Implementing carbon capture in EU refineries

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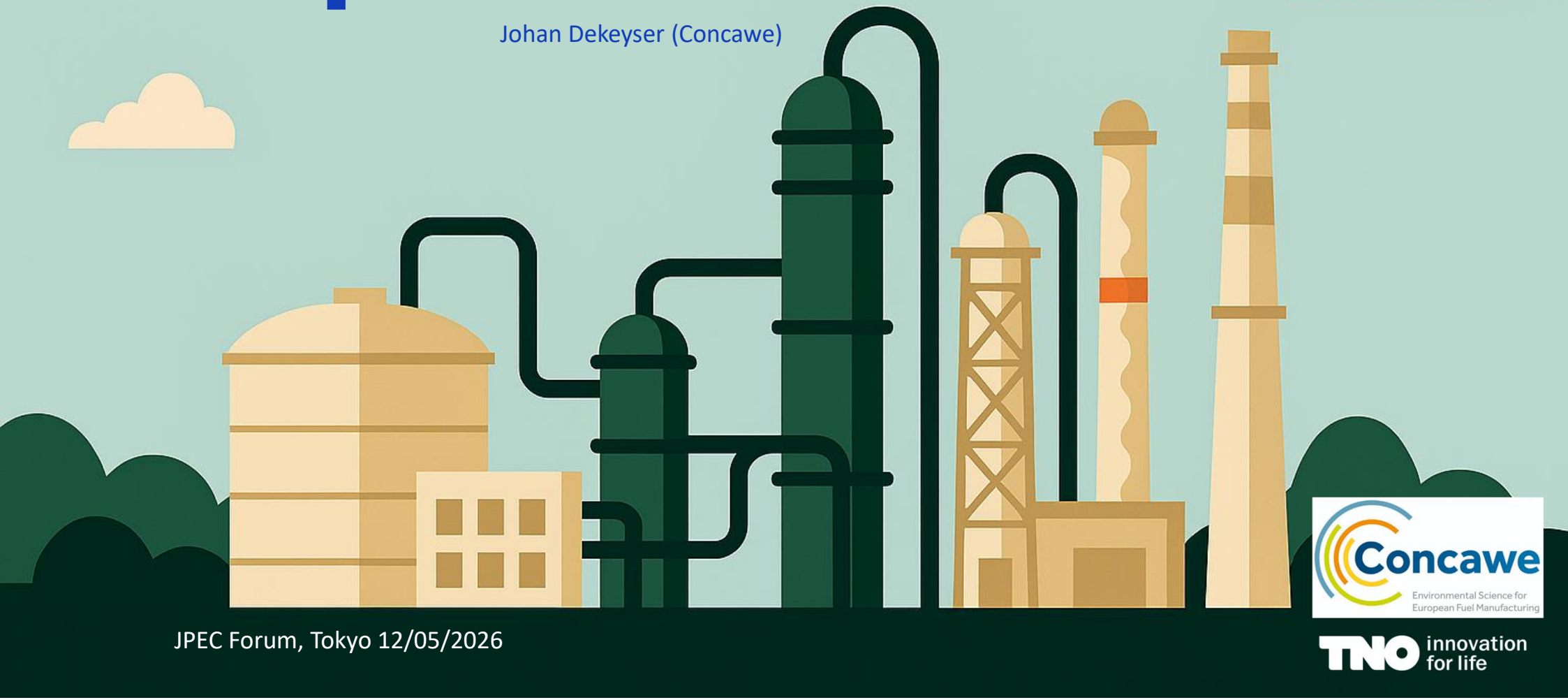

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TNO innovation for life

Introduction

- Concawe has commissioned TNO from The Netherlands in 2025 to conduct a study towards implementation of carbon capture in EU refineries

Focus of this presentation:

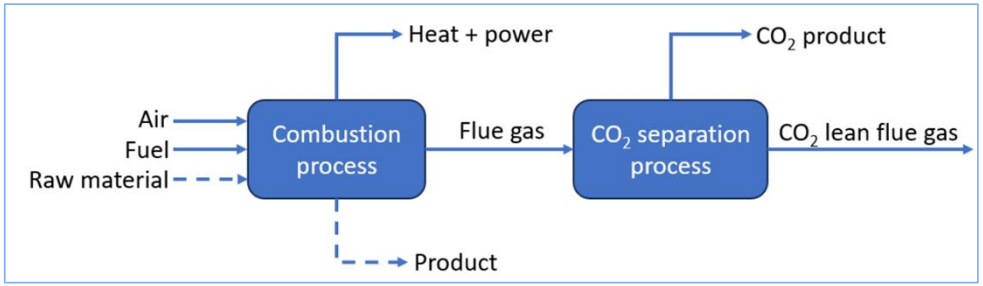
- **Part 1:** Review of carbon capture technologies and their commercial implementation (public report available on Concawe.eu website)

- **Part 2:** Two refinery case studies considering multi-column integration (on-going in project, will be published by summer 2026)

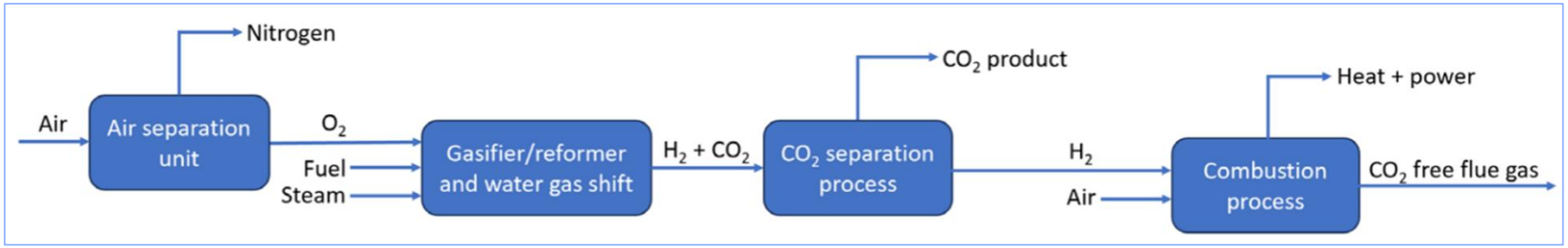
Part 1: Review study

Focus of review

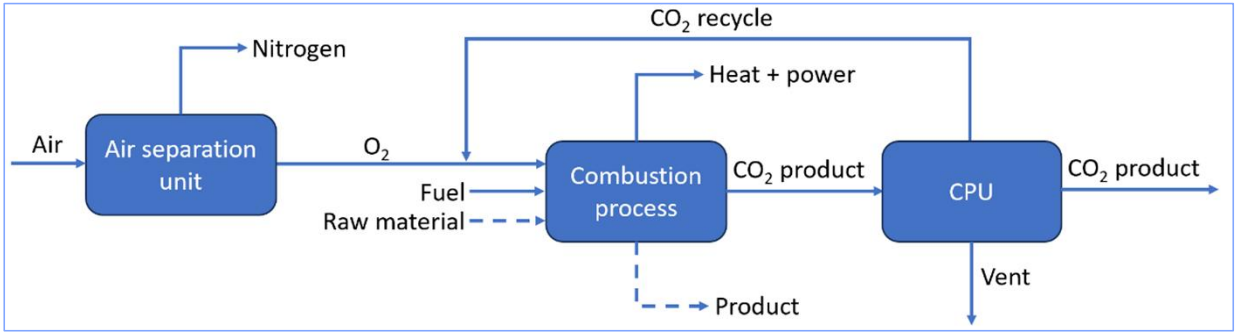
Post-combustion capture



Pre-combustion capture



Oxyfuel combustion capture



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Highlights: post-combustion capture

- Chemical absorption is the most considered technology, and is used in full-scale processes operating in several industries
- Aqueous amines are mostly used in these full-scale processes, but other solvent technologies (e.g. water lean/phase change amines or inorganic solvents) are increasing in TRL level
- Information basis for the technology is relatively good, with much information published on open solvents (e.g. MEA/CESAR1)

Solvent based systems in operation (>100 ton/day)

Company	Solvent name	Largest demonstration/operation	Flue gas source	Capacity (tCO_2/day)
MHI	KS-1	Petra Nova, USA	Coal-fired power	4776 [33]
Shell (Cansolv)	DC-103	Boundary Dam, Canada	Coal-fired power	3200 [31]
China Energy	Not specified	Taizhou, China	Coal-fired power	1370 [37], [38]
SLB capturi	S26	Brevik CCS, Norway	Cement	1100 [35]
Toshiba	TS-1	Mikawa, Japan	Biomass	640 [39]
Sinopec (NRICI)	MA-2	Jinjie, China	Coal-fired power	411 [37]
Fluor	Econamine FG Plus	Bellingham, USA	NGCC	330 [37]
Huaneng	HNC-5	Shidongkou, China	Coal-fired power	330 [40]
TPI	MEA	AVR, The Netherlands	Waste-to-energy	300 [20]
Carbon Clean	APBS-CDRMax	Tuticorin, India	Coal-fired power	164 [41]
BASF/Linde	Oase blue	Solvay, Italy	Mixed	120 [42]

Highlights: post-combustion capture

- Adsorption, membranes and cryogenic technologies are also considered for post-combustion capture
- **Adsorption**: rotating packed beds are at TRL 7. No public data is available on the technology
- **Adsorption + cryogenic**: at TRL 7. Information basis is very low. Technology is considered in several EU Innovation projects
- **Membranes + cryogenic**: at TRL 6-7. Information basis is relatively good with the publication of a public FEED study and some pilot results
- **Gas-solid cryogenic**: at TRL 6. Information basis is relatively low with only selective pilot results published

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Highlights: Pre-combustion capture

- Sorbent and solvent technology are most considered for pre-combustion capture, with several operational full-scale processes
- Several process intensified sorbent-based technologies are being explored at TRL 6-7
- Little public information is available on the operation and performance of the different technologies

Solvent based systems

Company	Technology name	Largest demonstration/operation	Application	Capacity (tCO_2/day)
Linde/Air Liquide	Rectisol	The Great Plains, USA	Coal gasification to natural gas	8220
Shell	ADIP Ultra	Quest CCS facility, Canada	Hydrogen production	2740
Dow chemicals/Honeywell UOP	Selexol	Coffeyville, USA	Hydrogen production	548
Honeywell UOP	Benfield	No information available	N/A	N/A
Dow chemicals/Honeywell UOP	UCARSOL	Ras Laffan, Qatar	LNG production	N/A
Air Liquide	Purisol	N/A	N/A	N/A
Fluor	Fluor solvent℠	N/A	N/A	N/A

Sorbent based systems

Company	Technology name	Largest demonstration/operation	Application	Capacity (tCO_2/day)
Air products	No technology name	Port Arthur, USA	Steam methane reforming	2530
Air Liquide	CRYOCAP™ H_2	Port Jérôme, France	Steam methane reforming	300
Honeywell UOP	Polybed™	N/A	N/A	N/A
Linde	HISorp® CC	N/A	N/A	N/A
TNO	SEWGS	Luleå, Sweden	Steel-mill off gas	14
CSIC	CASOH	Asturias, Spain	Steel-mill off gas	0.4

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Highlights: Oxyfuel combustion capture

- Many pilot and demonstration systems were built the past decades for heat and power, but no full-scale systems were ever built for this application

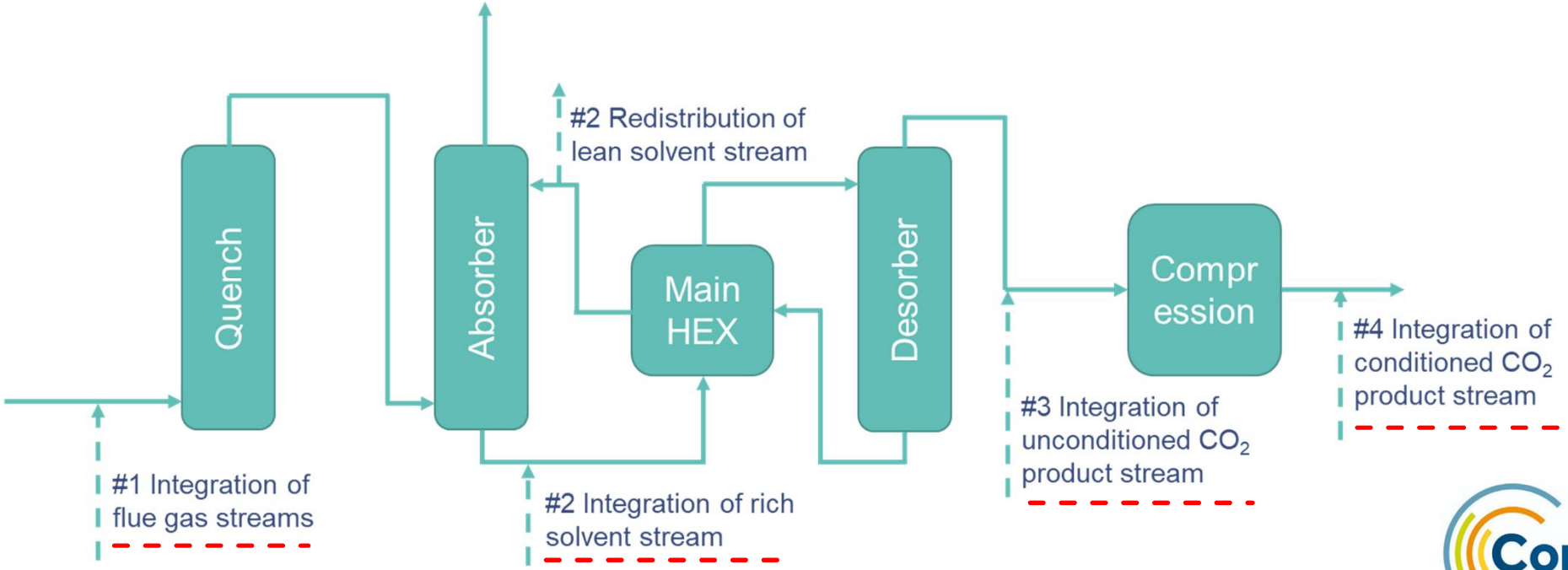
- Oxyfuel capture is also considered for industrial applications, like glass, steel, cement and refineries

- Oxyfuel capture in cement seems to have high potential, with one full-scale plant in operation, several operational large pilot demonstration systems and several EU Innovation fund projects granted considering this technology for cement application

Part 2: Refinery case studies

How to optimize integration of carbon capture in refineries?

Overview of solvent-based carbon capture integration options



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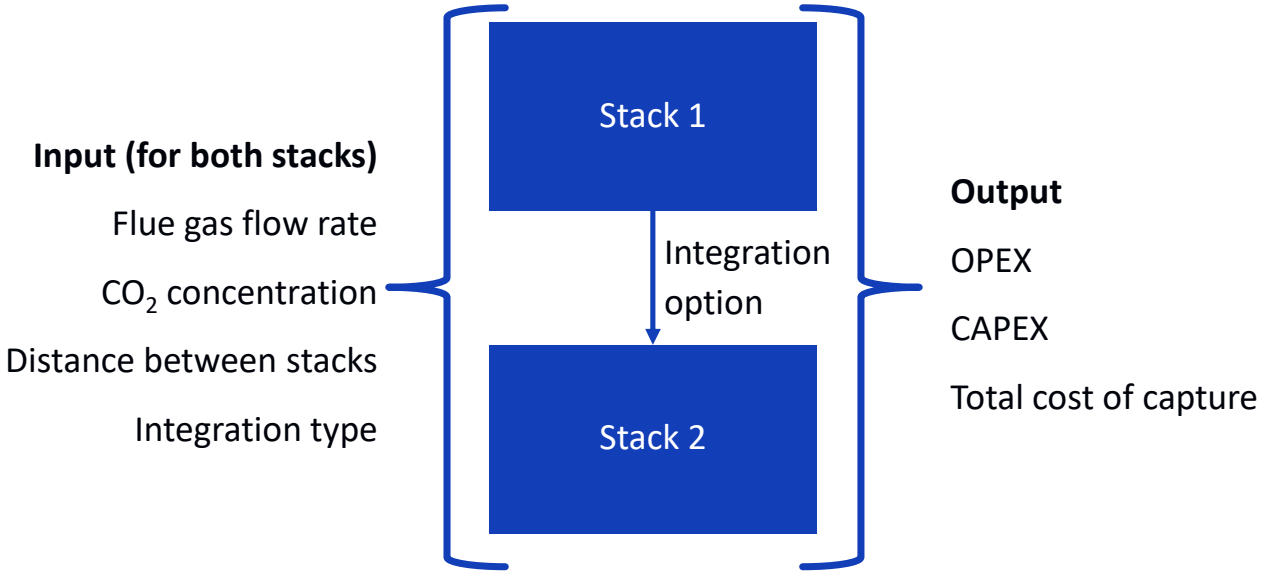
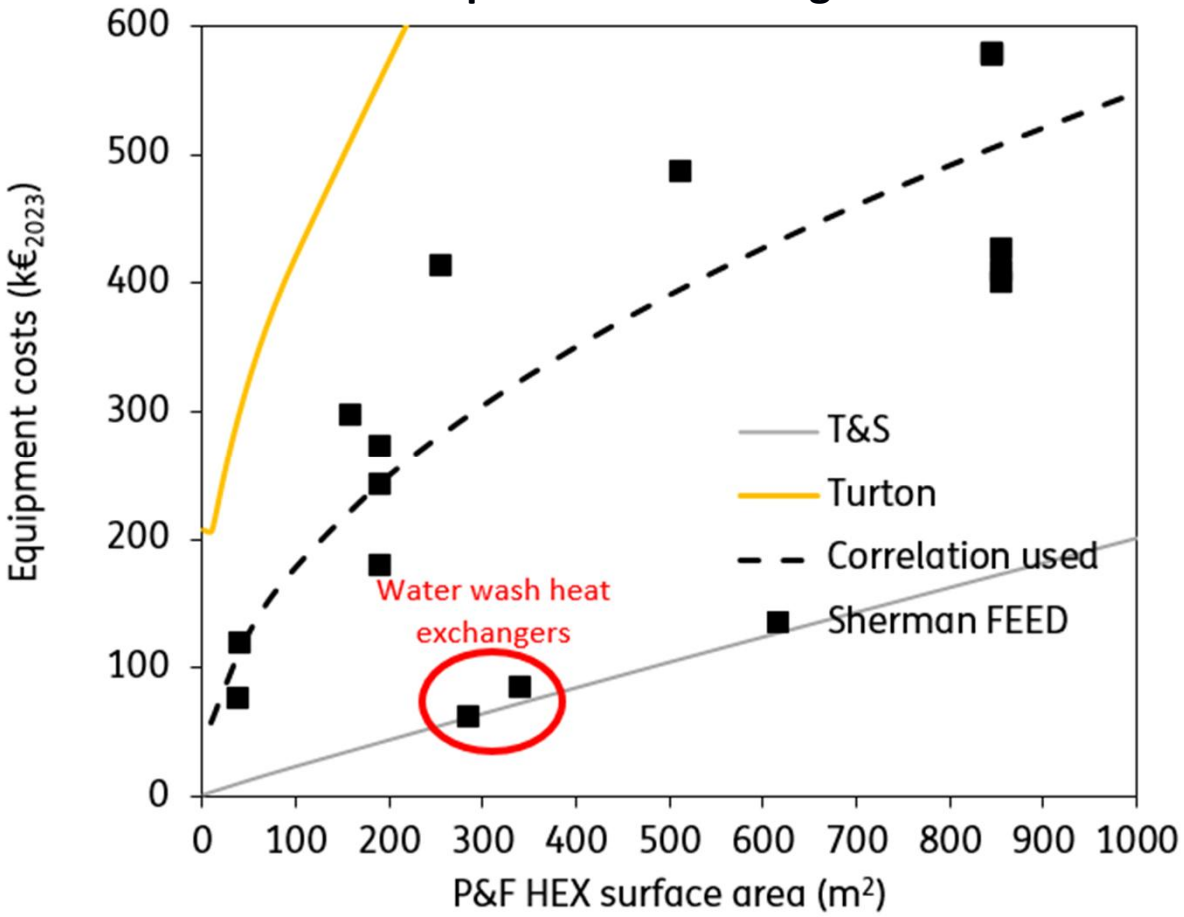
Two-stack model - Methodology

A simplified two-stack model is built to scout the efficiency of the different integration options



Open literature CAPEX correlations

Example – Heat exchanger



Equipment cost correlations for relevant equipment are generated for this study based on cost models, open literature and public FEED studies

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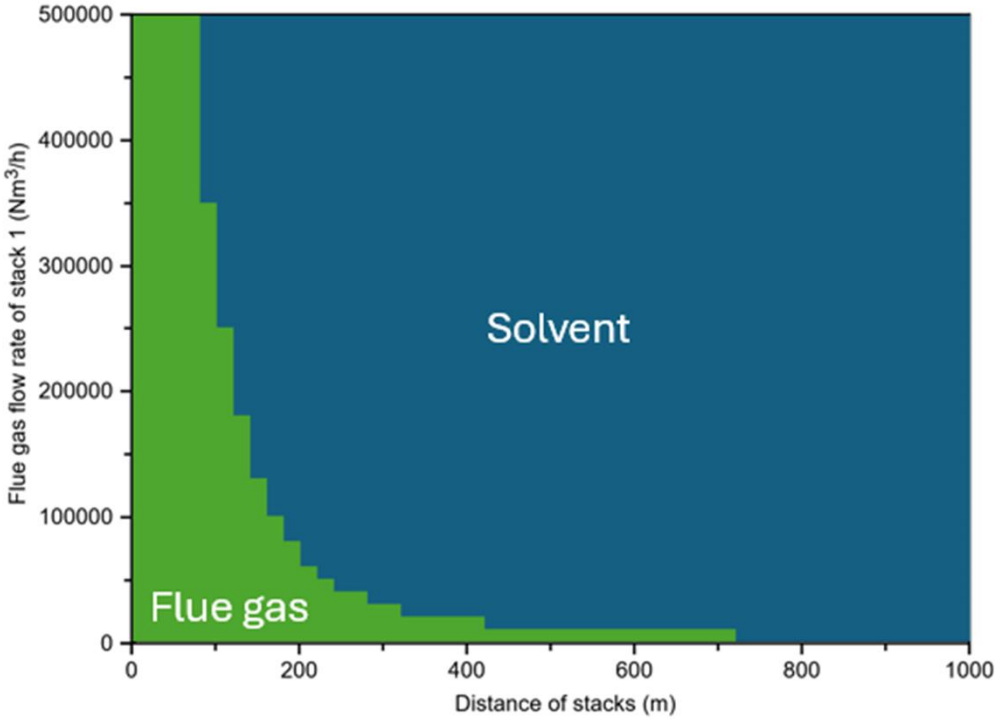
Two-stack model – example of results

Example result – changing distance and stack 1 flue gas flow rate

Stack 1 concentration: 10 vol%
Stack 2 concentration: 10 vol%
Stack 2 flow rate: 500000 Nm^3/h



The two-stack model allows quick evaluation of multiple scenarios

For most of the scenarios evaluated, either flue gas or solvent integration is found as the optimal solution

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Detailed case studies for two refineries

- Two European refineries containing multiple emission sources are evaluated in detail
- Learnings from the two-stack model to determine optimal integration scenario(s) for the different refineries
- A techno-economic analysis is performed for both refineries. Gas boilers and heat pumps are considered as heat sources
- The full analysis is planned to be published by summer 2026

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