IEA Bioenergy
Technology Collaboration Programme

Deployment of BECCS/U – technologies, supply chain setup & policy options

Olle Olsson (SEI), Tero Tynjälä (LUT), Christian Bang (Ea Energy Analyses) & Daniela Thrän (DBFZ/UFZ)

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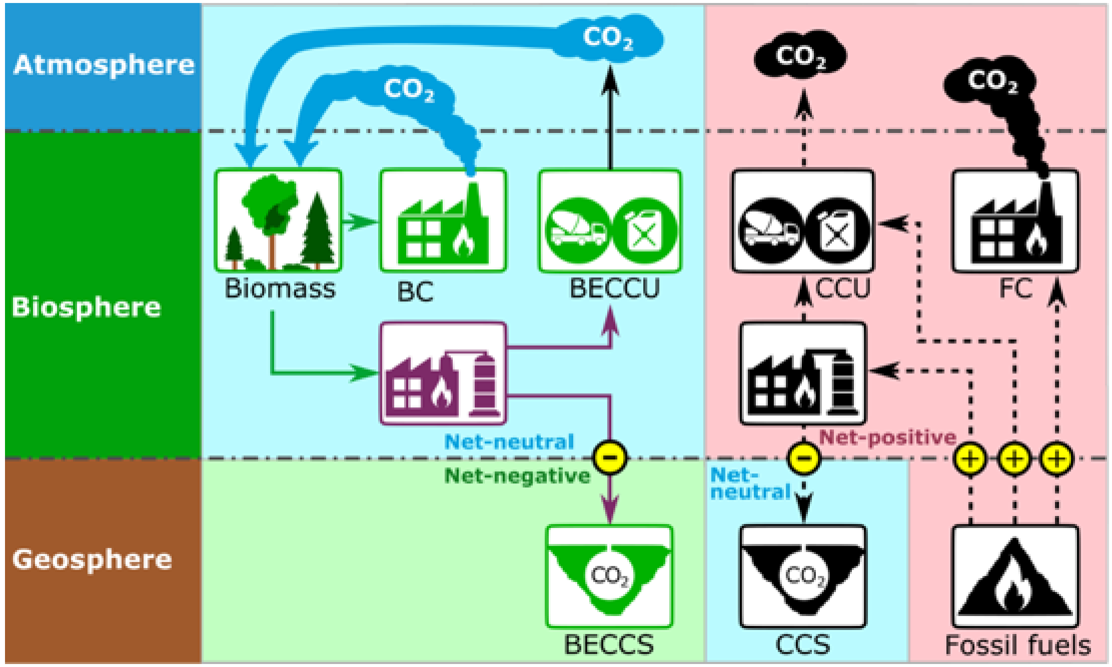
Today's program

- Presentation (16.00-16.30)
  - Overview of the BECCS value chain (capture-transport-storage)
  - Utilization of biogenic CO_2
  - Business models & role of policy
  - Key points moving forward

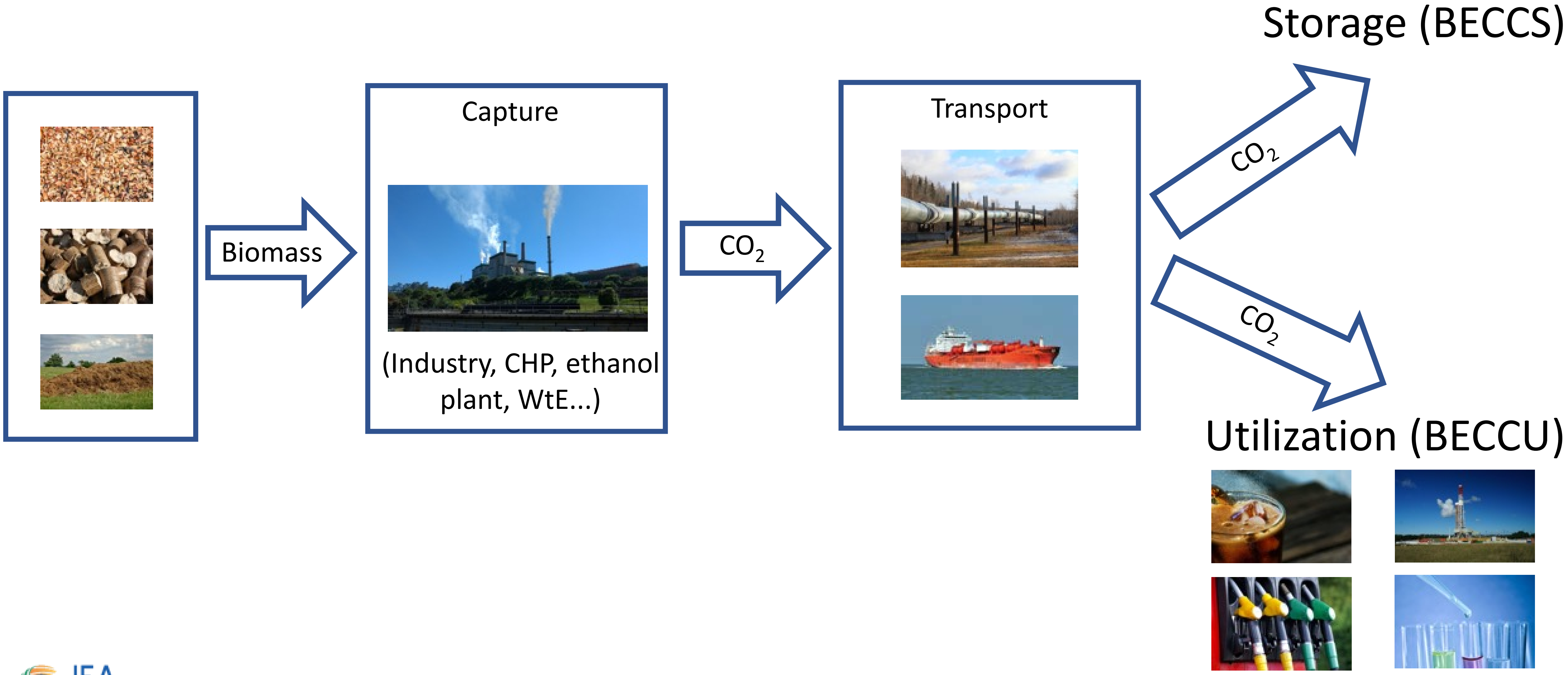
- Q & A Session (16.30 - 17.00)

IEA Bioenergy Inter-task Project on BECCS/U

- Negative emissions/CO_2 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



CO_2 Capture Technologies

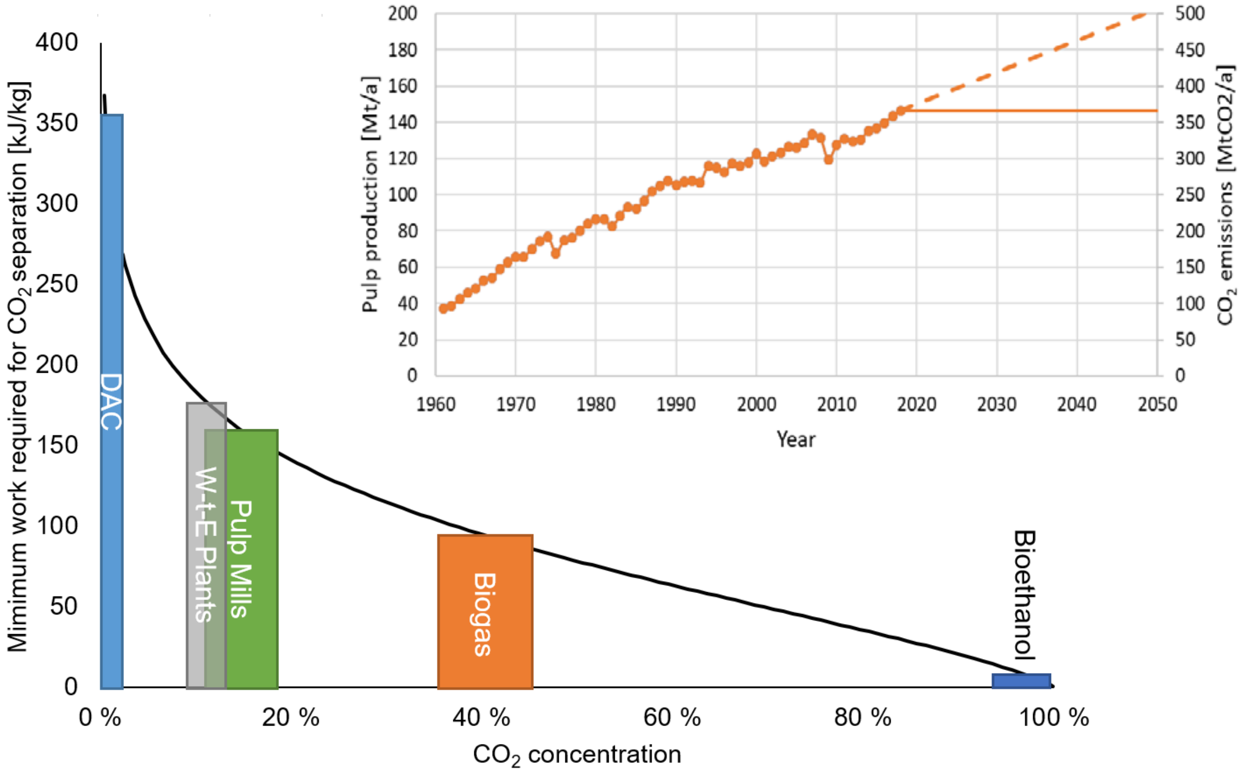
- Similar technologies as in fossil fuel CCS, except often smaller plants.
- High moisture and hydrogen content of fuel leads to large flue gas condensers.
- Low-temperature heat could be utilised in CHP plants and/or in CO_2 capture.
- Oxyfuel and Calcium looping technologies may provide additional integration benefits in biorefineries where CaO, O_2, CO_2 are used also in primary process.
- In CCU integration with hydrogen production by electrolysis, also byproduct O_2 could be utilised for CO_2 capture.

Precombustion	Postcombustion	Oxyfuel
Biomass gasification & CO_2 capture Hydrogen / Syngas production	Amine absorption Post-combustion calcium looping process Membranes	Oxy-combustion Chemical looping combustion

Sustainable sources of biogenic CO_2

- Bioethanol production
  - High CO_2 content, only drying needed for CO_2 capture
  - Most existing large scale BECCS plants
- Anaerobic biogas digesters
  - High CO_2 content (35-45 %)
- Pulp mills / Biorefineries
  - CO_2 content (10-20 %, dry)
  - Specific CO_2 emission 2-2.5 t,CO_2/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 CO_2 from Archer Daniel Midland's Decatur corn processing facility and stores it almost a mile and a half underground. Credit: Archer Daniel Midland / CarbonBrief https://www.carbonbrief.org/guest-post-how-use-of-land-in-pursuit-of-1-5c-could-impact-biodiversity/adm-beccs



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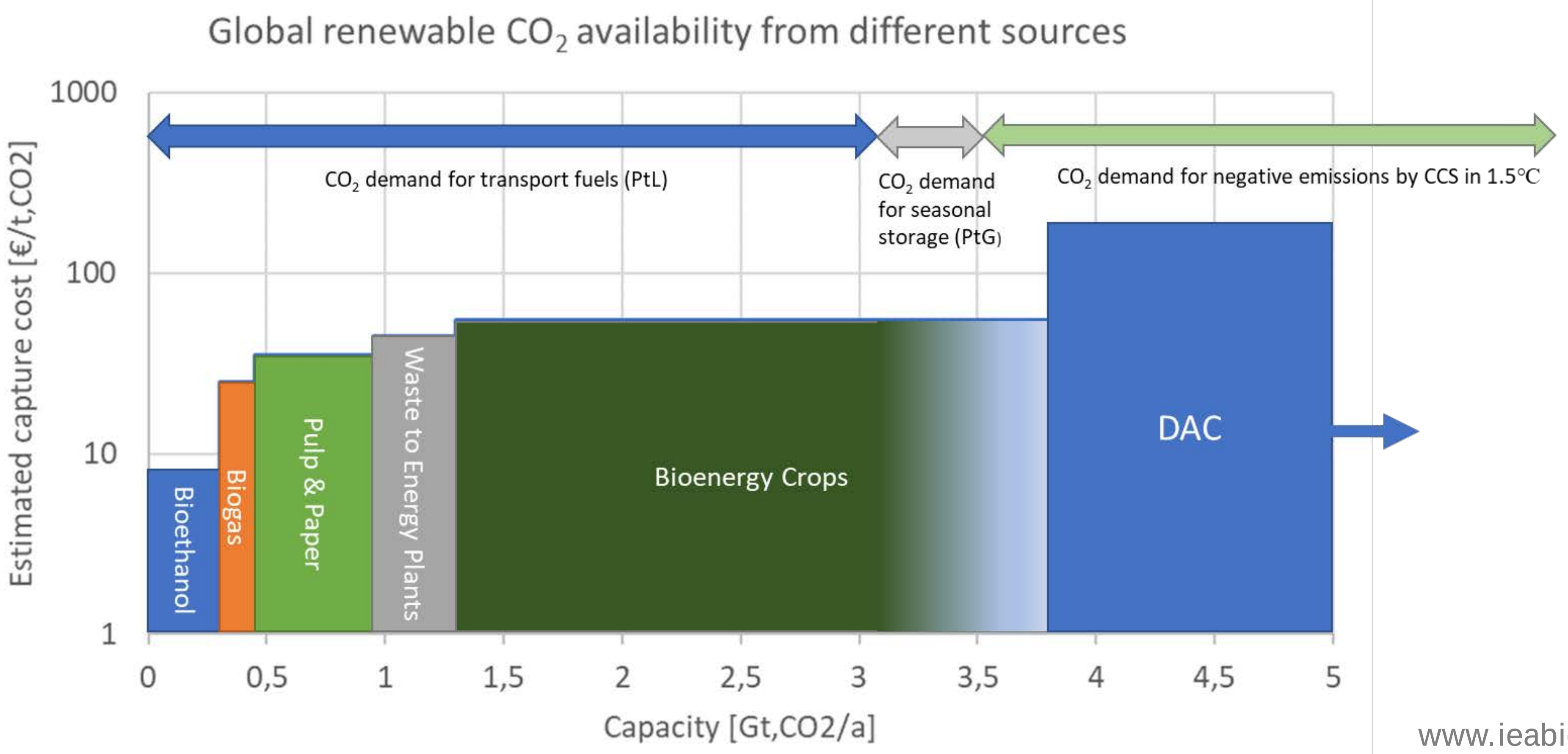
Availability vs. capture cost

- Limited availability of concentrated CO_2 streams with low capture costs
- BioCO_2 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)



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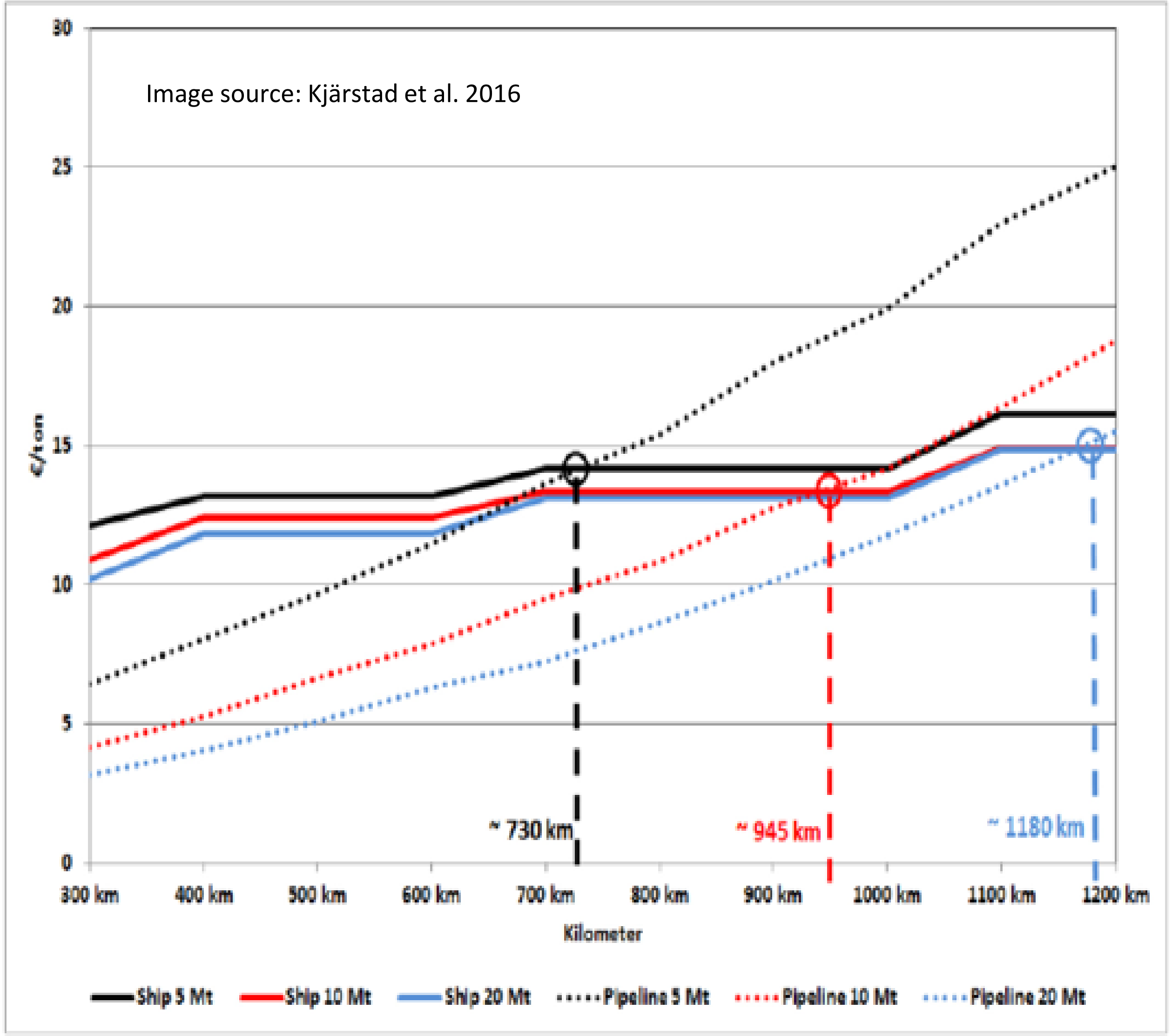
Transport of CO_2

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



Sequestration of CO_2 - Geological storage

Deep saline formations

- Saline aquifers are plentiful world-wide, both onshore & offshore
- Involves pumping CO_2 deep underground into a layer of porous rock

Depleted oil and gas reservoirs

- Are prime locations for injecting CO_2 as the pore space that was once occupied by oil or gas can now be filled with the CO_2
- Geologists are familiar with the sites and they have already proven that they can contain oil or gas for millions of years

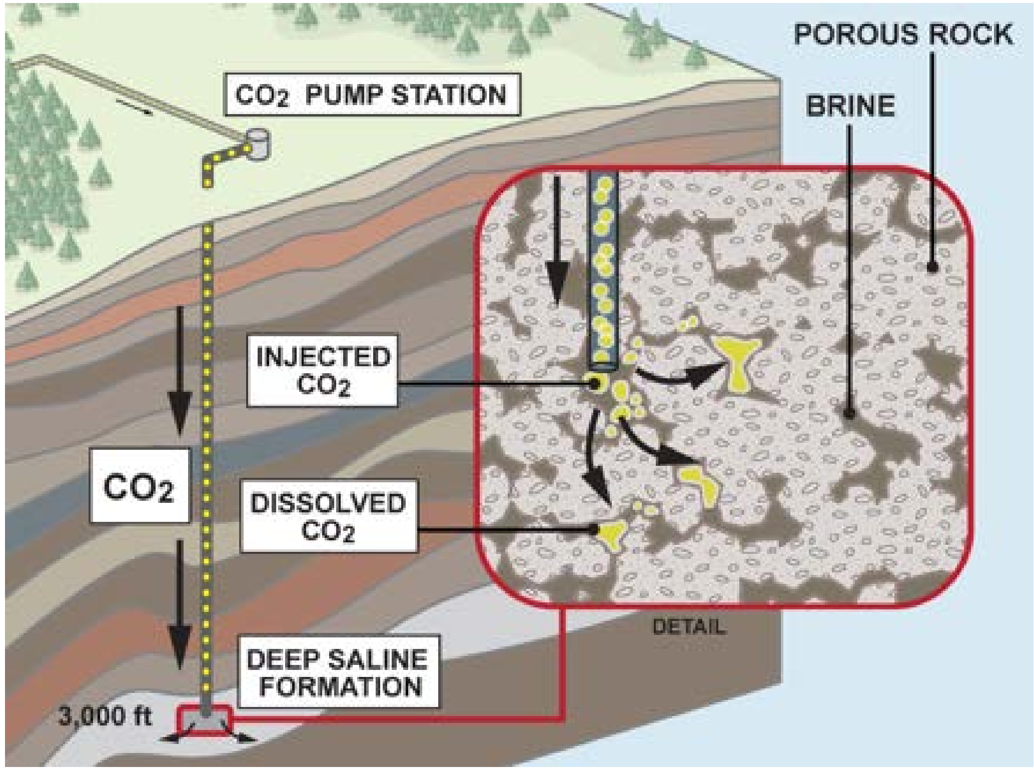


Image source: Clean Air Task Force

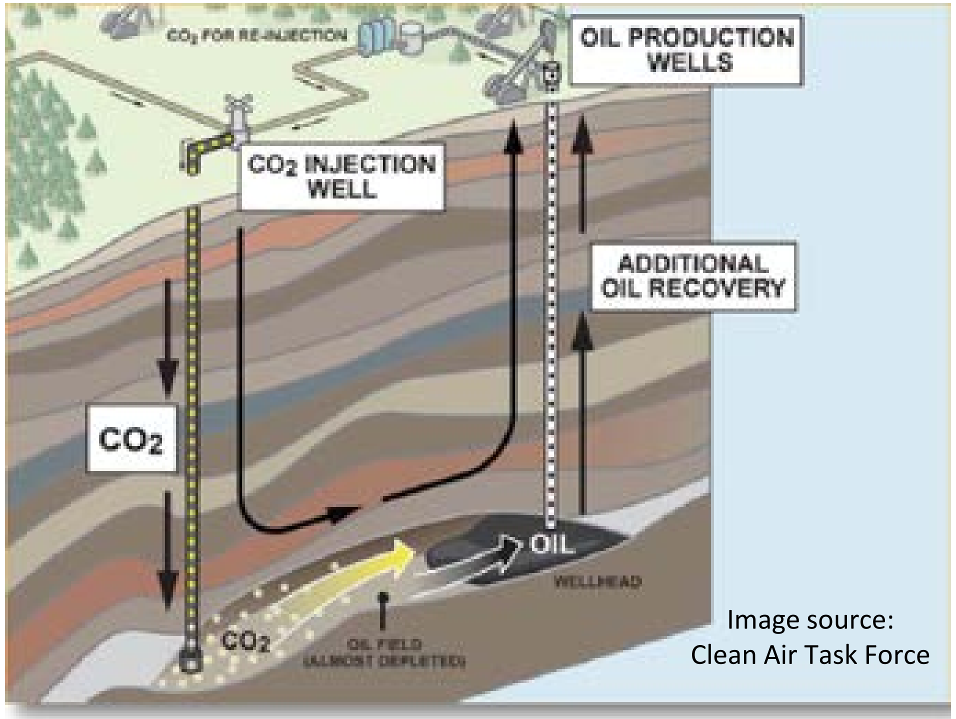
Utilisation of CO_2 - example of CO_2 EOR

Enhanced oil recovery (EOR) - today

- Injection of CO_2 into an oil well increases recovery rates significantly
- While some of the CO_2 returns to the surface with the oil, a portion of the injected CO_2 is sequestered permanently.
- As of 2017, nearly 100 CO_2 EOR projects globally, producing nearly half a million barrels per day (IEA database)
- Currently, the vast majority of CO_2 utilized in CO_2 EOR comes from nearby natural sources

Bioenergy based CO_2 EOR – opportunity for tomorrow

- If the CO_2 utilised in CO_2 EOR instead was captured from a biomass based power plant, this would greatly reduce the CO_2 footprint of the additonal oil produced
- Gives rise to numerous discussion points



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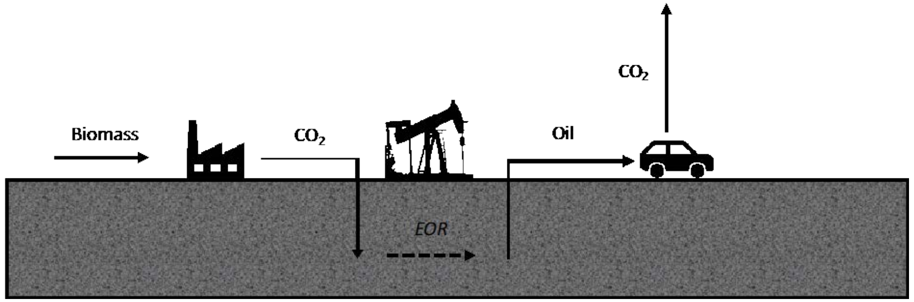
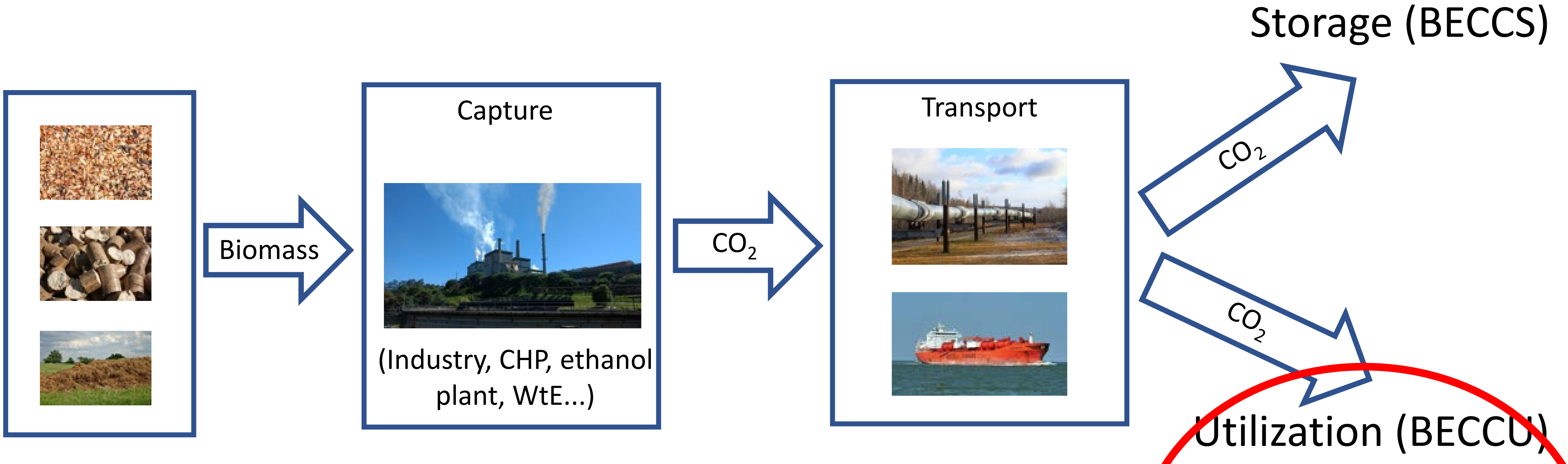


Utilisation of biogenic CO_2 - BECCU value chain



Advantages of biogenic CO_2 sources

- Mature capture technologies
- concentrated streams of CO_2
- additional revenue for bioenergy plant operators when CO_2 sold for CCU/S

Utilisation of biogenic CO_2 - pathways

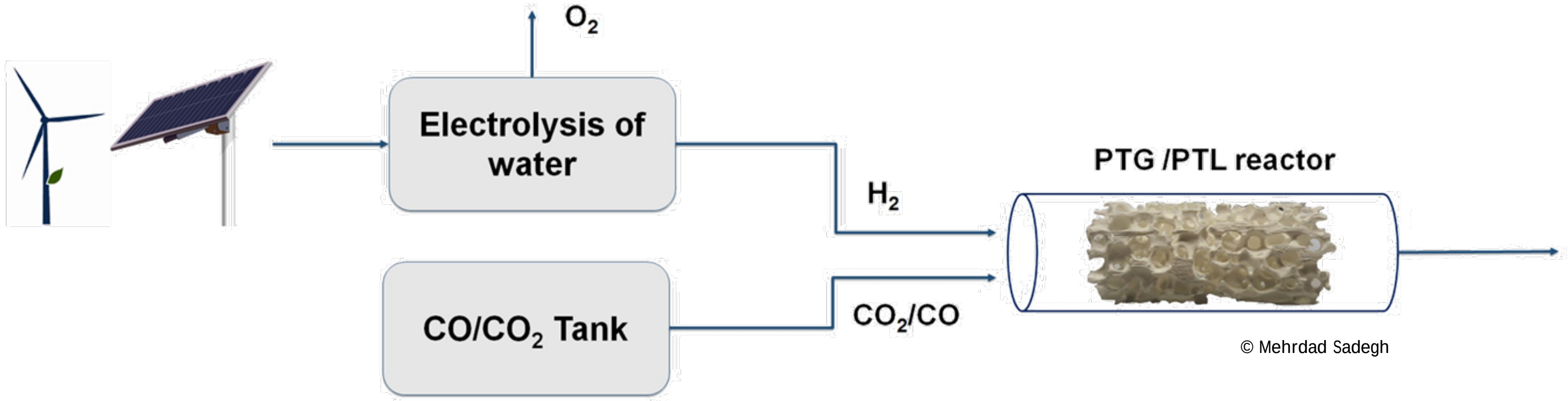
physical	material	energetic
direct use of CO_2 in liquid or gaseous form • beverages • greenhouses • EOR | EGR	CO_2 & H_2 ↓ synthetic hydrocarbons ↓ e.g. platform chemicals and plastics	production of synthetic hydrocarbon fuels, e.g. • diesel • jet fuel • methane for grid injection

https://www.gasworld.com

Forbes/Getty Images

https://www.velocys.com

Power-to-X for sector coupling



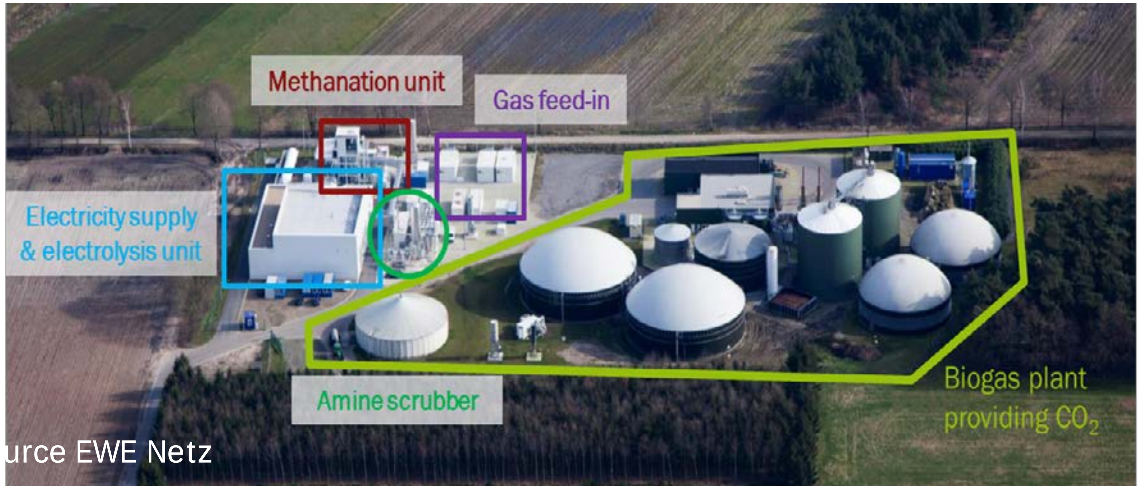
Power-to-Liquid

Power-to-Gas

Power-to-Chemicals

Power **to** **X**

Source: EWE Netz. Published in Audi AG/ Reinhard Otten. 2014. The first industrial PtG plant – Audi e-gas as driver for the energy turnaround. http://www.cedec.com/files/default/8-2014-05-27-cedec-gas-day-reinhard-otten-audi-ag.pdf



Audi Power-to-Gas pilot plant in Werlte, GE:
Electricity input: 6 MW
H2 production: 1.300 m³/h
CCU: 2 800 t CO_2/a
SNG production: 300 m³/h

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!

TRL-9	Full-Scale Commercial Deployment
TRL-8	Sub-Scale Commercial Demonstration Plant
TRL-7	Pilot Plant
TRL-6	Component Prototype Demonstration
TRL-5	Component Prototype Development
TRL-4	Laboratory Component Testing
TRL-3	Analytical, "Proof of Concept"
TRL-2	Application Formulated
TRL-1	Basic Principles Observed

(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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