The Hiilensidonta 2022 -event (“Carbon Capture 2022”)

The role of bioenergy carbon capture and storage (BECCS) in achieving net zero targets

24 May 2022 – 15:30 (Finnish Time)

The role of BECCS in achieving net zero targets

Naser Odeh
Associate Director, Head of CCUS and Biofuels, Ricardo Energy & Environment

Agenda

- Ricardo: Who we are
- The role of carbon dioxide removals (CDRs) in in achieving net zero targets
- Bioenergy carbon capture and storage (BECCS) in the EU
- Integrating BECCS with CHP, EfW and DH systems provides a valuable opportunity
- EU case studies of BECCS with DH
- Innovative community scale BECCS could offer great benefits

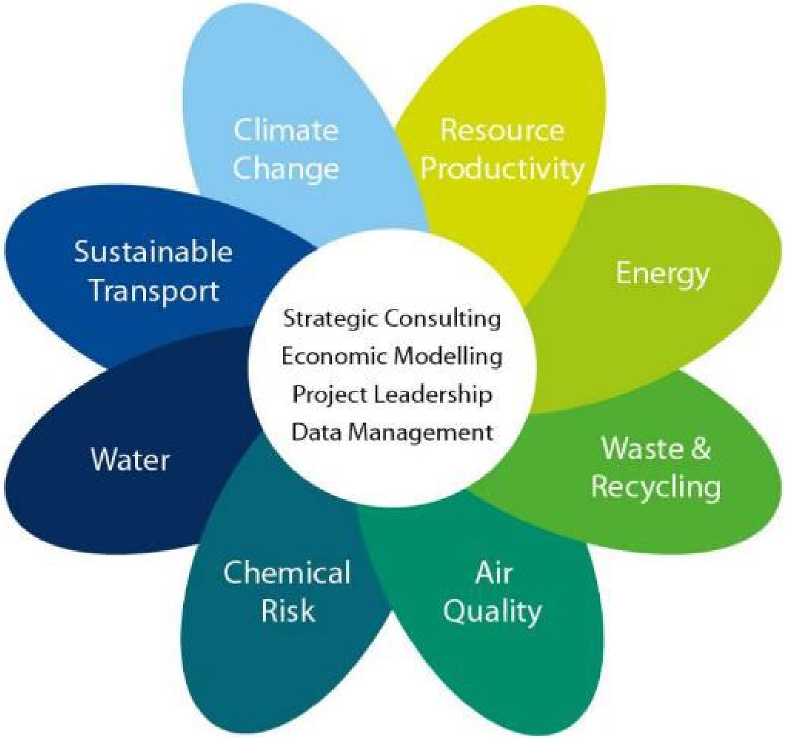
Ricardo Group

Our ambition is to create a **world fit for the future**, meeting the challenges within the markets of Transport & Security, Energy, and Scarce Natural Resources & Waste

- A global, multi-industry consultancy for engineering, technology, project innovation and strategy
    - Circa 3,000 staff
    - 55 sites
    - 9 Technical Centres
    - 21 countries

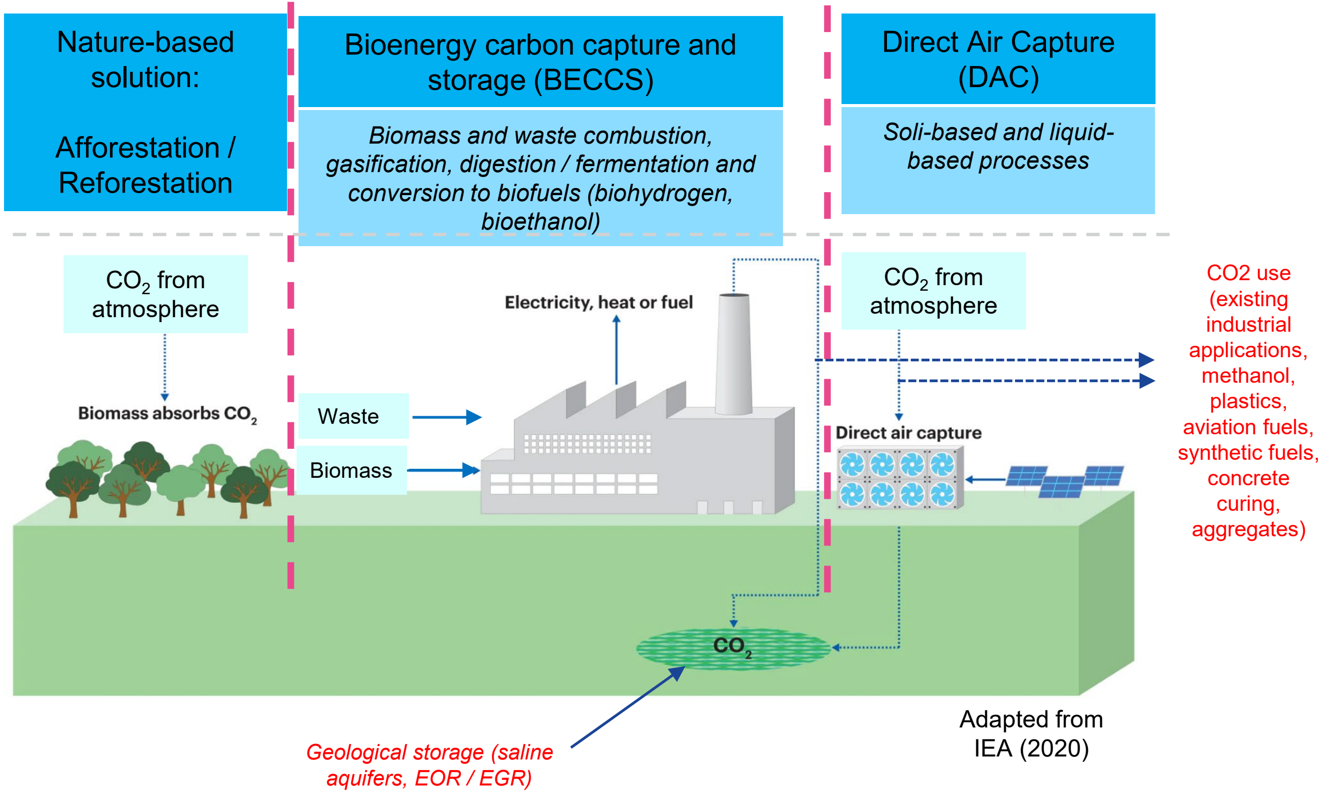
Our core services promote environmental sustainability

- Two main business units: (i) Sustainability Infrastructure & Operations, (ii) Policy & Evidence
- Energy services include CHP, Heat, CCUS and Biofuels business unit
- Support on net zero strategies and industrial heat decarbonisation roadmaps
- Supported by Ricardo Group with >100 years of heritage developing low emission, high-efficiency technologies and product designs



Reaching Net Zero requires more than just reducing emissions

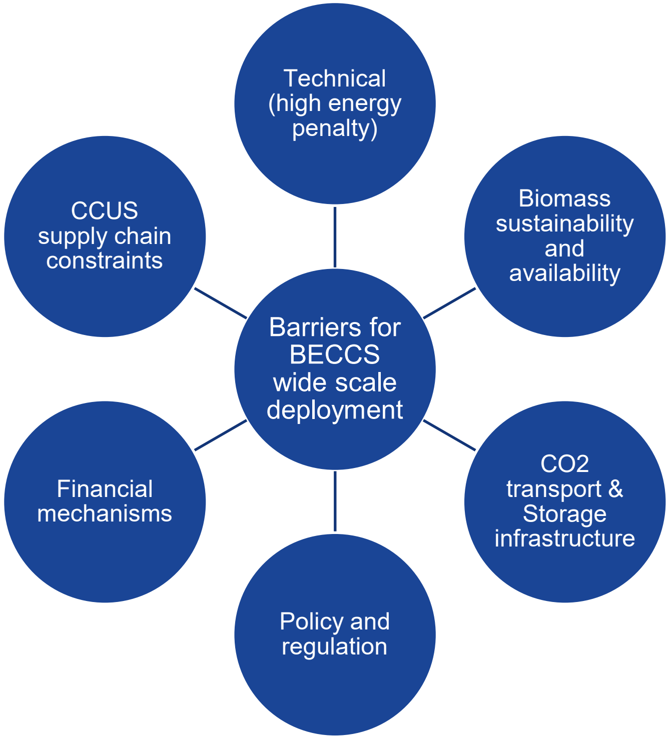
- Paris 2015 and the IPCC Report (AR6) 2018 highlight importance of Carbon Dioxide Removals
- Nature-based and engineered options
- EU introduced a cap of 225 $MtCO_2$ /year for CDR on route to its 55% GHG reduction target by 2030
- The EU is in process developing certification mechanism for NETs



Adapted from IEA (2020)

BECCS has significant CDR potential but challenges need to be overcome

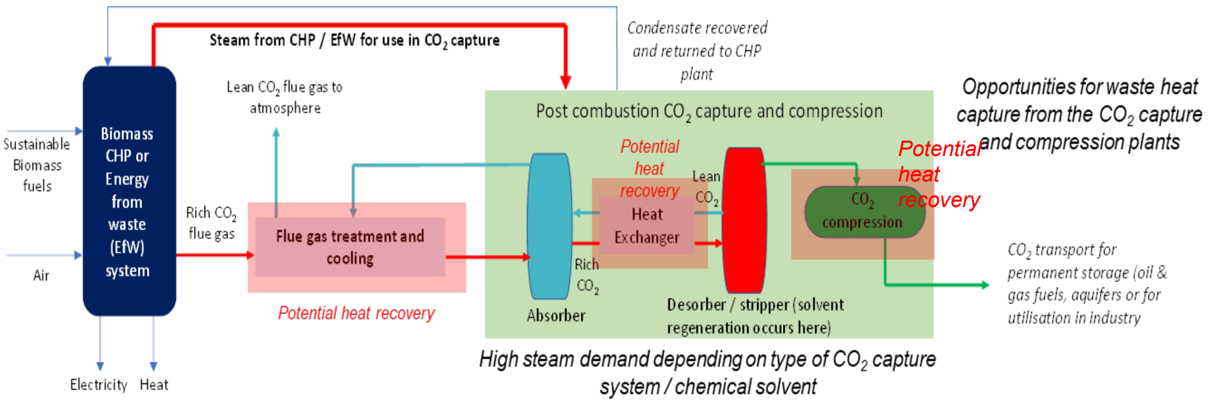
- Current: 19 BECCS projects worldwide mainly ethanol plants
- In planning: BECCS on power, hydrogen BECCS, BECCS in industry (cement, paper mills), BECCS on biogas
- Absorption-based post-combustion CO_2 capture technology is well-established and can be easily retrofitted
- Several demonstrations are planned in Europe
- A meaningful combination: synergy between BECCS plants on the one hand and CHP, EfW and DH on the other



BECCS with CHP and district heating significantly reduces the energy penalty

- CO_2 capture on a power station reduces efficiency by >30%
- If integrated with CHP systems, this energy penalty reduces significantly
- The CO_2 capture process uses low pressure steam from the CHP plant and reduces power output
- On the other hand, useful heat can be recovered back from the capture plant and used in DH
- Heat from the FG cooling process, gas compression and other processes is available at different temperatures.
- Additional heat recovery improves plant efficiency and economics leading to 25-30% reduction in capture cost

- Work is needed related to Energy Efficiency Directive (EED) to allow CHP heat used in the carbon capture plant as “useful heat” and “economically justifiable”
- Also to encourage waste heat recovery from the CO_2 capture system for DH.



Fortum Oslo Varme BECCS EfW plant

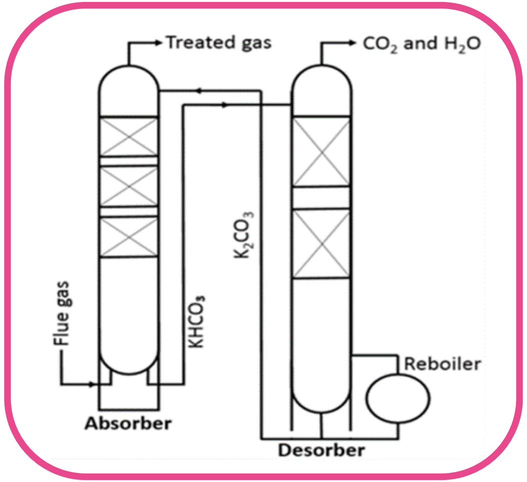
- Part of a wider Norwegian full-chain CCS project called **Longship** which also includes the Norcem cement factory
- EfW plant in Oslo incinerating 350k tonnes of household and commercial waste (150 GWh power, 700 GWh heat per year for DH)
- CO_2 emissions: 400-460 ktCO_2 /year (50% biogenic content). FOV BECCS is expected to reduce Oslo's emissions by 14%
- CO_2 transport by trucks to the Port of Oslo and then shipped for permanent storage (Northern Lights project)
- Two pilots and FEED completed (execution starts 2022/23 and operation in 2026/27)
- Three incinerators and two turbines. Selected Shell's amine based DC-103 technology
- Pilot monitored amine degradation and slip (90% capture and 95% availability giving NET potential of ~180 kt CO_2/y)

- Estimated CapEx of ~$600M and OpEx of $30M/y (around $360/t CO2 stored)
- Norwegian Government provides $340M of funding (project applied for EU Innovation Fund)

The Stockholm Exergi (SE) biomass CHP plant

- Swedish net zero targets requires 3-10 Mt CO_2/y BECCS by 2045.
- 125 MWe biomass CHP plant with ~300MWth thermal output
- SE's selected technology is hot potassium carbonate CO_2 capture at existing biomass CHP plant
- Swedish forest residues used as the feedstock
- Existing district heating network with heat pumps in combination with low return temperatures for maximum recovery of waste heat
- Possible CO_2 storage as part of the Northern Lights project
- A capture capacity of close to 800kt CO_2/y leading to high negative emission potential.

- Selected CO_2 capture process is hot potassium carbonate which provides various advantages:
  - Cheap non-toxic solvent with no degradation
  - High CO_2 selectivity and low regeneration heat
  - Compact layout



$K_2CO_3 + CO_2 + H_2O \Leftrightarrow 2HCO_3^{-1} + 2K^+$

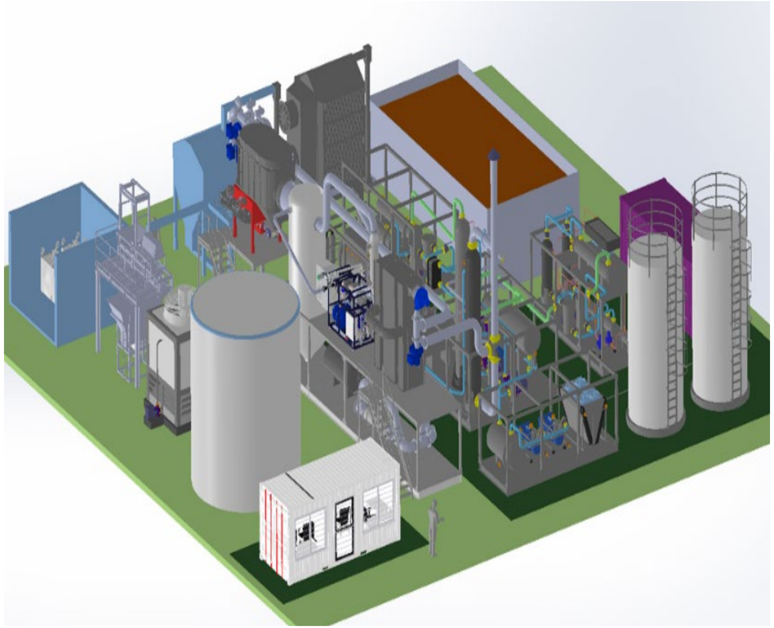
C4: Carbon Capture Cluster Copenhagen

- Collaboration of a number of major utility companies in the Copenhagen metropolitan area
- Aims to capture and store 3 Mt CO_2/y (15% of the total 20Mt Danish target by 2030)
- Cluster aims to capture CO_2 from **3 EfW** plant, **2 biomass CHP** plants and **one wastewater treatment** plant
- Two district heating networks
- Around 80% of the captured CO_2 is biogenic leading to significant negative emission potential
- Operation to start in 2025
- Storage as part of the Northern Lights project and in the Danish North Sea (transport by both pipe and ship)

- ARC (EfW) and Copenhagen Malmö Port (CMP) applied for EU Innovation Fund in 2021 but were not successful
- EfW uses 560k t of waste / y
- ARC is aiming at capturing 500kt CO_2 /y with its project ClimAid.
- Significant energy penalty reduction as waste heat will be recovered and used in DH (<€100/tCO_2 captured)
- CO_2 will be shipped for storage

Benefits of small community scale CHP BECCS systems

- Decoupling from the need of complex T&S infrastructure
- Proximity to the biomass resource
- Modular design
- High costs but high potential for reduction with effective heat integration
- Potential for decentralised hydrogen BECCS systems

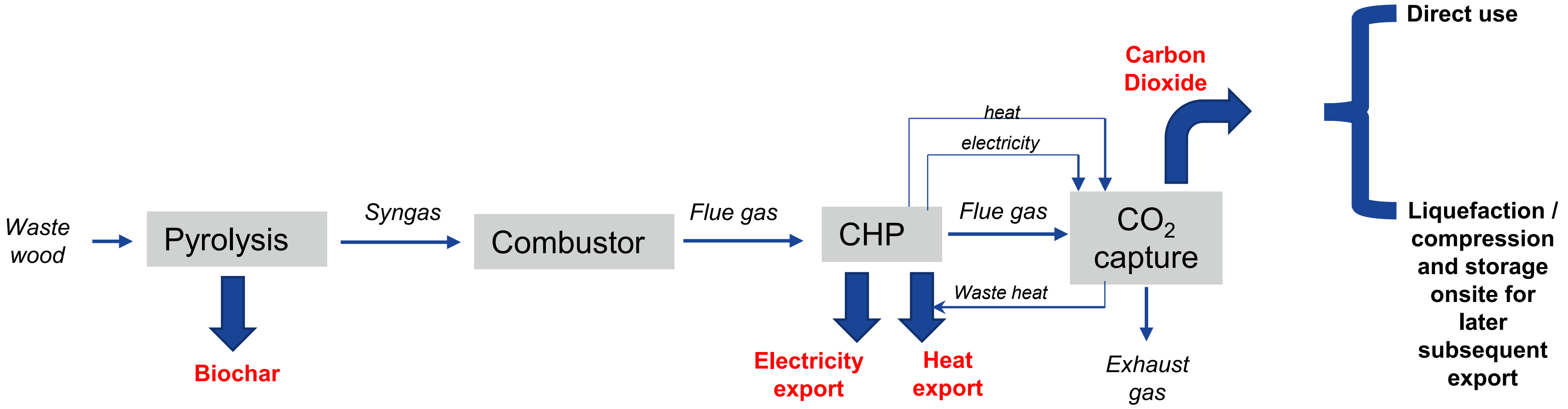


*Innovation led by Ricardo-led: A pyrolysis **BIO**mass-based cogeneration system with **C**O_2 **C**apture, **U**tilisation and **S**torage*

Biomass-based cogeneration system with biochar and CO_2 production

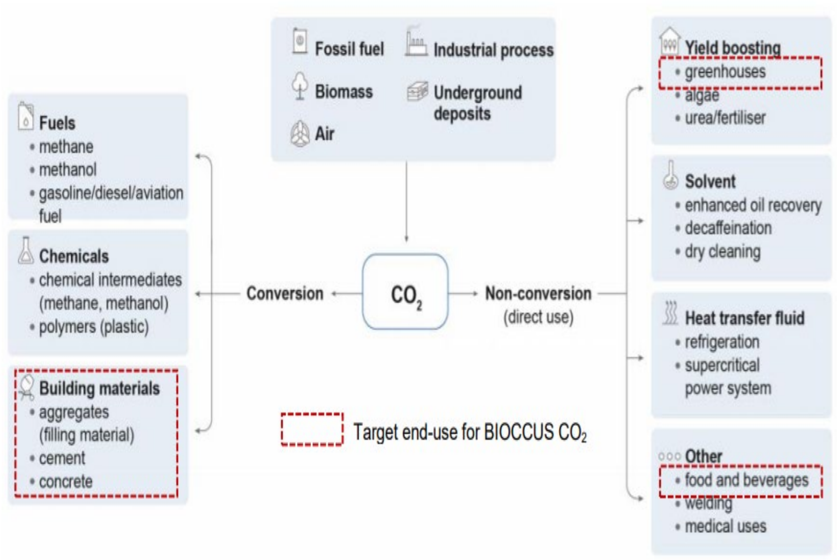
- A combination of two CDR technologies
- Full design of 320 kWe / 1.5 MW_{th} system completed
- Achieves 95% capture rate in biochar and from flue gas
- >99.5% CO_2 purity
- Applications include AD sites and greenhouses

- Surplus heat and electricity from CHP
- Commercial grade CO_2 and biochar are in high demand



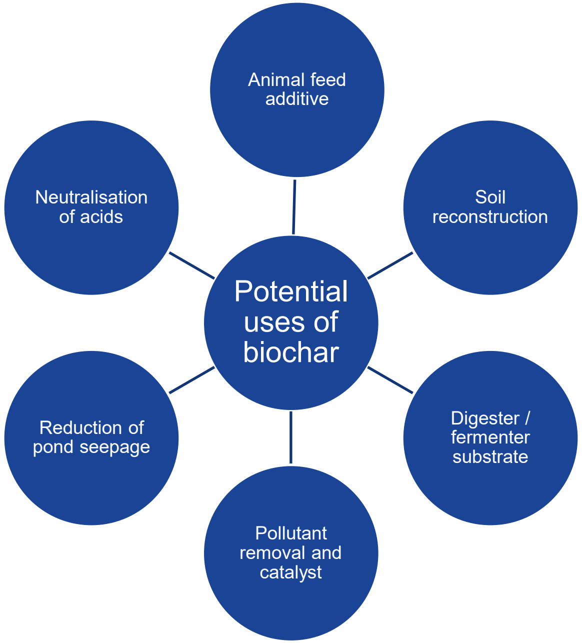
Biochar and carbon dioxide markets

CO_2 utilisation



- Main sources currently are steam methane reforming and bioethanol
- Emerging applications for permanent storage of CO_2 should be prioritised

Biochar uses

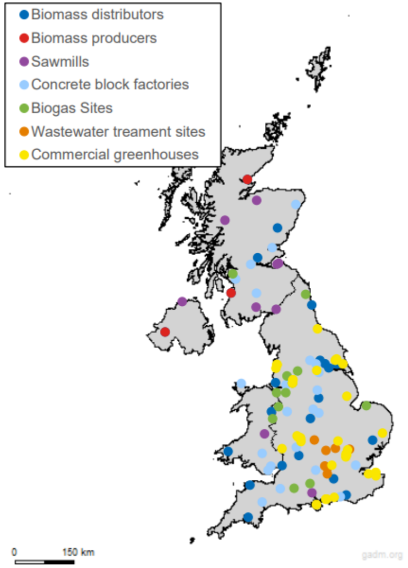


- Uses in industry, agriculture, cosmetics, sanitation, construction
- Legislation and market needs to develop further

High level results from feasibility study and preliminary design

- 20-60% surplus electricity (main consumer is flue gas scrubber) and 55% surplus heat
- 0.2 tonnes of biochar produced per tone of biomass and 0.97 tonnes of compressed CO_2 per tonne of biomass
- CO_2 savings of 2.6 tonne CO_2 per hr (21 tonnes CO_2 annually)
- Simple payback of 2.3-3.5 years

Based on conservative market analysis for technology	
CDR (GGR or NETs) potential by 2030	*300 – 800 kt CO_2 /year*
Reduction in CO_2 emissions	*340 – 900 kt CO_2 / year*
Total contribution to net zero	0.7 – 1.7 Mt CO_2/year



Biomass sources and potential market outlet - UK

Thank you!

Naser Odeh,
Associate Director, Head of CCUS and Biofuels, Ricardo Energy & Environment

Naser.Odeh@ricardo.com