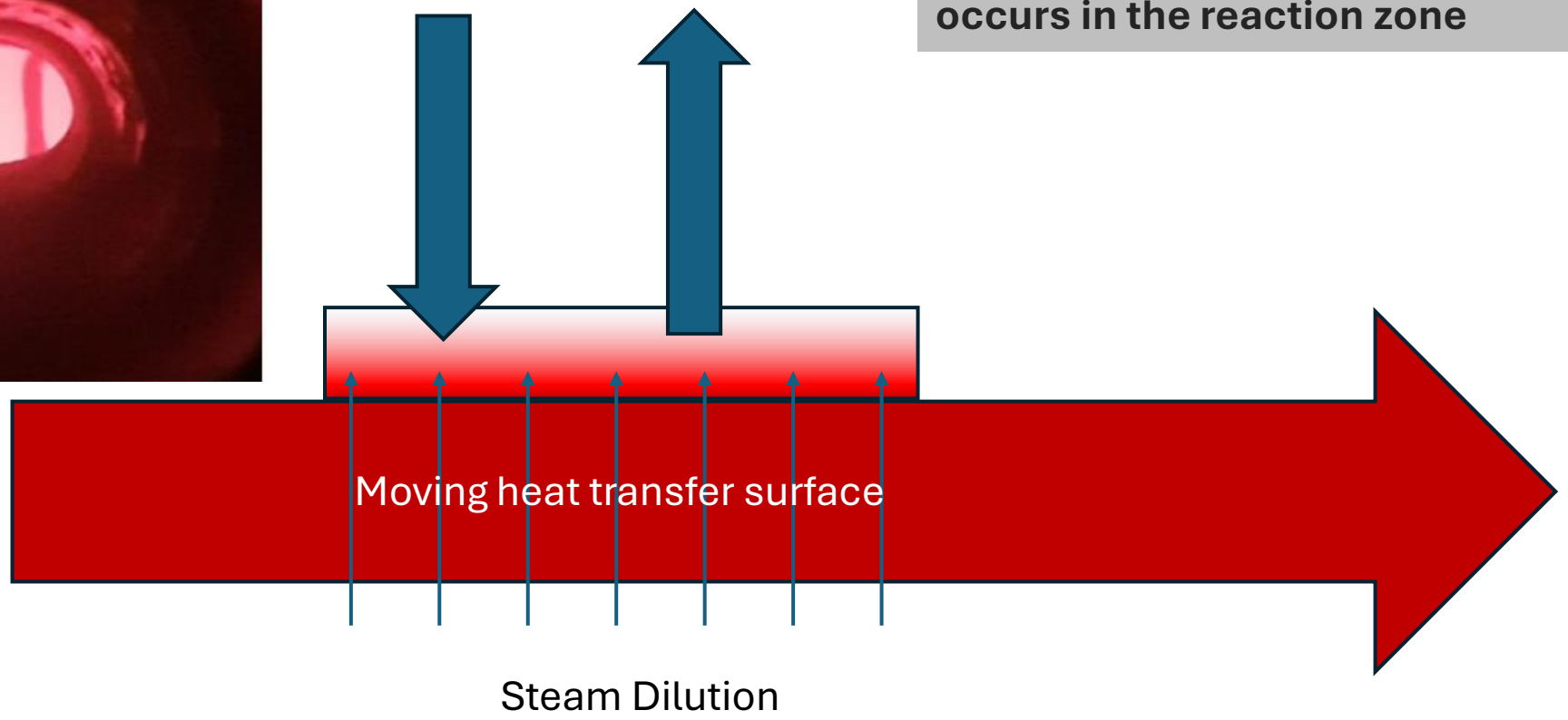


Heat from the wall drives the exothermic reactions

A longer residence time means that a gas pocket hits the heated wall more frequently

Residence time

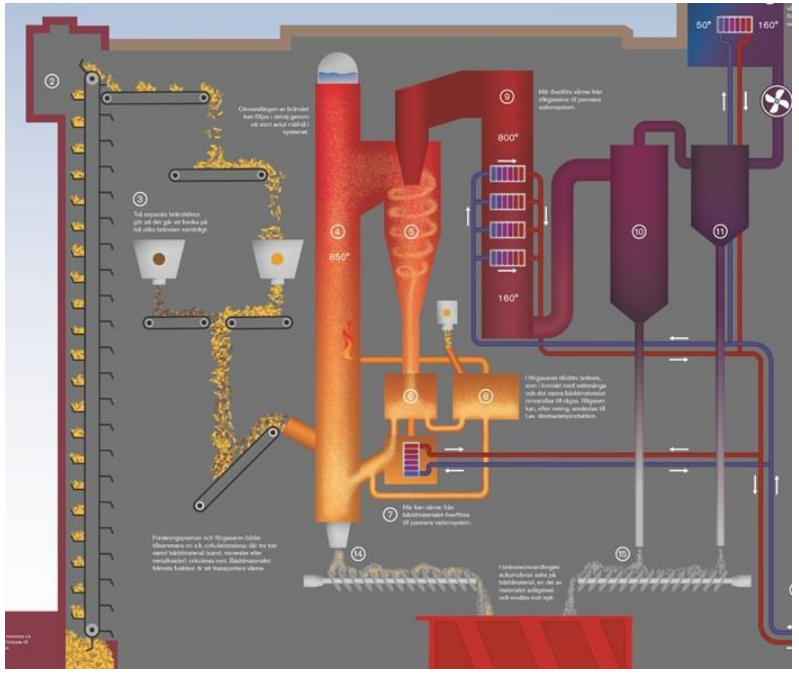


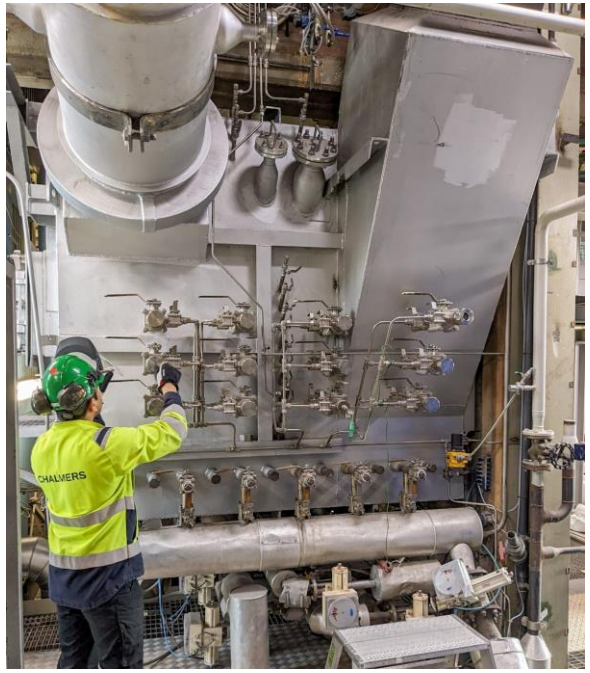


The feedstock to be cracked is heated only once, and the dilution occurs in the reaction zone

Reactor System at Chalmers Mimics this System

12 MW research boiler





Integrated Steam Cracker
~200 kg carbon/hour
Corresponds to
230 kg PE per hour, or
320 kg PET per hour

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Example of Feedstocks tested

Plastic Waste

PE/PP

ASR

Tetra Pak

Textiles

Shredded Tires

Medical Wastes

Naphtha

Pyrolysis Oil

Vegetable Oil

Tall Oil Pitch

Animal Fat

Crude Oil

Nylon airbags

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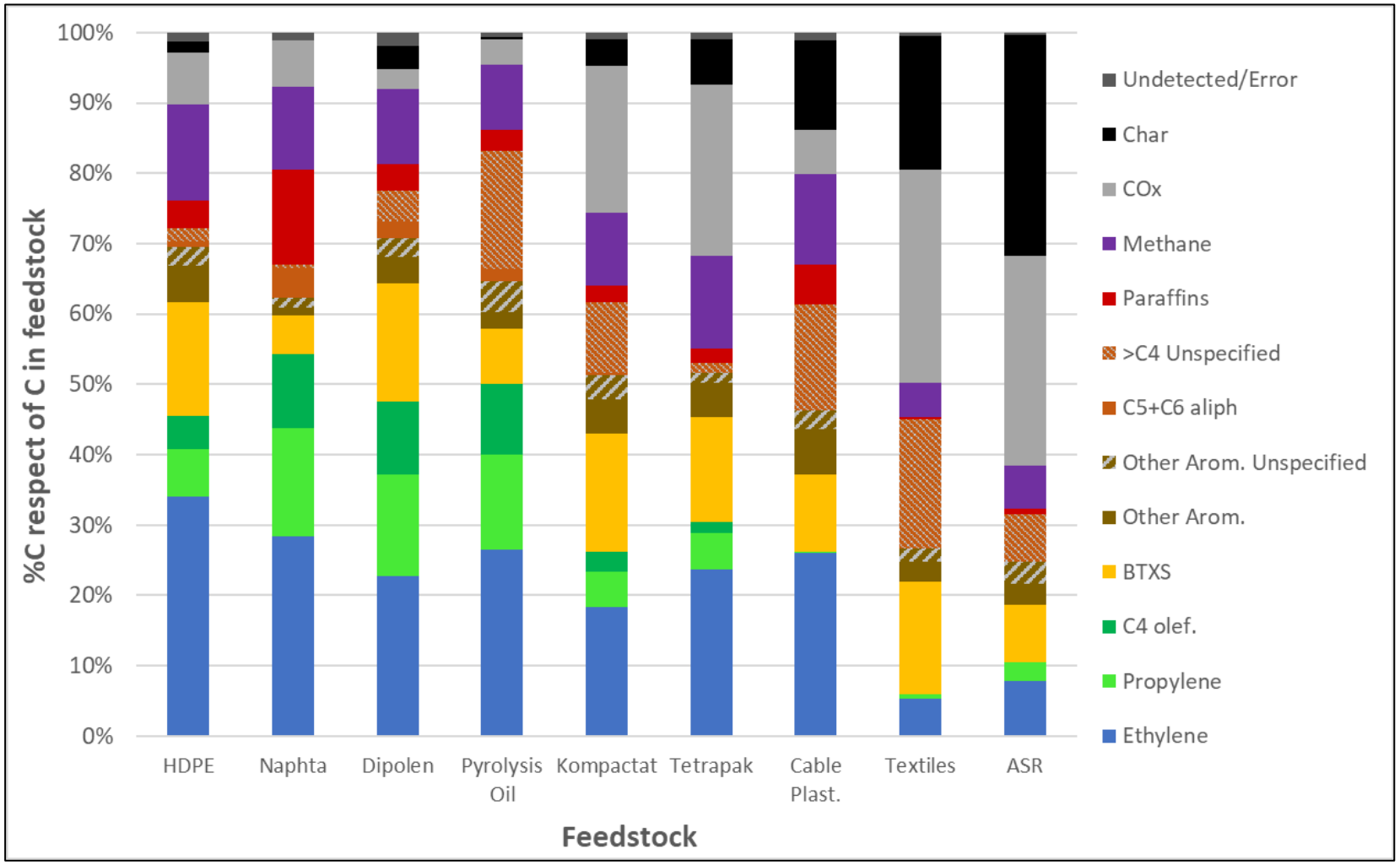
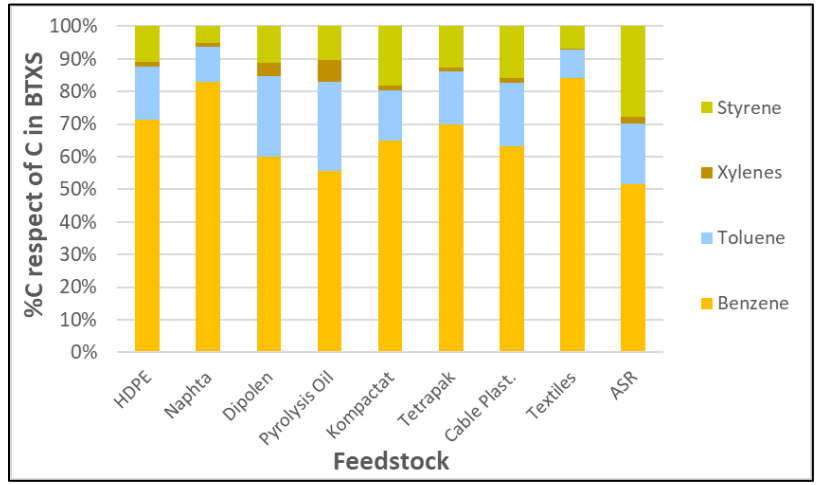
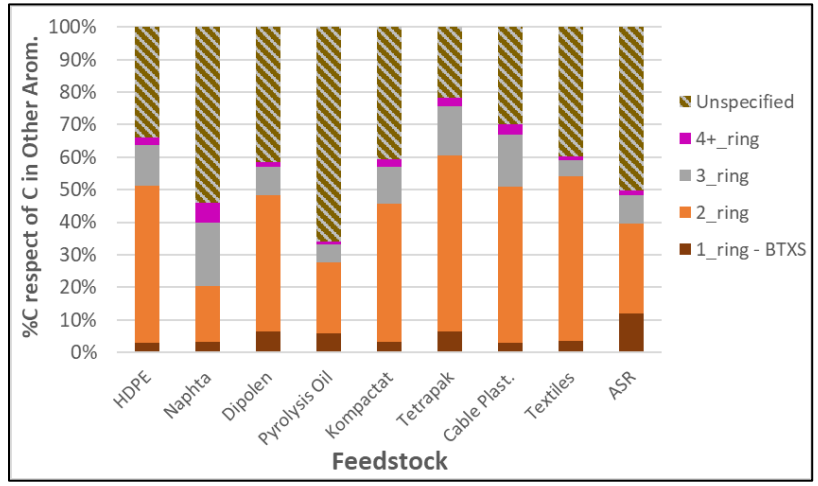
Species Carbon Conversion for different feedstocks



BTXS Fraction



Other Aromatics Fraction



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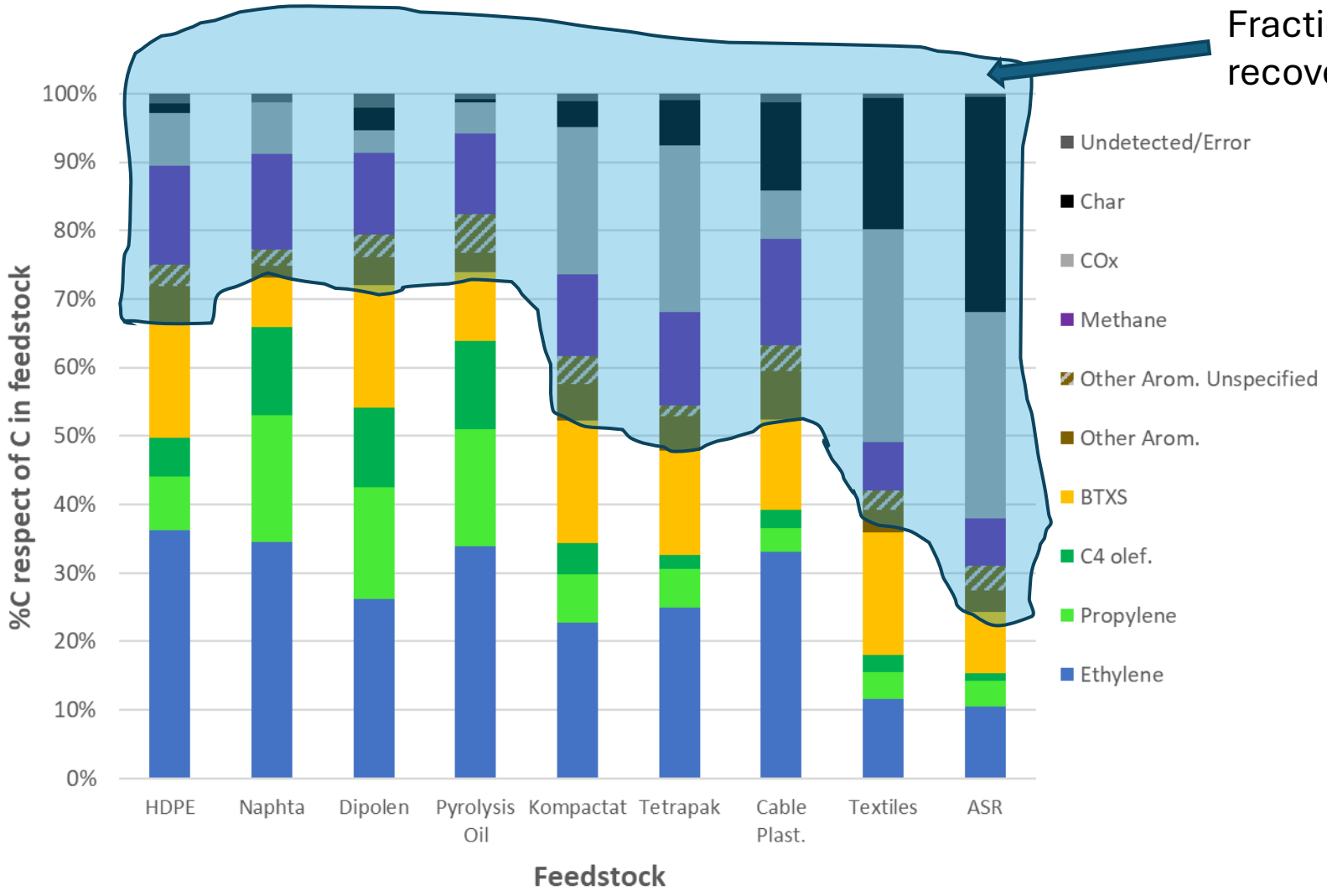
Estimated End Product Distribution



Fraction that need to be recovered via carbon recovery process, if not used as fuel

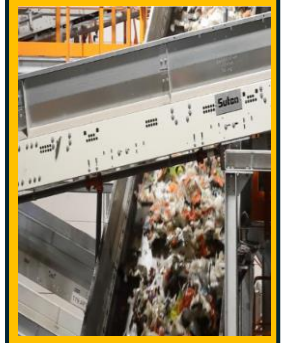
Paraffins
C4+ aliphatics
→ Cracker

Char
Other Aromatics
→ Combustor

The steam cracking step is the feedstock limiting

Plastic Waste

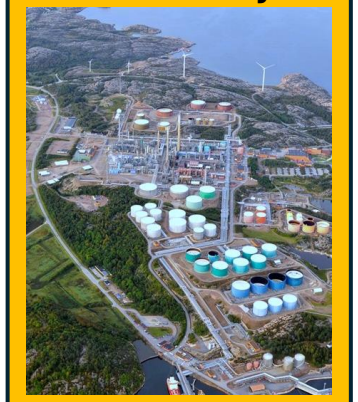
Advanced Sorting



Pyrolysis

Hydrogenation

Refinery



Steam Cracking+

Fractionation

Olefins and other concentrated gases

Petro Chemical Cluster

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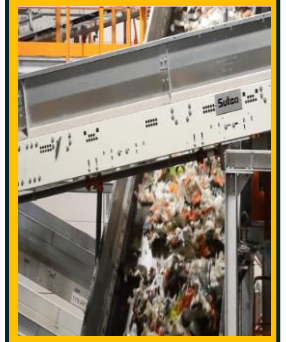
Simplifications that can be achieved by introducing Fluid Bed Steam Crackers

Plastic Waste
+ Other organic feedstocks

~~Advanced~~ Sorting



Pyrolysis

~~Hydrogenation~~

Refinery

Fluid Bed Steam Cracking + Gas conditioning

Fractionation

Olefins and other concentrated gases

Petro Chemical Cluster

Concluding remark

- To replace fossil feedstocks with recycled alternatives **at scale** in existing petrochemical clusters, more robust steam cracker processes need to be introduced

- A **fluidized bed** system offers **a viable and robust solution**, as now is proven at a semi-industrial scale.

- Experimental evidence from our work demonstrates that this type of system performs **equally well** on naphtha as conventional naphtha crackers, while also handling a wide range of solid and liquid feedstocks.

- For a commercial process, depending on local conditions, it would be beneficial to use solid plastic waste or crude pyrolysis oil. The pyrolysis oil **do not require hydrogenated or decontaminated beforehand**, which expands the range of usable feedstocks and simplifies decentralized pyrolysis processes.

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Research Team at Chalmers

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Adam Sköld


Renesteban Forero


Iacopo Aloisi


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Ivan Gogolev


Nidia Diaz Perez

Research Engineers


Jessica Bohwalli


Rustan Hvitt


Johannes Öhlin

Process PhD & PostDocs


Tharun Roshan Kumar


Johanna Beiron


Judit Fortet Casabella

Available literature and video

- Circular use of plastics-transformation of existing petrochemical clusters into thermochemical recycling plants with 100% plastics recovery – ScienceDirect

  https://doi.org/10.1016/j.susmat.2019.e00124
- Co-recycling of natural and synthetic carbon materials for a sustainable circular economy – ScienceDirect

  https://doi.org/10.1016/j.jclepro.2022.132674
- Steam Cracking in Dual Fluidized Beds - One Step Towards Complete Recyclability of Plastic Waste Using Thermochemical Conversion

  https://research.chalmers.se/publication/542360/file/542360_Fulltext.pdf
  https://doi.org/10.1016/j.cej.2024.156892

- Video

Waste – from a problem to a valuable feedstock - YouTube

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Industrial partners that has contributed to the research

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Enviro

Mölnlycke®

STENA RECYCLING

BLÅKLÄDER WORKWEAR

essity

Tetra Pak®
PROTECTS WHAT'S GOOD

Fiskeby 1637

Autoliv

Public funding

Swedish Energy Agency

Climate-Leading Process Industry

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VINNOVA

Area of Advance Energy
Chalmers University of Technology