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Today’s program

• Presentation (16.00-16.30)
  • Overview of the BECCS value chain (capture-transport-storage)
  • Utilization of biogenic CO₂
  • Business models & role of policy
  • Key points moving forward

• Q & A Session (16.30 - 17.00)
• Negative emissions/CO₂ removal likely needed

• Discussions on BECCS largely focused on long-term issues

• Long-term CC mitigation impact will require near-mid-term deployment

• Where are the opportunities? What are the bottlenecks?
BECCS/U Supply Chain Overview

Biomass → Capture (Industry, CHP, ethanol plant, WtE...) → Transport → Storage (BECCS) → Utilization (BECCU)
CO₂ Capture Technologies

- Similar technologies as in fossil fuel CCS, except often smaller plants.
- High moisture and hydrogen content of fuel leads to large flue gas condensers.
- Low-temperature heat could be utilised in CHP plants and/or in CO₂ capture.
- Oxyfuel and Calcium looping technologies may provide additional integration benefits in biorefineries where CaO, O₂, CO₂ are used also in primary process.
- In CCU integration with hydrogen production by electrolysis, also byproduct O₂ could be utilised for CO₂ capture.
Sustainable sources of biogenic CO₂

- Bioethanol production
  - High CO₂ content, only drying needed for CO₂ capture
  - Most existing large scale BECCS plants

- Anaerobic biogas digesters
  - High CO₂ content (35-45 %)

- Pulp mills / Biorefineries
  - CO₂ content (10-20 %, dry)
  - Specific CO₂ emission 2-2.5 t CO₂/t, pulp
  - Role of pulp-based products expected to increase

- Waste-to-Energy Plants
  - Typically > 50 % biogenic
  - WtE reduces also landfill gas GHG emissions

The Illinois Industrial Carbon Capture and Storage plant captures CO₂ from Archer Daniel Midland’s Decatur corn processing facility and stores it almost a mile and a half underground. Credit: Archer Daniel Midland / CarbonBrief
Availability vs. capture cost

- Limited availability of concentrated CO₂ streams with low capture costs
- BioCO₂ point sources (+cement) are enough for aviation and shipping fuels
- Role of BECCS/U varies greatly in different scenarios (Hepburn et al. 2019, Nature 575, 87-97)
Transport of CO$_2$

Onshore
- Small-scale/pilot project: Tanker (rail or truck)
- Large scale: Pipeline is the most cost-effective method

Offshore
- Ship vs pipeline decision will depend on project-specific factors
- Pipelines more suitable for:
  - Short transport distances
  - Large volumes
  - Long project lifetimes
- Other factors include flexibility, reliability, and environmental considerations

Image source: Kjärstad et al. 2016
Sequestration of CO₂ - Geological storage

*Deep saline formations*
- Saline aquifers are plentiful world-wide, both onshore & offshore
- Involves pumping CO₂ deep underground into a layer of porous rock

*Depleted oil and gas reservoirs*
- Are prime locations for injecting CO₂ as the pore space that was once occupied by oil or gas can now be filled with the CO₂
- Geologists are familiar with the sites and they have already proven that they can contain oil or gas for millions of years

Image source: Clean Air Task Force
Utilisation of CO₂ - example of CO₂ EOR

Enhanced oil recovery (EOR) - today
- Injection of CO₂ into an oil well increases recovery rates significantly
- While some of the CO₂ returns to the surface with the oil, a portion of the injected CO₂ is sequestered permanently.
- As of 2017, nearly 100 CO₂ EOR projects globally, producing nearly half a million barrels per day (IEA database)
- Currently, the vast majority of CO₂ utilized in CO₂ EOR comes from nearby natural sources

Bioenergy based CO₂ EOR - opportunity for tomorrow
- If the CO₂ utilised in CO₂ EOR instead was captured from a biomass based power plant, this would greatly reduce the CO₂ footprint of the additional oil produced
- Gives rise to numerous discussion points

Image source: Clean Air Task Force
Utilisation of biogenic CO₂ - BECCU value chain

**Biomass**

Capture

(Industry, CHP, ethanol plant, WtE...)

Transport

Utilization (BECCU)

Advantages of biogenic CO₂ sources

- Mature capture technologies
- Concentrated streams of CO₂
- Additional revenue for bioenergy plant operators when CO₂ sold for CCU/S

Storage (BECCS)
### Utilisation of biogenic CO$_2$ - pathways

#### physical
- **direct use of CO$_2$ in liquid or gaseous form**
  - beverages
  - greenhouses
  - EOR | EGR

#### material
- **CO$_2$ & H$_2$**
- synthetic hydrocarbons
  - e.g. platform chemicals and plastics

#### energetic
- **production of synthetic hydrocarbon fuels, e.g.**
  - diesel
  - jet fuel
  - methane for grid injection

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[Forbes/Getty Images](https://www.gasworld.com)  
[Forbes/Getty Images](https://www.velocys.com)  
[IEA Bioenergy](https://www.ieabioenergy.com)
Power-to-X for sector coupling

Power-to- Liquid
Power-to-Gas
Power-to-Chemicals

Audi Power-to-Gas pilot plant in Werlte, GE:
Electricity input: 6 MW
H2 production: 1.300 m³/h
CCU: 2 800 t CO₂/a
SNG production: 300 m³/h

Source: EWE Netz.
Published in Audi AG/ Reinhard Otten. 2014. The first industrial PtG plant – Audi e-gas as driver for the energy turnaround.
Key messages

CCU is a key set of technologies for a resource-efficient economy

- CO\(_2\) from renewable sources extends the resource base
- CCU is a form of waste treatment that contributes to a circular economy
- CCU generates additional value and can drive innovative business cases, e.g. new market segments for bioenergy plants

... but there are limitations

- Large CO\(_2\) volume flows are required for a cost-efficient CCU process
  - Large biomass (co-)firing plants are advantageous
    - or pooling of small-scale CO\(_2\) sources in decentralized systems
- Even under optimistic long-term assumptions, CCU could only contribute to 6% reduction of anthropogenic emissions (Naims et al. 2015)
Role of public policy: innovation support

- Need to climb the TRL ladder and scale up

- Pilot & demonstration facilities risky & expensive - public financing important!

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(Adapted from Global CCS Institute, 2009)
Role of public policy: create opportunities to generate revenue from CDR

• Voluntary carbon offsets welcome & valuable but not sufficient

• Public policy measures needed

• Different alternatives discussed, planned or implemented
  • Inclusion in ETS (EU)?
  • Public procurement of CDR (Sweden)?
  • Tax credits (45Q in US)
Key points moving forward

• Close the fossil CCS/BECCS policy gap

• How to develop BECCU for maximum mitigation benefits?

• Bio-EOR & “negative emission fossil fuels” raise difficult questions
Thank you!

IEA Bioenergy Task 40 - deployment of biobased value chains

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