Business from technology

Bio-CCS: going carbon negative in Scandinavia

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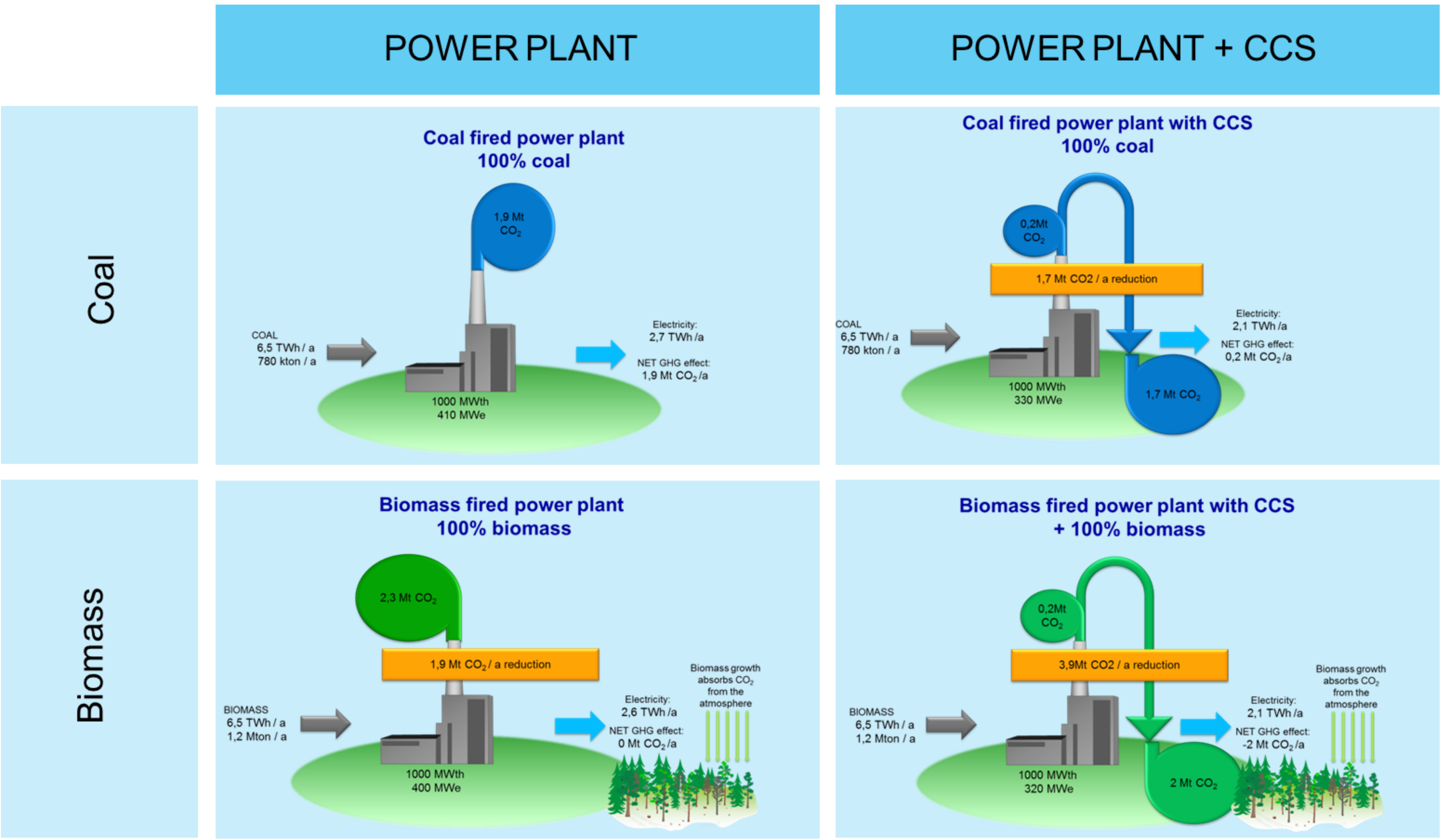
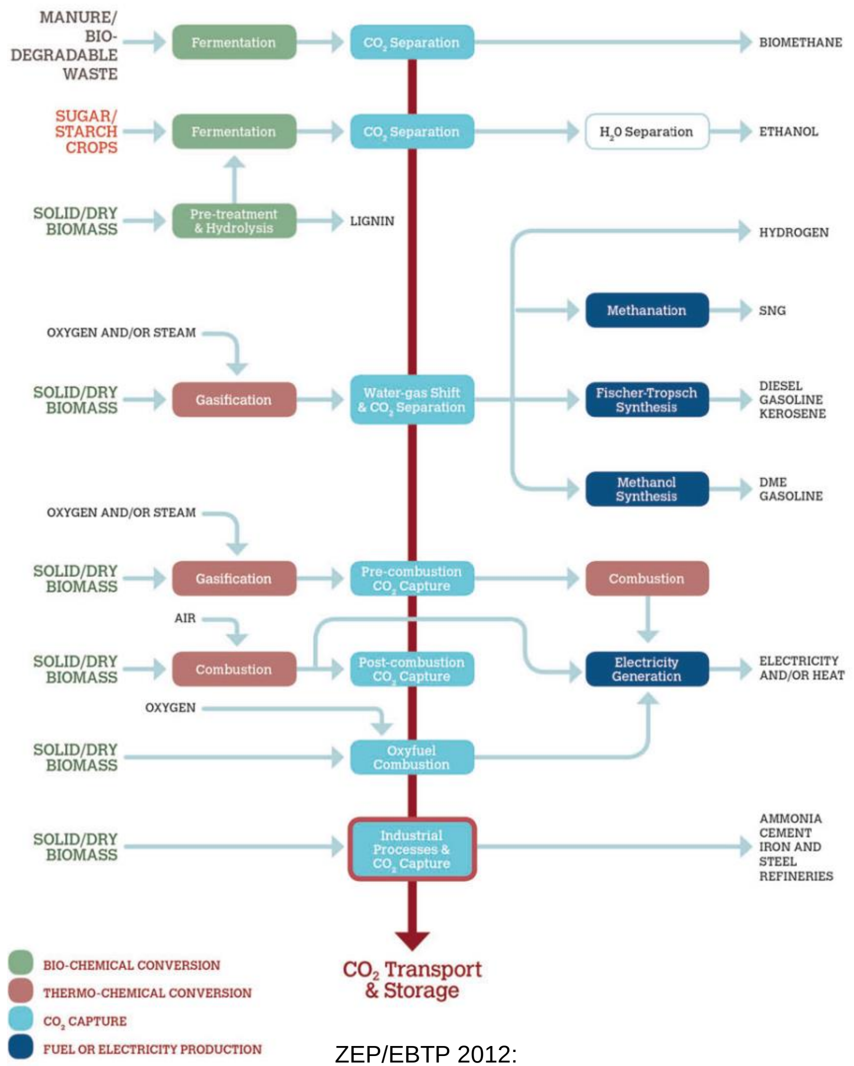
Bio-CCS combines sustainable biomass conversion with CO_2 Capture and Storage (CCS) – impact 2 x coal with CCS



Because Bio-CCS binds CO_2 from the atmosphere, the net CO_2 reduction impact per unit energy produced can be multifold in comparison to fossil CCS or 2nd generation biofuels alone

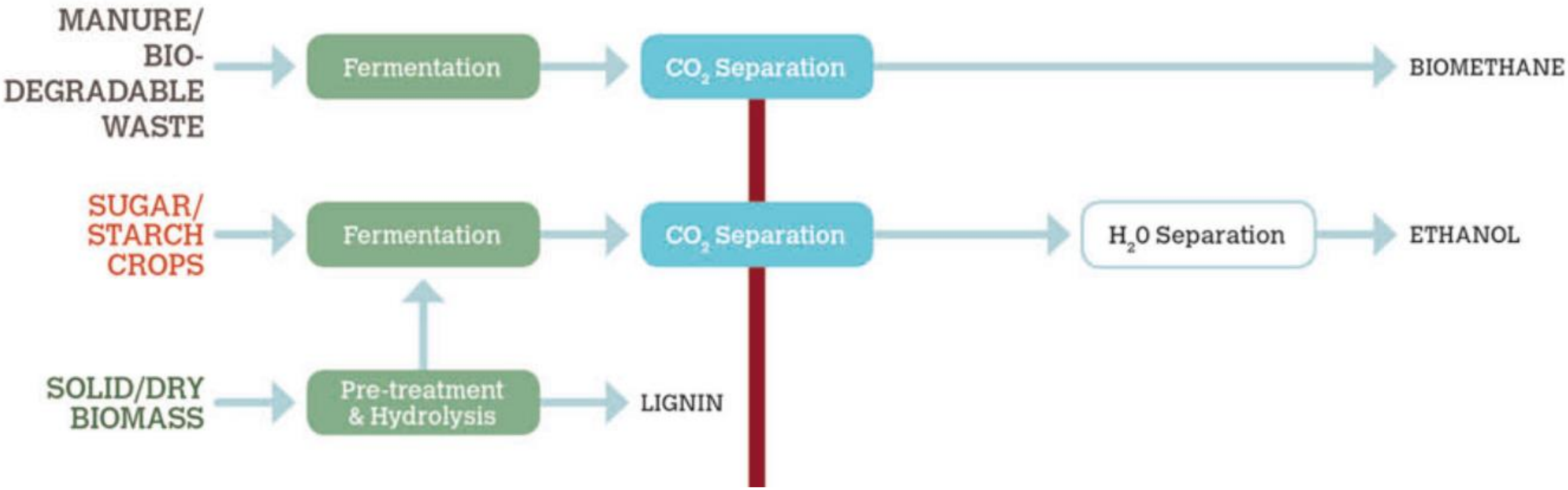
Biomass-based conversion routes with CCS

generally Bio-CCS has no fundamental differences in comparison to fossil CCS besides accounting of negative emissions



ZEP/EBTP 2012:
http://www.biofuelstp.eu/downloads/bioccsjtf/EBTP-ZEP-Report-Bio-CCS-The-Way-Forward.pdf

Bio-CCS in biochemical conversion routes of biomass



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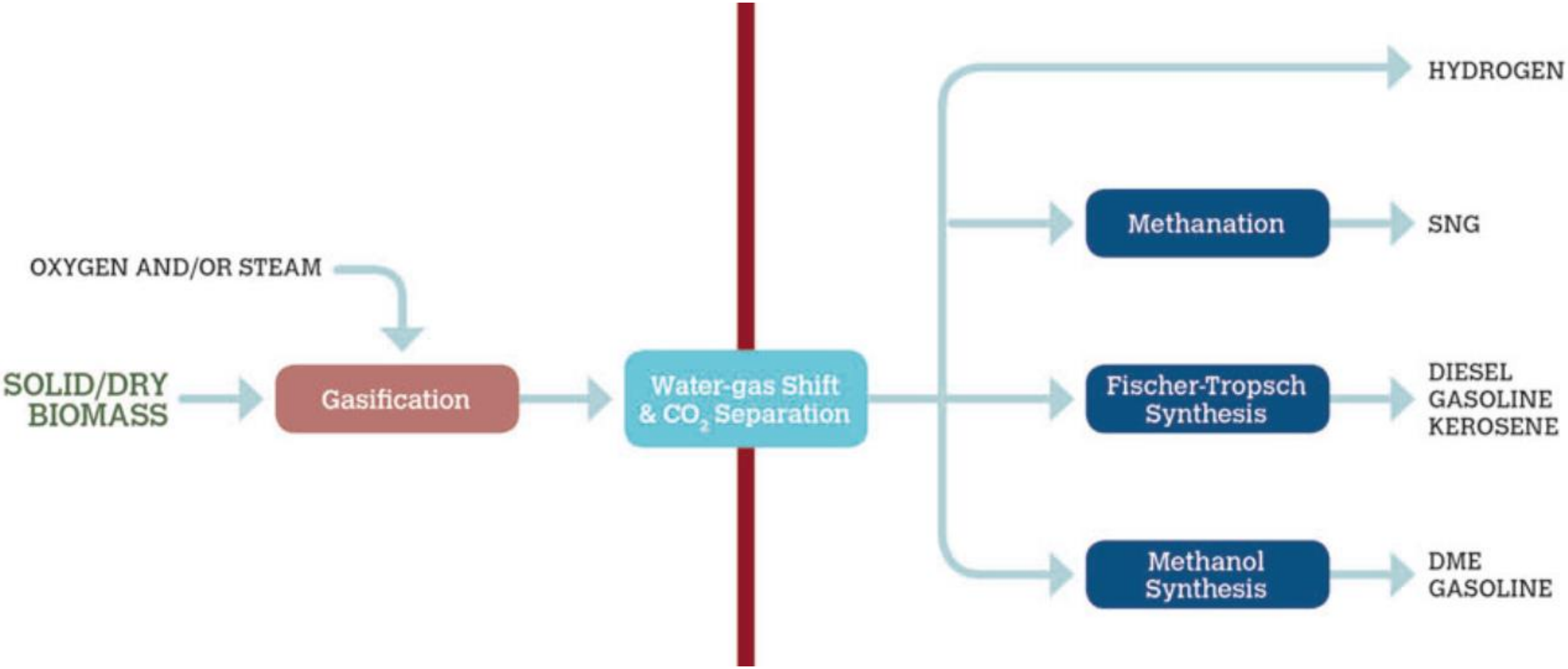
Bio-CCS in thermo-chemical conversion routes of biomass



ZEP/EBTP 2012:
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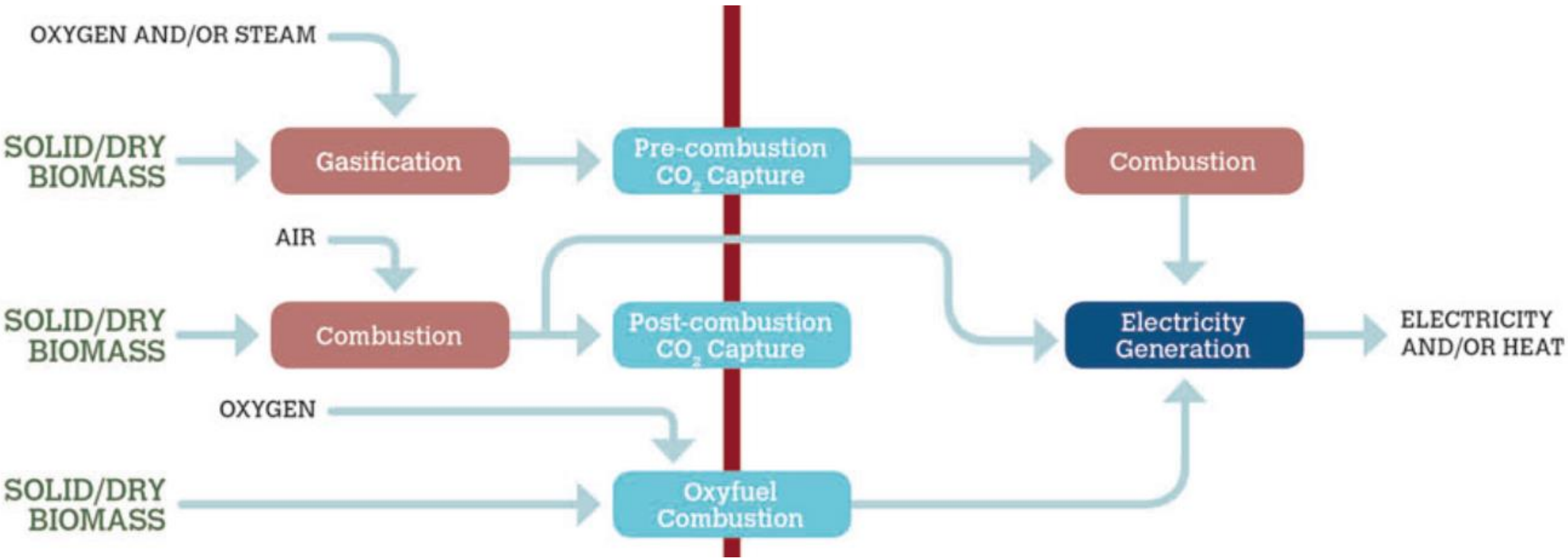
Bio-CCS in power production



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Bio-CCS in industrial processes

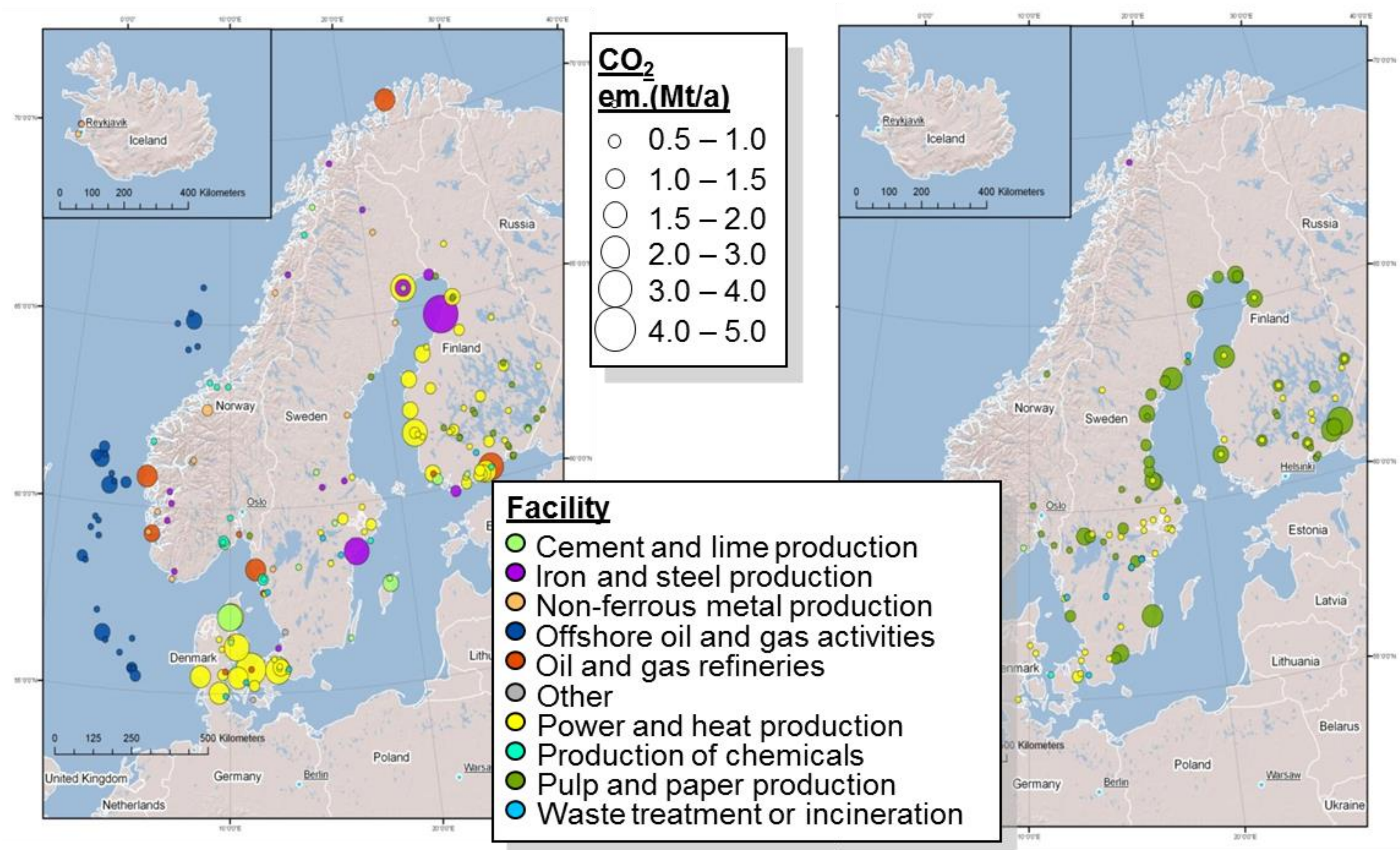
ZEP/EBTP 2012:
http://www.biofuelstp.eu/downloads/bioccsjtf/EBTP-ZEP-Report-Bio-CCS-The-Way-Forward.pdf

Biomass utilisation in Nordic is mainly forest biomass

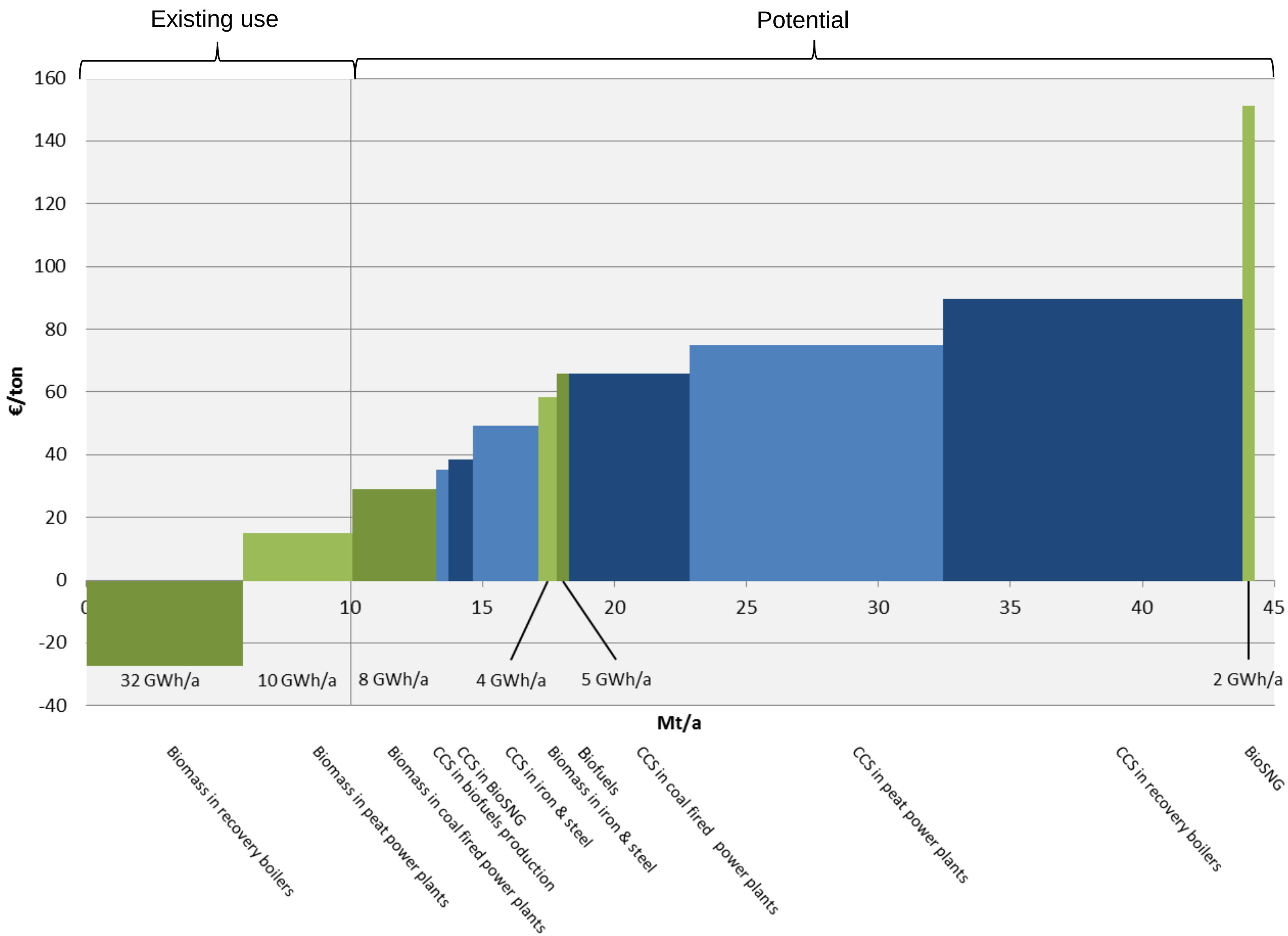
dominated by pulp and paper industry, Combined Heat and Power production in CFB boilers and future biorefineries

Fossil and inorganic CO_2 emissons

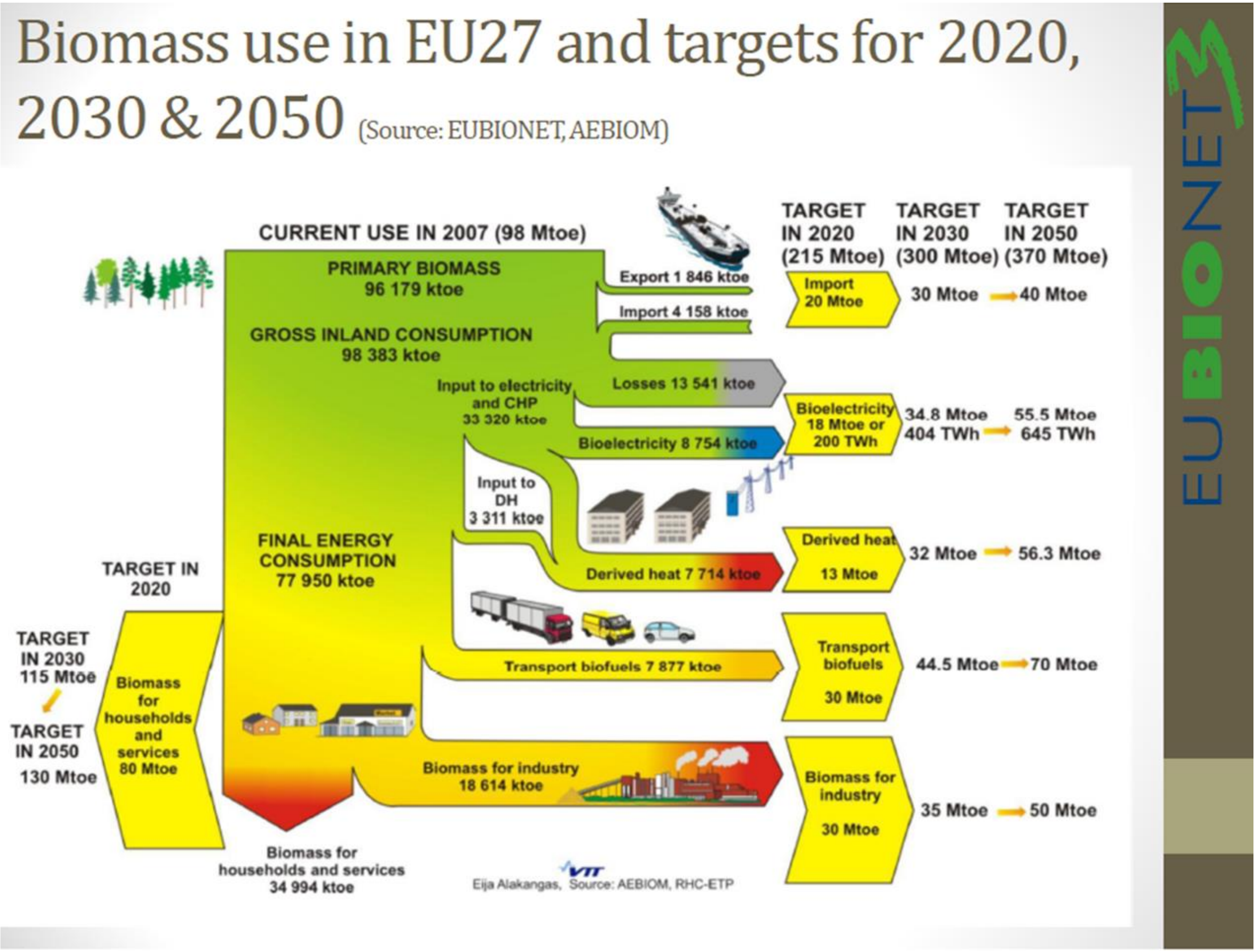
Biogenic CO_2 emissons



Techno-political Bio-CCS potential in Finland 2025



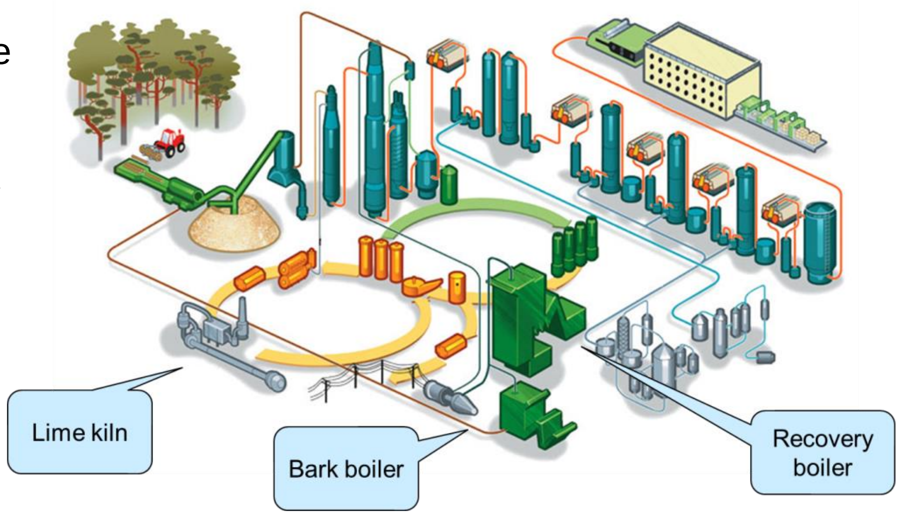
The critical question is the sustainable biomass supply



Industrial applications of Bio-CCS

CCS in pulp and paper industry

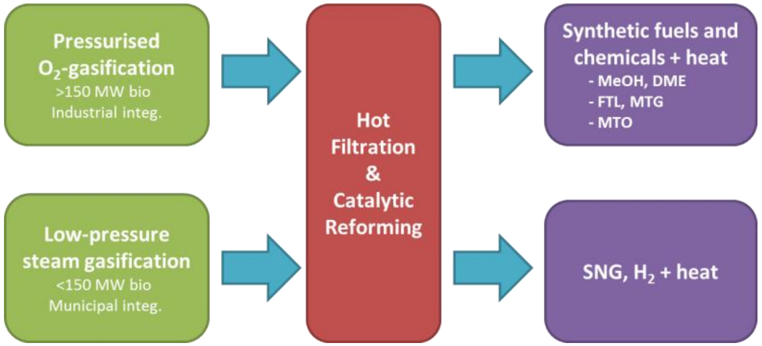
- Kraft pulping process is the most common modern pulping technology currently in use
- Majority of emissions from a pulp mill site are biogenic (Mt/a scale)
  - Fossil free pulp mills are possible but some amounts of fossil fuels generally utilised
  - Emissions scattered to several stacks on site
- Largest point sources on site
  - Lime kiln
  - Recovery boiler
  - Power boiler
- Essential parts of Kraft pulping process and chemical cycle -> high availability and operability are a MUST
  - Recovery of cooking chemicals
  - Recovery of energy
  - Producing power and heat

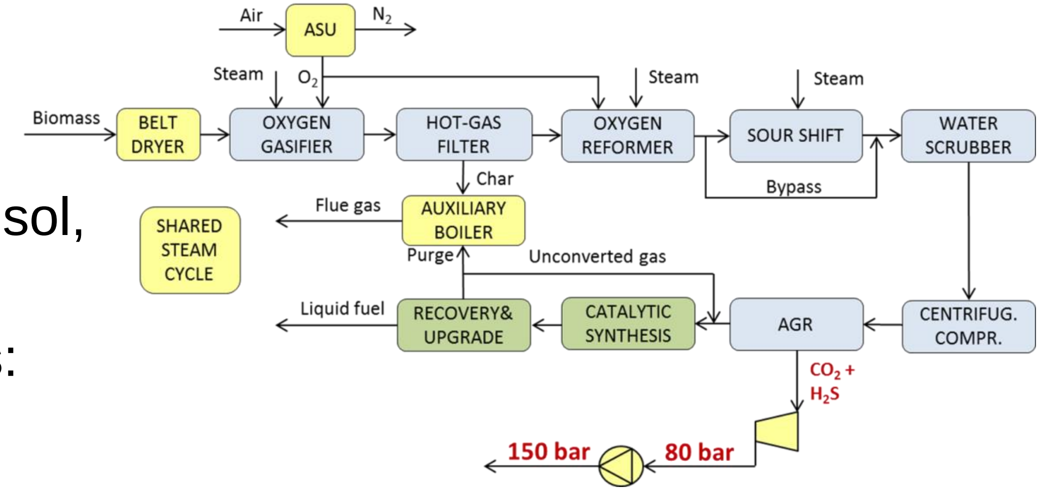


Kraft process for wood chemical pulping: 50% pulp yield from wood, 100% of biogenic carbon utilised as product or energy

CCS in BtL (Biomass to Liquids) production
(+ C1 chemistry)

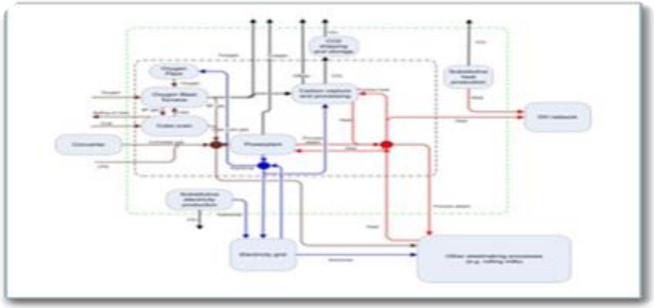
- Gasification and sythesis based liquid biofuels production
    - MeOH, DME, FTL (e.g. FT diesel) & MTG
- Carbon capture is an essential part of the process, as H2/CO ratio of synthesis gas must be adjusted according to the requirements of synthesis
- Pre-combustion capture technologies, such as Rectisol, Selexol etc…
- Updated techno-economics: http://bit.ly/192Vl3G





CCS in Iron and Steel industry

- BF + BOF most common process route globally (no alternative to fully replace, e.g. DRI)
  - Coke utilised as a reducing agent in blast furnace to extract iron from iron ore
- Largest emission sources (fossil fuel based): Blast furnace, blast furnace gas combustion in hot stoves, coke oven gas and converter gas
- Emissions can be reduced by utilising biomass as co-feed with coal
  - Up to levels of ~40% of coke consumption (PCI)
  - Cannot fully replace coal
- Options for reduction of emission: Oxygen blast furnace with flue gas circulation and CCS, Post combustion CCS, advanced smelting technologies etc.
- Significant reductions in GHG emissions possible with both, the PCC and OBF technologies



More information:

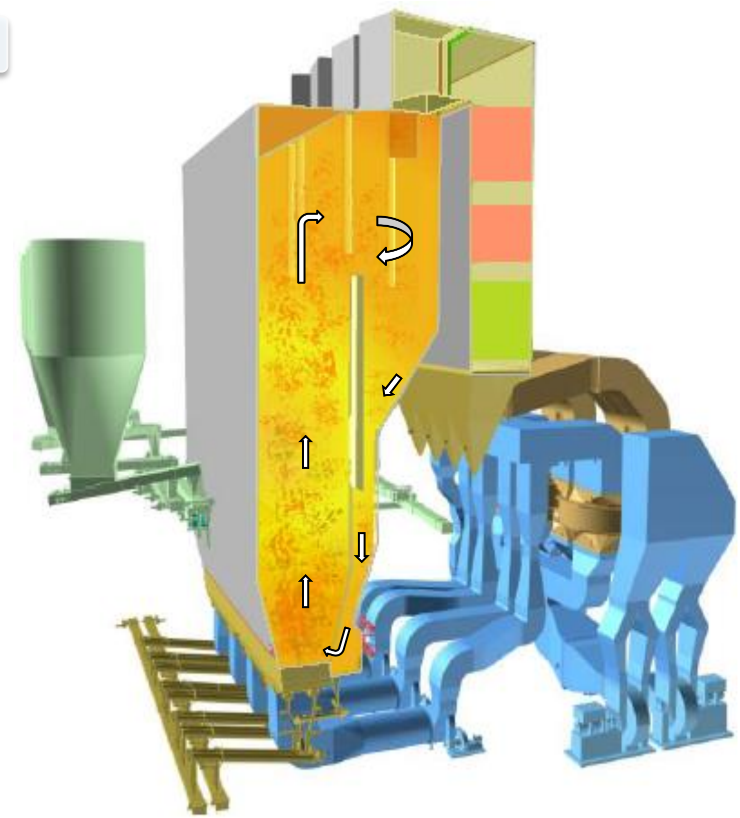
http://dx.doi.org/10.1016/j.egypro.2013.06.648
http://10.0.3.248/j.ijggc.2014.09.004
http://dx.doi.org/10.1016/j.ijggc.2012.08.018
http://dx.doi.org/10.1016/j.ijggc.2012.08.017

CFB Co-combustion of Biomass and Coal Up to 800MW$_e$ Scale

CFB Technology with:

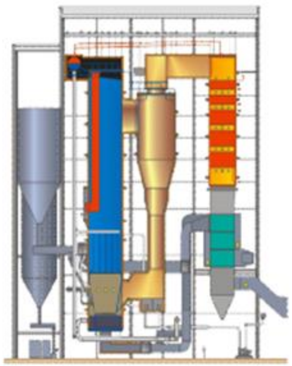
- sub-critical steam parameters available up to scale 600MW$_e$ with 100% coal and 100% Biomass firing (or anything between)
- super-critical steam parameters available up to ~600MW$_e$ scale with 50% solid biomass share
- super-critical steam parameters available up to ~800MW$_e$ scale with 20%

1. Fuel Flexibility



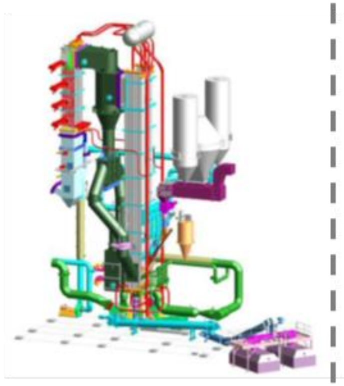
Towards negative CO_2 emissions with Oxy-CFB technology

Fossil
- Low solids
- High solids



- **High plant efficiency**
- **Fossil CO_2 emissions**

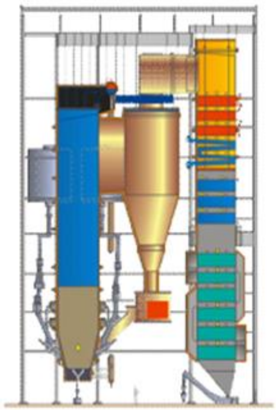
Fossil with CO_2 capture



- **8…10 %-pts eff. penalty in CCS**
- **Up to 95% CO_2 capture rates**

Higher OPEX* and CAPEX than without capture

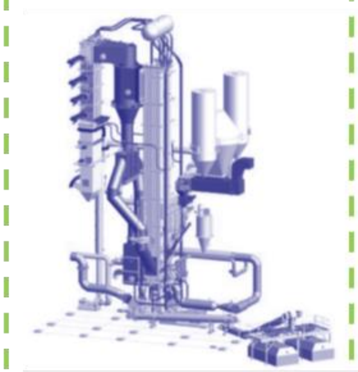
Bio/Multi
- Agro
- Wood



- **Good plant efficiency**
- **Zero (biogenic) CO_2 emissions**

Higher OPEX* and CAPEX than with fossil fuels

Bio/Multi with CO_2 capture



- **Efficiency penalty similar to fossil**
- **"Negative" CO_2 emissions**

Highest OPEX* and CAPEX

Valmet

* without CO_2 allowances

FOSTER WHEELER

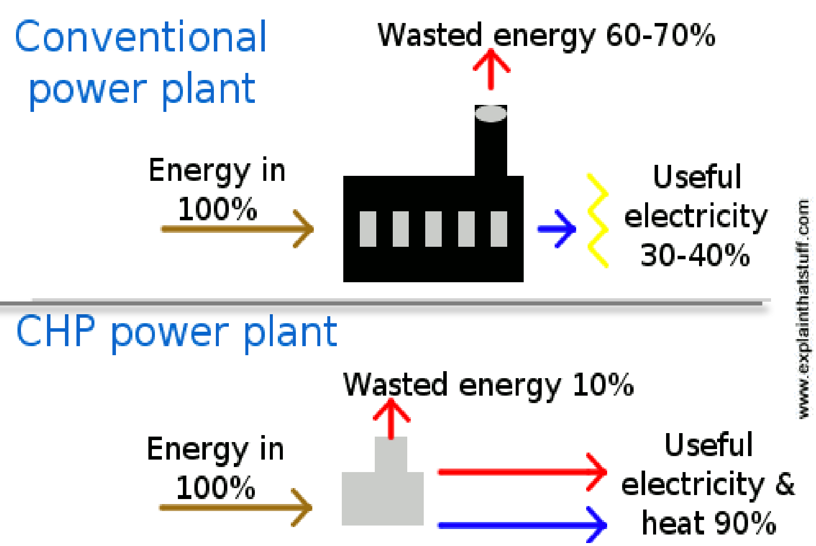
Impact of CCS to CHP

- Generally, over 90 % process efficiency is achievable in CHP production if large heat distribution system and relatively continuous heat consumption exist.
- In CCS processes utilisation of relatively low temperature heat from capture plant, ASU or CO_2 compression in district heating system (and/or industrial applications) offers significant potential to increase overall efficiency.

CHP vs. power only:

Several CCS estimations available under public domain

Lower break-even price for CCS due to heat utilisation



Conclusions across technologies and sectors

- Bio-CCS can lead to carbon negative impact e.g. remove CO_2 from the atmosphere
  - In order to go carbon negative sustainability of biomass has to be secured
  - However, storing biogenic CO_2 should be considered as storing fossil CO_2 (as there is no difference in climate perspective) independent on the discussion regarding carbon neutrality of biomass
- In general, same technologies for carbon capture can be considered as with fossil power production and industries
  - Liquid biofuels production may be a appealing target for deployment with near-pure CO_2 streams
- Some differences and restrictions regarding implementation of Bio-CCS in comparison to fossil CCS such as shares of biomass in co-firing, regional availability, typical sizes of installations and availability of sustainable raw material

Thank you for your attention!

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