CHALMERS

MASTER THESIS PROJECT/RESEARCH INTERNSHIP – SPRING 2021

MODELING FUTURE REFINERIES ON THE PATH TO NET-ZERO

The Intergovernmental Panel on Climate Change (IPCC) concluded (IPCC SR15, 2018) that the global temperature rise should be limited to 1.5°C above pre-industrial levels to minimize the effects of climate change such as loss of human life. In all of the outlaid scenarios P1-P4, greenhouse gas (GHG) emissions must fall significantly before Year 2030 in order to achieve this goal, hence the urgency for large-scale mitigation across all sectors. The transport sector stands globally for about 25% of carbon emissions (IEA, 2020), and about 32% of GHG emissions in Sweden. Ambitious climate policies have been implemented in many countries. The EU aims to be climate-neutral by 2050 (EC, 2020), whereas Sweden is aiming for net-zero emissions by 2045. Sweden's largest domestic petroleum refining company, Preem AB, responsible for ca. 80% of domestic fuel sales, has adopted corporate goals in line with the Swedish national targets. Preem has set GHG emission reduction targets that comprise its entire value chain (scope 1-3, "well-to-wheel"), where emissions from crude oil extraction, conversion, and final distribution and end-use currently correspond to 12%, 3%, and 85% of the total value chain emissions respectively (Preem, 2019). Various mitigation technologies, e.g. electrification (inter alia green hydrogen), renewable feedstocks (e.g. pyrolysis oils from forest residues) as well as carbon capture and storage (CCS) are available to meet the ambitious goals in 25 year's time. To address the largest value-chain emissions, the combustion of refinery products in aviation, shipping and road transport, a vast import and conversion of renewable feeds is required which have different composition and properties than the current fossil feedstock. The inclusion of CCS and possibly green hydrogen production will undoubtably affect the operation and overall flows of energy and GHG emissions in future refinery value chains. Alternatively, geological offsets can be sought by refinery operators, i.e. the purchase of decarbonized fossil feedstocks from upstream oil & gas extractors which sequester a rising fraction of extracted carbon. National policy mechanisms will have to be implemented that guarantee that the targets will be met – noteworthy in this context is the notion of mandatory sequestration for fossil fuel suppliers, as laid out by Oxburgh et al. (2016) and Allen (2020).

AIM

The overall aim of the proposed project is to analyse the interplay between different mitigation options in future refinery settings and their effect on energy consumption, feedstock conversion, and value-chain emissions. More specifically, the project will investigate how to integrate CCS, green hydrogen and renewable (biogenic) feedstocks into a refinery and how the mitigation technologies need to be ramped up over time to reach the Swedish climate goals, in the form of a roadmap analysis. Interesting aspects to be investigated include the mix of desirable refinery products and the role that negative emissions can play (potentially relevant post 2045). The work will include the development of a simplified model of a complex refinery, based on feed and product compositions and simplified models of the main refinery unit operations (e.g. crude distillation, cracking, hydrotreating, CO_2 separation etc.). Real data or a detailed flow-sheet model will be used as reference case to develop and validate the simplified refinery model.

PRELIMINARY STRUCTURE OF WORK

Below is a tentative structure of the work, which of course may change after initial discussions. Also, results of the initial work may change the focus of the work. The aim is to make a new contribution and to restrict the work to be within the scope of a MSc Thesis/research internship while maintaining a high quality.

- Establish a time plan for the project

- Initial literature review of refinery processes and existing refinery models
- Establishing a modeling framework (excel, matlab, etc.) and a process model of a reference case
- Evaluation of different scenarios (varying shares of mitigation options) and mapping of their performance in terms of energy consumption, feedstock conversion efficiency, value chain emissions
- Establishing of a roadmap for Swedish refineries that meets the 2045 target.
- Reporting

ORGANISATION

The proposed project may be performed by one or two students with a chemical or mechanical engineering (or similar) background at the Division of Energy Technology at Chalmers. The research group has a long history in working with carbon capture processes and process simulations. The following persons will be supporting the work at Chalmers:

Supervisors: Åsa Eliasson asa.eliasson@chalmers.se Tharun Roshan Kumar tharunr@chalmers.se

Co-Supervisor: Max Biermann max.biermann@chalmers.se

Examiner: Simon Harvey simon.harvey@chalmers.se

Timeframe: 5 months for M.Sc.; 4-6 months for research internship

Start: January 2021

Requirements: Background (B.Sc.) in chemical or mechanical engineering (or similar), thorough understanding of thermodynamics and chemical reactions as well as a basic understanding of refinery processes and.

For more information about the Divisions of Energy Technology check out our website:

http://www.chalmers.se/en/departments/see/research/energy_technology/Pages/default.aspx

References:

IPCC SR15, 2018 https://www.ipcc.ch/sr15/
IEA, 2020 https://www.iea.org/data-and-statistics/?country=WORLD&fuel=CO2%20emissions&indicator=CO2BySector
Preem, 2019 https://www.preem.com/globalassets/om-preem/hallbarhet/hallbarhetsredovisning/preem_sustainability_report_2019_eng.pdf
Oxburgh et. al, 2016 http://www.ccsassociation.org/news-and-events/reports-and-publications/parliamentary-advisory-group-on-ccs-report/
EC, 2020 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
Allen, 2020; TCCS Keynote by Prof. Myles Allen “Decarbonizing fossil fuels” https://www.youtube.com/watch?v=9SuAoU50uus#action=share