WP2
CO_2 capture

E-Fuel project
Final seminar, 17.1.2024
Tuula Kajolinna

CO_2 capture / One slide overview

Tasks

- T2.1 State-of-the-art review and evaluation of suitable CO_2 capture technologies for E-fuel concept
- T2.2 Enhanced soda scrubbing technology development
- T2.3 CO_2 capture & purification pre-testing for the e-fuel concept

Deliverables and dissemination

- D2.1 “State-of-the-art review and evaluation” Available
- D2.2 “Pre-tests of VTT carbon capture units and indicative concept integration designs” Draft on Teams
- D2.3 “Mass Transfer Efficiency for CO_2 Capture Using Soda Solutions” Available
- Blog text on E-fuel webpage
- Conference presentation and article at GHGT-16 Available
- *Extra:* Article1 on concept of VTT carbonate-based CO_2 capture process Submitted
- *Extra:* Article2 on TEA of VTT carbonate-based CO_2 capture process Under work

Company and other collaboration

- Andritz, CarbonReUse Finland, Kleener Power Solutions, LUT University

T2.1 State-of-the-art review and evaluation of suitable technologies for e-fuel concept

Available at
www.e-fuel.fi/publications/

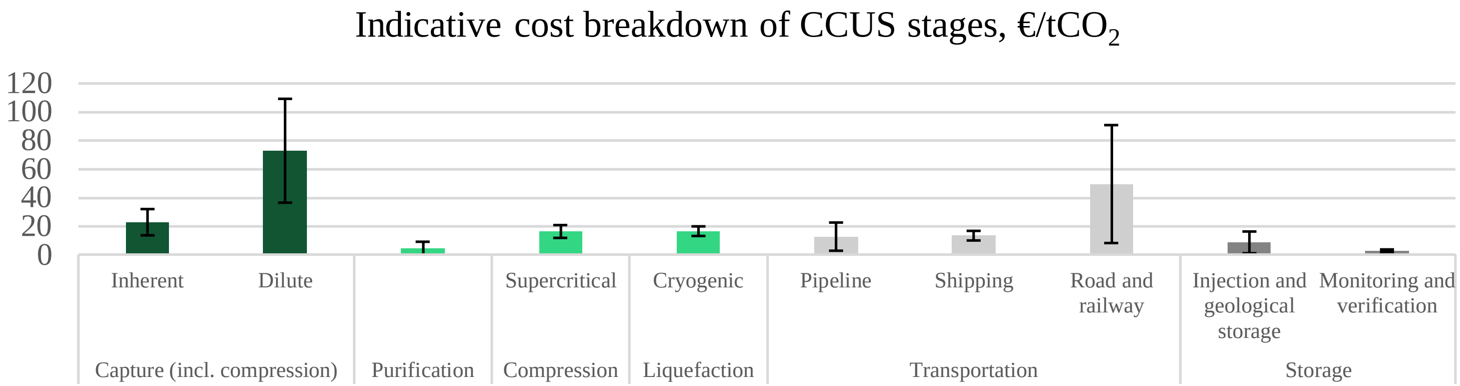
Report title: Industrial CO_2 supply pathways for CCU-based electrofuel production in Finland

- Focus on point source capture over DAC due to high maturity and more favorable economics

- Objectives of the study
  - Gain a *holistic understanding on technical requirements* and economics of CCUS stages
  - *Map potential carbon capture technology options* for industrial point source capture
  - *Identify industrial emission point sources* with high potential for carbon capture implementation

Conclusions of Task 2.1 (1/2)

- CCUS consists of several, *case-specific* stages that yield a
  - total cost ranging around 42–161 €/tCO_2, with the cost depending primarily on a) CO_2 concentration / partial pressure, b) scale of operation and c) required stages of logistics



- Several technology options for point source carbon capture are available
  - *Amines* are a proven option with a *low risk* of implementation.
  - *Alternative technologies* like carbonate salt solvents have emerged to TRL 8–9 and become reasonable to consider alongside amines.
  - Several other *emerging technologies* like solid sorbents, membranes, and fuel cell systems are on the brink of commercialization.

Conclusions of Task 2.1 (2/2)

- *Carbon capture potential* of forest industry, petroleum refining and biorefining in Finland

- Indicators:
  - Annual CO_2 emissions
  - Industry trend by 2030
  - CO_2 source concentration
  - Implementation status
  - Integration challenges
  - Origin of CO_2 (biogenic/fossil)

	Pulp and paper mills		Petroleum refineries (excl. SMR)		Steam methane reforming		Ethanol fermentation		Hydrotreated vegetable oils	
Annual CO2 emissions of the industry in Finland	2	20.6 Mtpa (2020)	1	2.9 Mtpa (2020)	1	Estimated based on facilities in Finland	0	18 ktpa (2017)	0	97.5 ktpa (est.)
Onsite CO2 emissions of an average Finnish facility/complex	2	1 Mtpa average of facilities reported in E-PRTR	2	2.7 Mtpa (Neste Kilpilahti)	1	192 ktpa Linde Kilpilahti	0		0	
Industry trend in Finland by 2030	2	Capacity to grow, e.g., Metsä Fibre Kemi bioproduct mill	1	Capacity expected to remain similar	1	Capacity expected to remain similar	2	Capacity expected to grow, e.g., Bioenergo Pori and NordFuel Haapavesi	1	Capacity expected to remain similar
Average CO2 concentration of the emission point source(s)	0	12–13 % (recovery and power boiler) 20 % (lime kiln)	0	8–10 % (heaters) 3–5 % (utilities) 10–20 % (FCC)	1	30–45 % (PSA exhaust stream)	2	>90 %	2	>90 % (best case scenario: decarboxylation)
Degree of carbon capture implementation	2	Commercial: e.g., Saipem at Resolute's kraft pulp mill in Quebec, Canada (TRL 8)	2	Commercial: e.g., Sinopec at Qilu refinery, China	2	Commercial: e.g., Air Products Port Arthur and Linde Kilpilahti	2	Commercial: widely used in the US to provide CO_2 for enhanced oil recovery	0	
System integration challenges (e.g., equipment size limitations, energy integration, utility and waste streams)	1	Requires post-combustion capture retrofit. Steam supply may be inadequate, and an auxiliary boiler may be required if the recovery boiler is targeted.	1	Several point sources of CO2, often limited space available, unique site configurations for which it is difficult to create a standard solution for CO2 capture.	1	Requires PSA-based capture or solvent-based CO2 scrubbing	2	Straightforward integration, requiring only dehydration and purification of the exhaust stream.	2	Straightforward integration expected if the exhaust stream is not mixed with other streams, requiring only dehydration and purification.
Natural origin of CO2	1	>90 % biogenic	0	Fossil	0	Fossil	1	Biogenic	1	Biogenic
Total score (max. 13)	**10**		**7**		**7**		**9**		**6**	

- Industrial CO_2 emissions in Finland provide high potential for bio-CCUS
  - *Pulp mills* have the most appeal *for large-scale* implementation
  - *Biorefinery processes* like fermentation and *HVO* yield potential for low capture cost and simple carbon capture implementation at *small scale*

T2.2 Enhanced soda scrubbing technology development

- VTT's carbonate-based CO_2 capture process
  - In freight container, easily transportable pilot-scale process
  - Modifications of process are easy
  - No need of steam, all temperature requirements < 80°C
  - Low pumping energy demand
- Study and developed further capture & energy efficiency
  - D2.3: Master Thesis "Mass transfer efficiency for CO_2 capture using soda solutions"
- VTT's carbon capture units and indicative concept –review, D2.2
  - CO_2 capture process and it's techno-economic scaling possibilities
  - Production concepts of Formate and Formic acid from bicarbonates
  - Electric Lime Kiln concept to produce pure CO_2 from lime calcination

Link at www.e-fuel.fi/publications/

Report on Teams

T2.3 CO_2 capture & purification pre-testing for the e-fuel concept

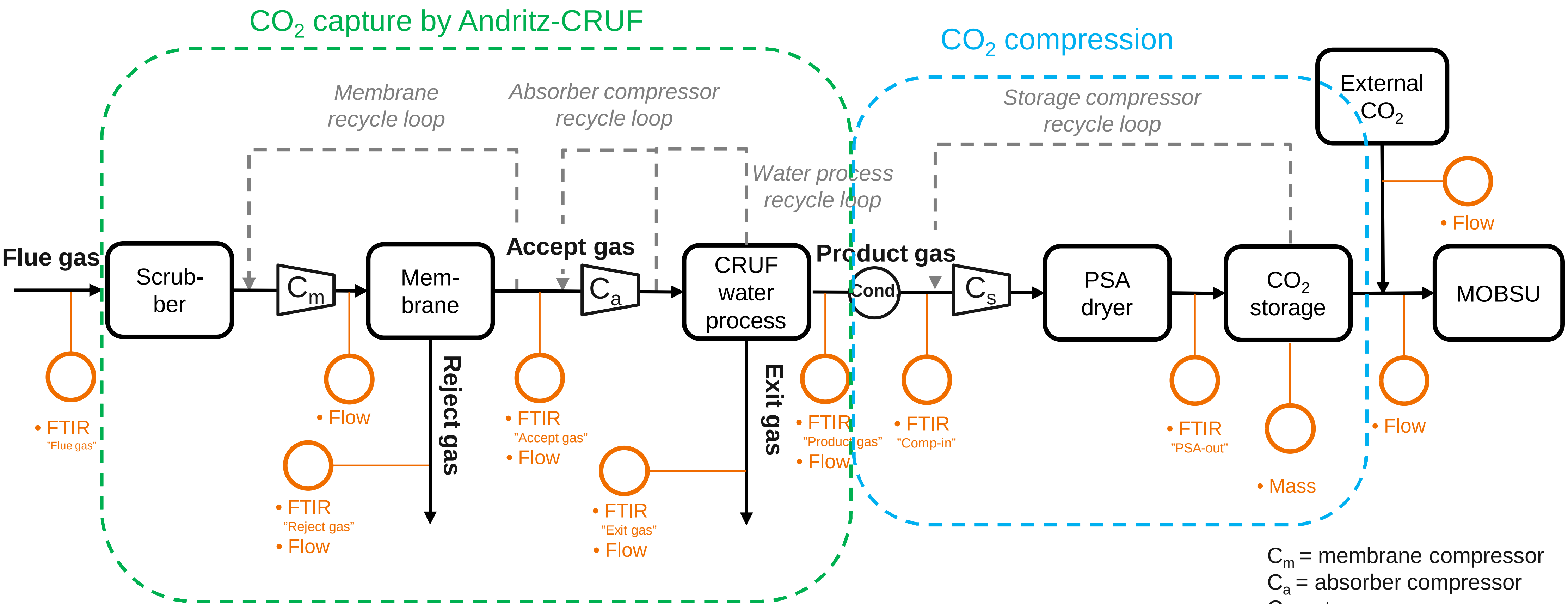
Presentation on Teams

- During WP4 Demonstration tests at Bioruukki 6/2023

- Aim to study CO_2 capture, purification and compression performances during Demo
  - Gas concentrations
    - Removal rates of each process
  - Energy consumptions

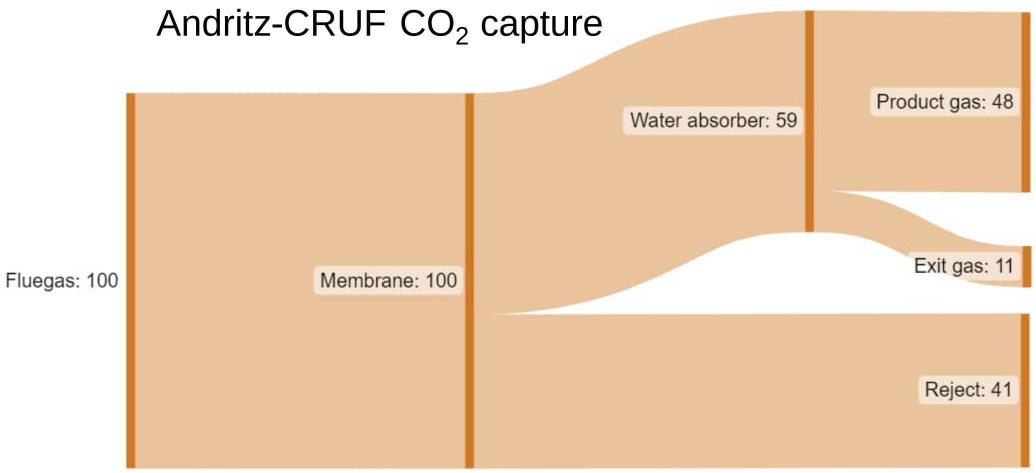
- CO_2 capture by Andritz-Carbon ReUse Finland (Andritz-CRUF)
- CO_2 compression by VTT

T2.3, Process and measurement flowchart



C_m = membrane compressor
C_a = absorber compressor
C_s = storage compressor
Cond. = condenser

T2.3, CO_2 flows and concentrations



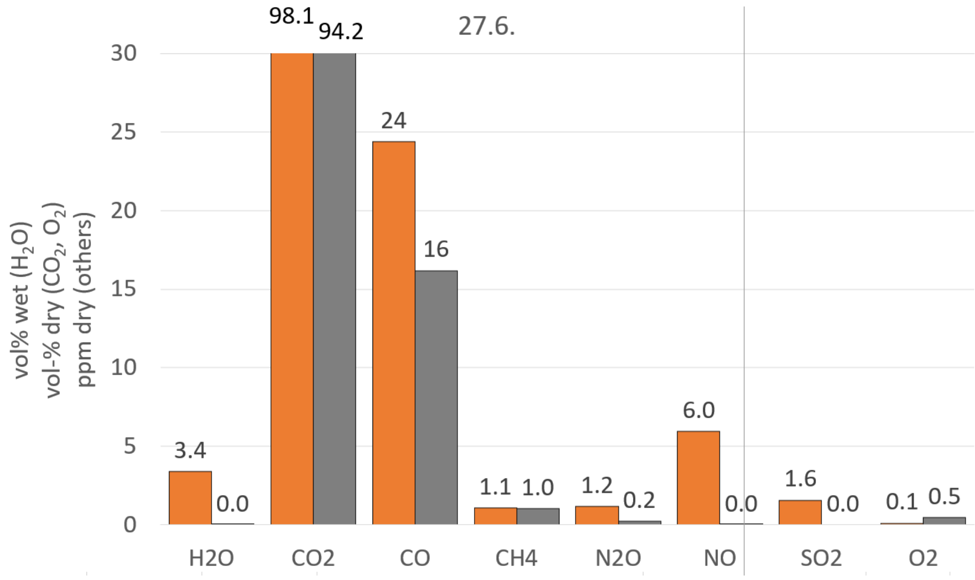
- Total CO_2 capture rate was ~48%
  - The main aim was to achieve a high CO_2 concentration in product gas – NOT a high capture rate
- Capture rates of membrane and water absorption processes were ~60% and ~80%, respectively

- Product gas
  - CO_2 up to 99 vol% (dry)
  - O_2 0.1 – 0.2 vol% (dry)

T2.3 Summary and conclusions

- CO_2 capture using a hybrid membrane-water absorption process and subsequent gas drying and compression was successfully demonstrated
- Up to 99 vol% CO_2 content in dry gas after capture process was achieved
- Very low amounts of harmful impurities (NO, SO_2) in the product gas
- Electricity consumption of the process was very high but not representative of an actual commercial processes

Concentrations before and after the PSA dryer & storage compressor



beyond
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