Towards Sustainable Aviation Fuel from CO_2: Energy Efficiency Assessment of the CO_2-to-Kerosene Pathway

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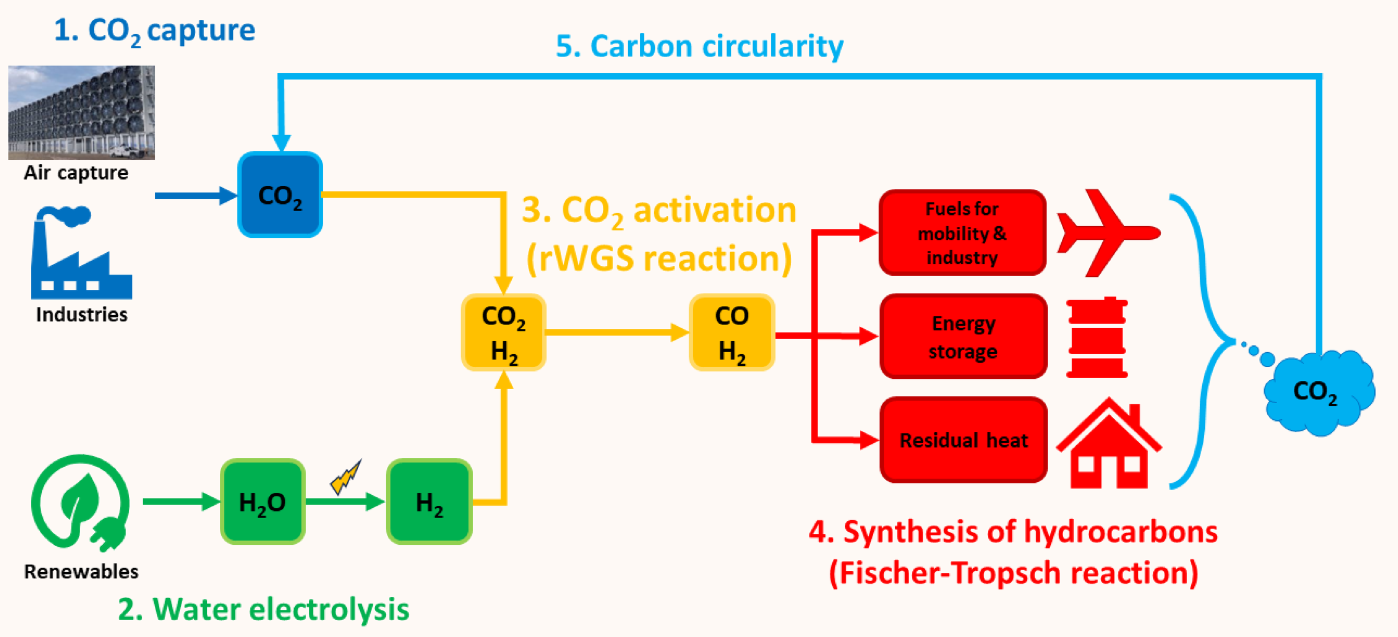
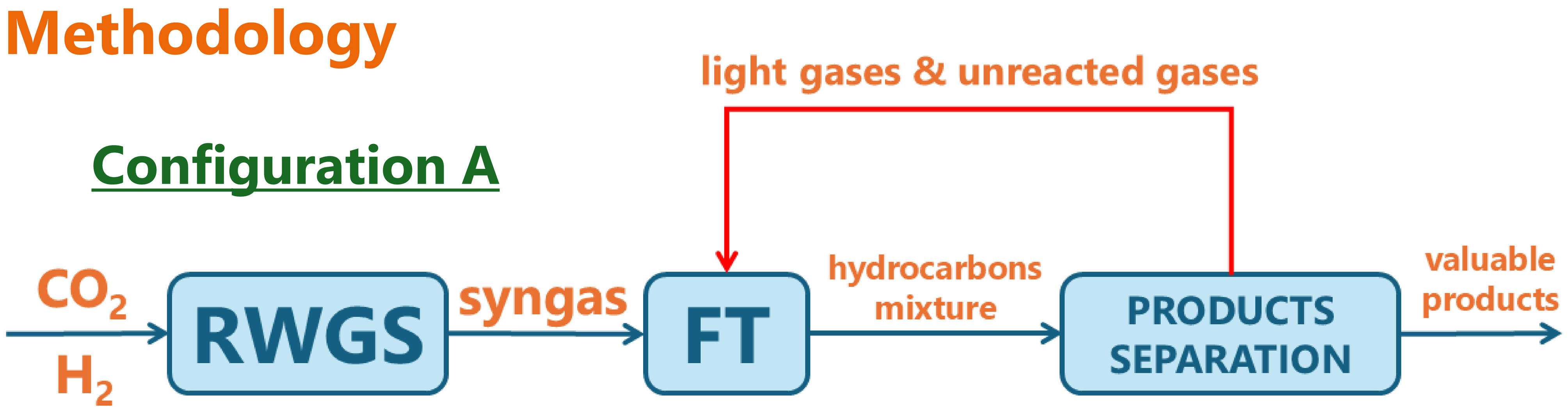
Context and Objectives

The Fischer-Tropsch (FT) process has continuously evolved over its 100-year history. Today, it stands out as a promising solution for synthesizing carbon-based fuels independently of fossil resources by replacing conventional coal or natural gas used for syngas production with **captured CO_2 and low-carbon H_2**. This approach is particularly relevant for sectors with hard-to-abate emissions, such as aviation. At ULiège, a **detailed Aspen Plus model** was developed to simulate the production of aviation fuel via a combination of the **reverse water-gas shift** (RWGS) and **low-temperature cobalt-based FT** reactions. The model incorporates advanced RWGS and FT kinetics and stoichiometry using **Aspen Custom Modeler blocks**. This work focuses on assessing the impact of a **recycling loop configuration** on Power-to-Liquid Efficiency (**PtLE**) and overall Energy Efficiency (**EE**).



Methodology

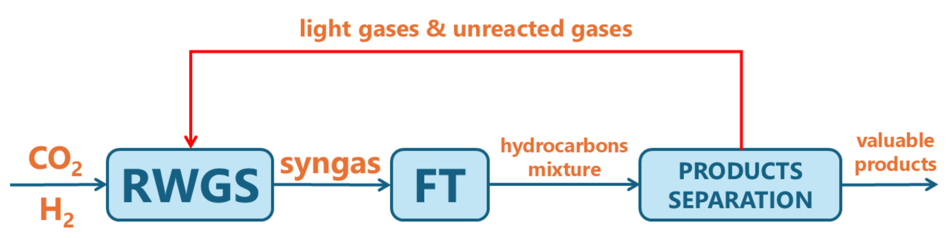
Configuration A



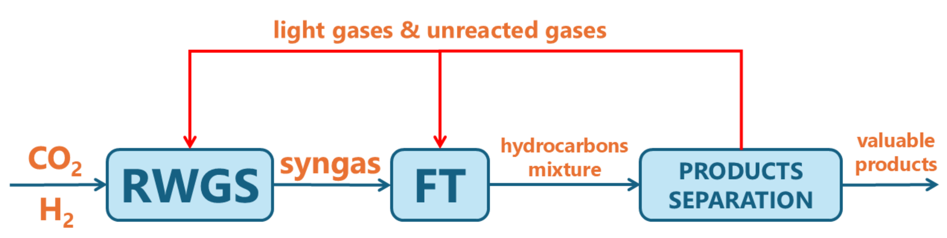
	RWGS	FT	Products separation
Temperature	850 °C	220 °C	5 – 150 °C
Pressure	20 bar	20 bar	2 – 20 bar
Modelling	Detailed kinetics incl. secondary reactions[1]	Detailed kinetics[2] and stoichiometry[3] incl. secondary reactions and deviations from ideal ASF distribution	Succession of flash separations

Alternative configurations for future work

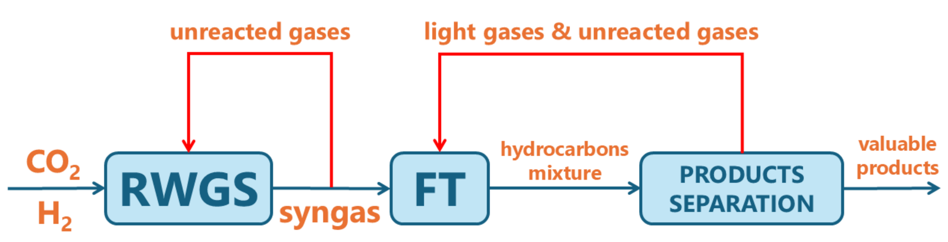
Configuration B



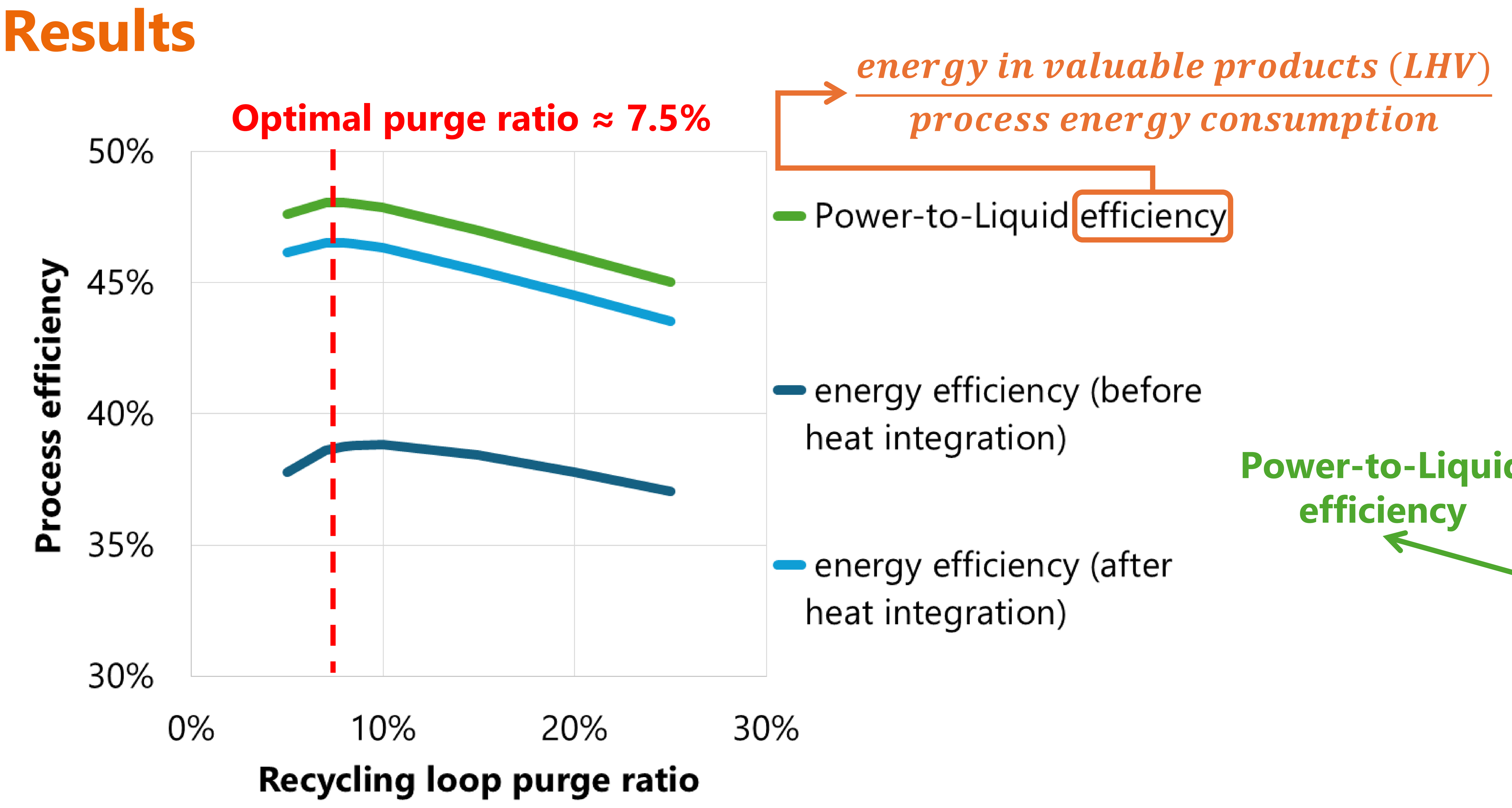
Configuration C

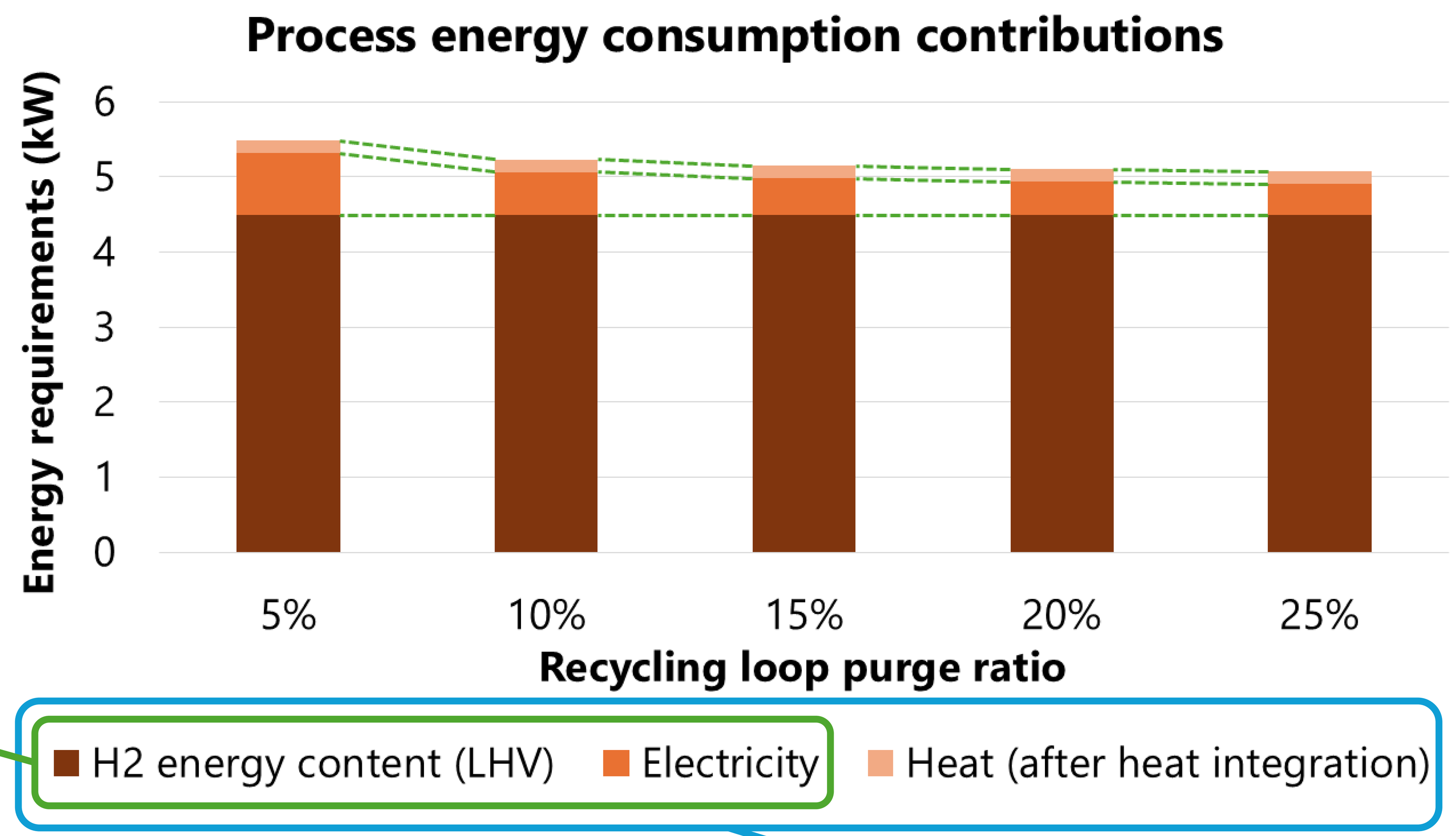


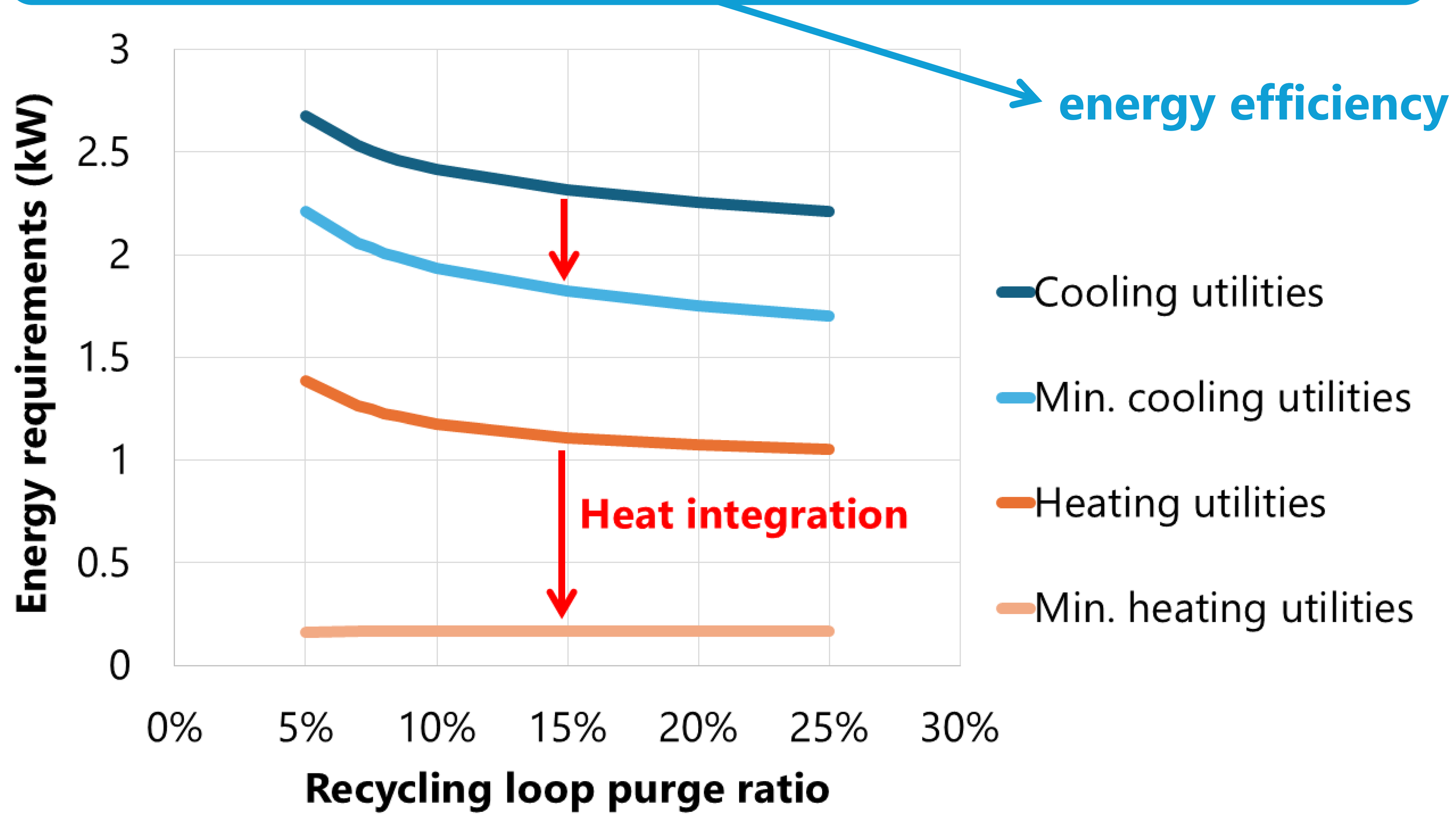
Configuration D



Results







- Decrease in efficiency at **low purge ratios**: due to increase in recycle flow rate, resulting in higher electricity consumption by the compressors
- Decrease in efficiency at **high purge ratios**: due to lower overall CO conversion, resulting in lower production of valuable products

Conclusion

This study highlights the significant impact of H_2 consumption and recycling loop design on overall process efficiency. An optimal purge ratio of approximately 7.5% was identified for the configuration involving gas recycling at the FT reactor inlet, where hydrogen-related energy demand can reach up to 88% of the total energy consumption. Future work will explore alternative recycling strategies to further optimize the performance of the combined RWGS+FT process for kerosene synthesis from CO_2.

References

[1] Vidal Vázquez F, Pfeifer P, Lehtonen J, Piermartini P, Simell P, and Alopaeus V, 2017, 'Catalyst Screening and Kinetic Modeling for CO Production by High Pressure and Temperature Reverse Water Gas Shift for Fischer–Tropsch Applications', Industrial & Engineering Chemistry Research, 56 (45): 13262–72.

[2] Pandey U, Runningen A, Gavrilović L, Jørgensen EA, Putta KR, Rout KR, Rytter E, Blekkan EA, and Hillestad M. 2021. 'Modeling Fischer–Tropsch Kinetics and Product Distribution over a Cobalt Catalyst'. AIChE Journal 67 (7): e17234

[3] Hillestad M. 2015. 'Modeling the Fischer–Tropsch Product Distribution and Model Implementation'. Chemical Product and Process Modeling 10 (3): 147–59.

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