E-fuel project, WP2 CO_2 capture

Mid-Term Workshop
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Tuula Kajolinna, VTT

WP2 short introduction

Tasks

- T2.1 State-of-the-art review and evaluation of suitable 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

Topics of this presentation

- Brief overview of CO_2 capture techniques
- Soda scrubbing concept, absorption kinetics research (M.Sc. Thesis)
- Next steps

Brief overview of CO_2 capture technologies

Cost data not well available and not easy to compare as capture costs are case-specific!

Technology	TRL	Cost, €/t_{CO2}	Advantages	Disadvantages
Amines, also hindered amines	6-9	25-40 (commercial)	Maturity, many commercial suppliers, intensive development ongoing	Volatile emissions, energy-intensive regeneration (steam), regulation
Inorganic salts (e.g. Capsol, Kleener)	5-8	28-	Variety of salts, low-temperature regeneration (no steam needed), environmentally-friendly and low-cost absorbent, non-corrosive	Risk of solid formation, slow absorption kinetics
Other liquid solvents (water-lean, phase change…)	5-8	40-80	Possible drop-in solvent, good impurity tolerance, latent heat	Volatility, viscosity, reaction kinetic speed, water pre-removal
Physical absorption (e.g. Selexol, Rectisol)	8-9	30-55	Widely used in natural gas processing, coal gasification plants	Water pre-removal, temperature conditioning
Solid adsorbents (PSA, TSA, VSA)	6-9	30-50	Maturity in industrial gas purification, low regeneration energy, many sorbent choices	Slow transfer kinetics (chemisorption), weak selectivity (physisorption)
Membranes	6-9	35-55	Long history with biogas/landfill gas, simplicity, several material choices for different applications	Pre-purification and often pre-cooling needed. Sensitive for impurities. Replacement cycle 3-5 yrs
Cryogenic separation (raw gas 5-50% CO2)	6-9	30-70	Purity and condition of product CO_2	Costs depends on impurities, often pre-purification before refridgeration
Electro-chemical separation	4-6	35-	Intensive development ongoing, often more efficient than thermo-chemical processes	Electricity consumption, fuel cell development
Inherent carbon capture, liquefaction (raw appr. >90% CO2)	7-9	5-25	Liquefaction to transport conditions	Costs depends on impurities

Short overview of (only) CCS status

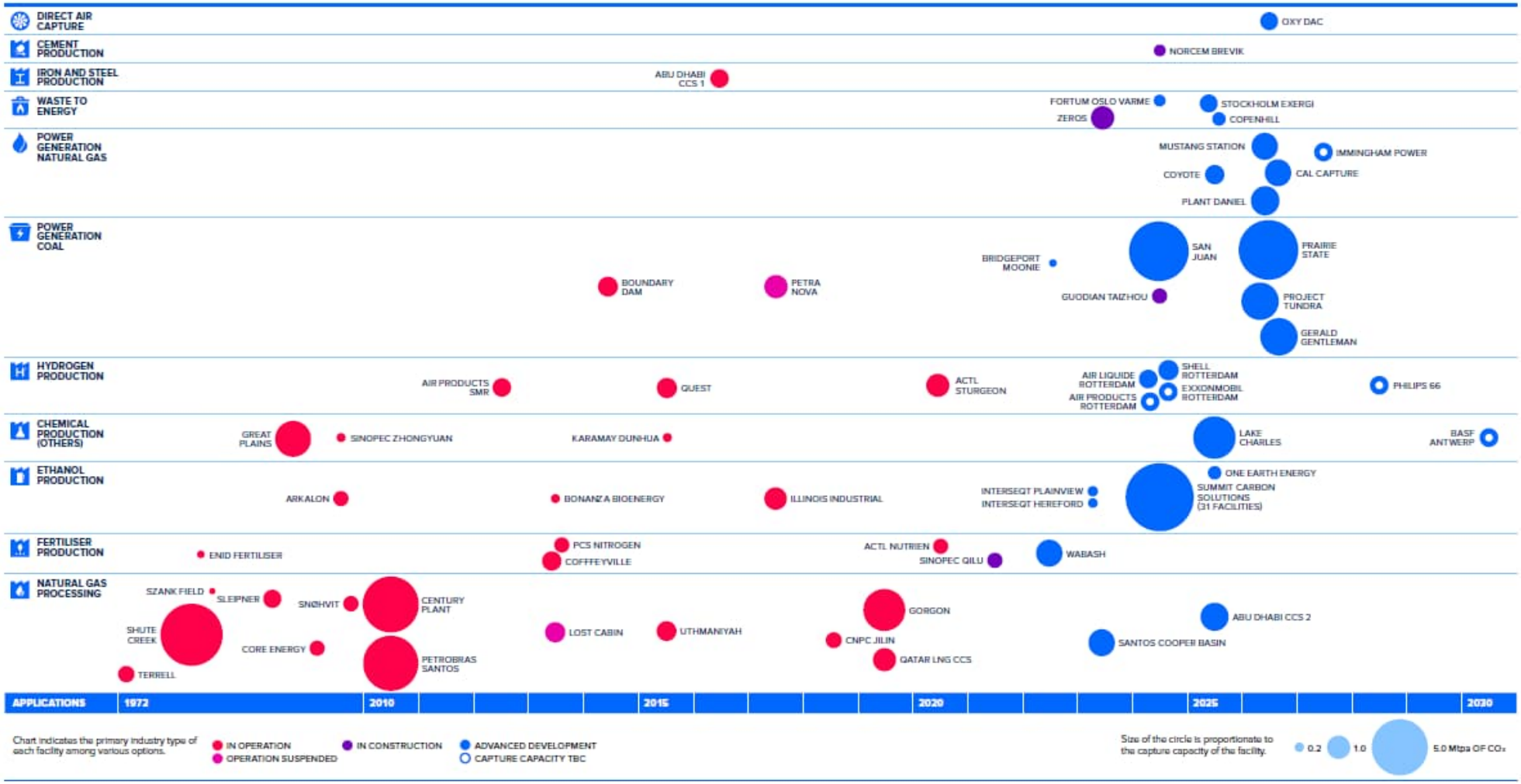


Figure: Global Status Of CCS 2021 – CCS Accelerating to net zero. Global CCS Institute. 2021

VTT Soda scrubbing CO_2 capture process, TRL 5-6

- Flexible setup, proof-of-concept tests, used only on daily basis
- Sodium carbonate liquid, other carbonates like potassium and ammonium are possible as well
  - $Na_2CO_3 + CO_2 + H_2O \rightarrow 2\ NaHCO_3$
  - Regeneration vice versa
- No toxic solvent-based emissions
- CO_2 production capacity ~2.5 l/min (~ 0.25 kg/hr)
  → max inlet fluegas ~ 15 l/min or max inlet biogas ~ 5 l/min
- Separated CO_2 outlet flow, CO_2 >97 vol-%
- No need of steam, all temperature requirements < 80°C

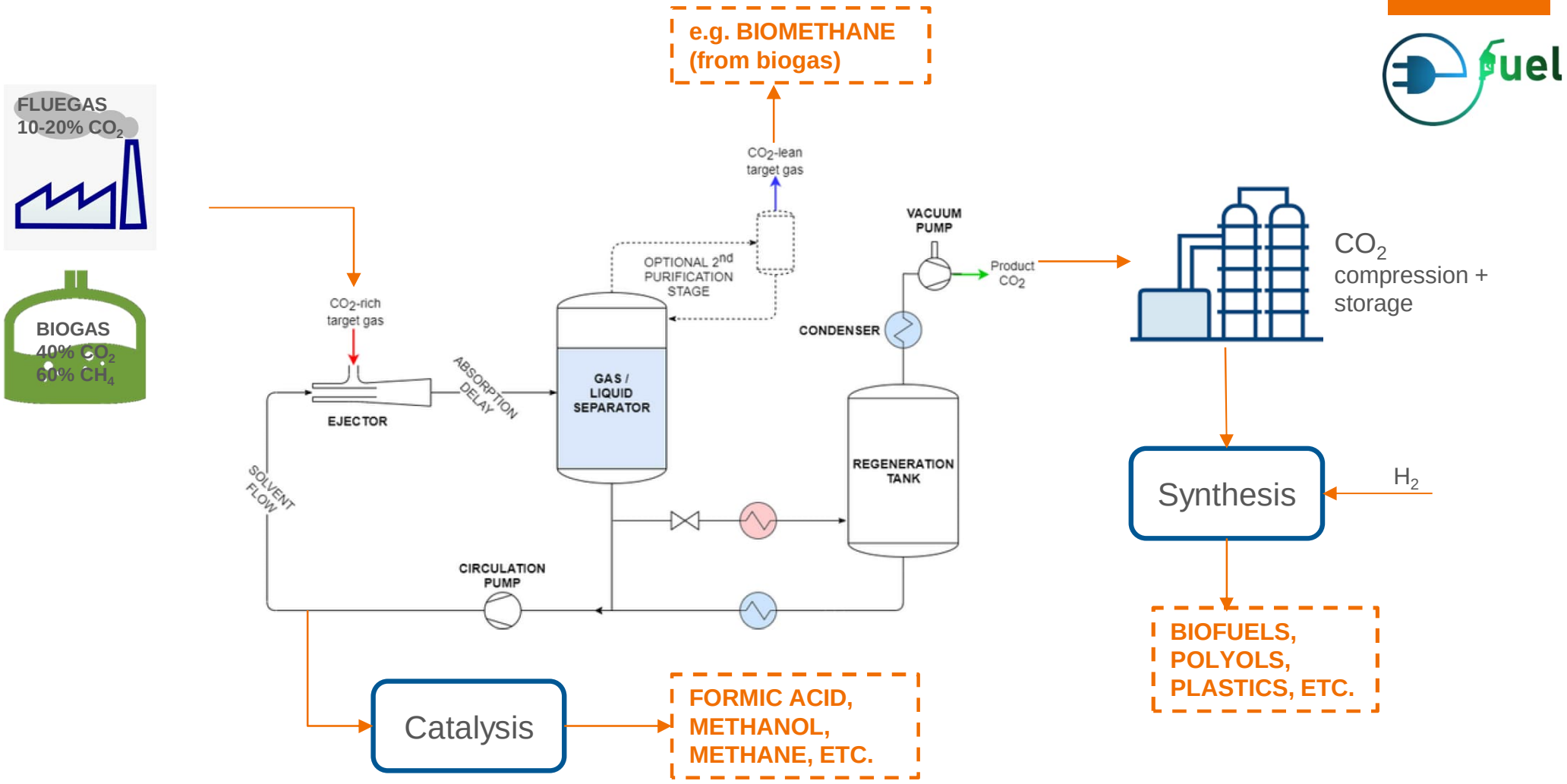
Improvements to VTT CO_2 capture container:

• gas-liquid mixer with larger capacities	Ready
• better cooling and heating cycles	Ready
• multiple delay time possibilities	Ready
• energy efficiency measurement facility	Started
• process concept modelling	Started

Commercialization status

- Licensing under preparation with industrial partner
- Capturing costs estimated 30–60 €/t_{CO2}

VTT Soda scrubbing CO_2 capture process

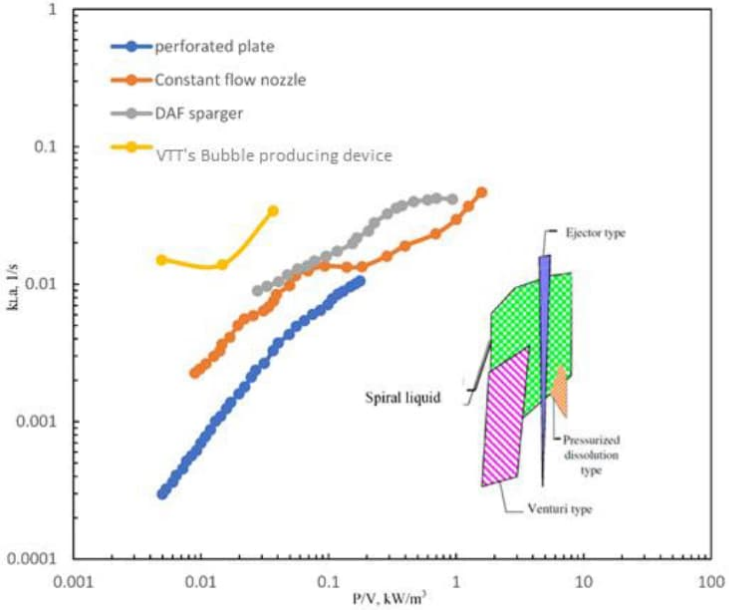


Central process figure: Linjala, Onni. Review on Post-Combustion Carbon Capture Technologies and Capture of Biogenic CO_2 Using Pilot-Scale Equipment. LUT University 2021.

VTT Soda scrubbing, Absorption kinetics research

- Test liquid 8 w-% Na_2CO_3 solution, CO_2 variated
- Tests made with LUT University
- Mass Transfer rate K_La
  - K_La defines reaction rate, the unit is 1/s. The higher value, the faster reaction
  - Without chemical reaction
  - With chemical reaction (around 10 times faster)
- Pumping Energy Input and Mass transfer Efficiency
  - VTT's process receives high mass transfer efficiency with lower pumping energy need than other bubble generator types

Pumping Energy Input and Mass Transfer:



VTT Soda scrubbing, Absorption kinetics research (2/2)

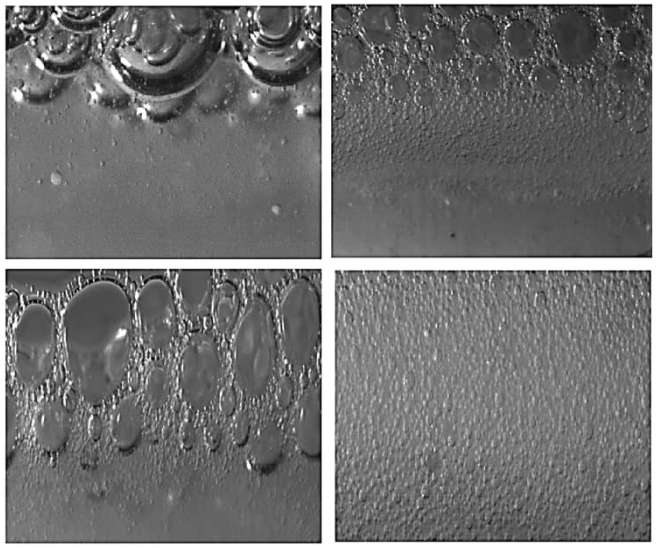
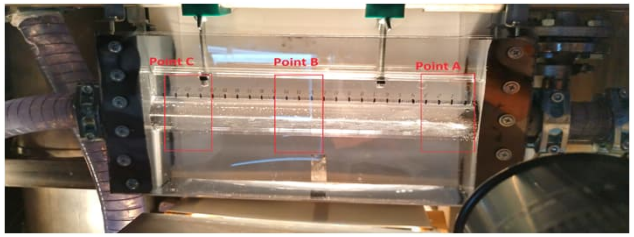


Figure 37 CO_2 bubbles in 8 w-% Na_2CO_3 solution, images recorded at point A using pipe B, L/G ratio 1(top-left), L/G ratio1 (Q_{CO_2}=10 L/min, $Q_{8w-\%Na2CO3}$= 10L/min) (top-right), L/G ratio 0.75(bottom -left), L/G ratio 1.25 (bottom-right)



Bubble size with high-speed camera:

- Average bubble sizes 300-4000 µm
- Large surface area enables fast absorption and reactions

Feasible CO_2 Capture rates >90-99% were obtained between pH 9.5 and 11

D2.3 MSc Thesis published in November 2021
http://urn.fi/URN:NBN:fi-fe2021110954433

Figures: Narayanasamy, Mohankumar. Mass Transfer Efficiency for CO_2 Capture Using Soda Solutions. LUT University 2021.

Next steps

- State-of-the-art review on CO_2 capture techniques and suitability for e-fuel concept (report)
- VTT Soda CO_2 capture process concept report
- Measurements for energy consumptions, gas qualities and emissions will be done during Bioruukki WP4 demo

VTT

beyond

the obvious

Tuula Kajolinna
tuula.kajolinna@vtt.fi
+358 40 562 4379

Onni Linjala
onni.linjala@vtt.fi
+358 50 355 3861

www.vtt.fi