Pathway to achieve negative CO2 emissions - combining biomass with CCS

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PATHWAY TO ACHIEVE NEGATIVE CO₂ EMISSIONS – COMBINING BIOMASS WITH CCS

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Bio-CCS is a systemic issue more than technical

The beauty of Bio-CCS and negative emissions is the ability to offset emissions over sectors and time
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VTT – Technology for business

VTT Technical Research Centre of Finland Ltd is the leading research and technology company in the Nordic countries. We provide expert services for our domestic and international customers and partners, and for both private and public sectors. We use 4,000,000 hours of brainpower a year to develop new technological solutions.

We develop new smart technologies, profitable solutions and innovative services. We cooperate with our customers to produce technology for business and build success and well-being for the benefit of society.

VTT is a non-profit organisation and a crucial part of Finland's innovation eco-system. VTT operates under the mandate of the Ministry of Employment and the Economy.

- Turnover 277 M€ (VTT Group 2014), personnel 2,600 (VTT Group 1.1.2015)
- Unique research and testing infrastructure
- Wide national and international cooperation network

Examples of research results

Finland’s first 5G test network to boost private-sector competitiveness

Patterned and flexible light-emitting surfaces at lower cost based on OLED technology

New display brings visual information directly into the user’s field of vision, as a high-definition image on an eyeglass lens.

A cost-efficient, 3D-printed, reliable hydraulic valve block that is 66% lighter than the original part

Increasing operational life of the high pressure turbine (HPT) blades of Hornet jet engines by 10% saves over 2.7 million euros for taxpayers

New patented technology enables the manufacturing of a revolutionary new fibre product with plastic-like properties

Fuel cell systems enable high-efficiency cogeneration of heat and power from biogas produced in connection with wastewater treatment

Fazer has secured a license to an oat technology developed and patented by VTT

Pure industrial chemicals by gasifying lignocellulosic biomass

Read more: www.vttresearch.com

13/04/2016
Bio-CCS?
Magnitude of issues at hand

- IPCC Working Group III reports that these **negative emissions technologies** (also called CDR—Carbon Dioxide Removing—technologies”) could enable removal of **10 Gt** a year from the atmosphere by **2050**, and perhaps 40 Gt a year by the end of century. To have a >50% chance of limiting warming below 2 °C, most recent scenarios from integrated assessment models (IAMs) require large-scale deployment of negative emissions technologies (NETs). These are technologies that result in the net removal of greenhouse gases from the atmosphere [Smith et al. 2015]
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 liquid biofuels alone.

A reduction of 3.9 Mt CO$_2$ compared to fossil power production.
Break even price for CO2 where CCS turns feasible

Results refer to comparison between new plant with and w/o CCS in each respective case.

- Cost of CO2 avoided, €/tn
- Break even price, €/tn

Net profit (M€/a):
- 100 % peat with CCS: 41
- Co-firing with CCS: 54
- 100 % bio with CCS: 52
Bio-CCS technologies
Biomass-based conversion routes with CCS
Generally Bio-CCS has no fundamental differences in comparison to fossil CCS besides accounting of negative emissions
Techno-political Bio-CCS potential in Finland 2025

Existing use:
- 32 GWh/a
- 10 GWh/a
- 8 GWh/a
- 4 GWh/a
- 5 GWh/a

Potential:
- 2 GWh/a

Costs in €/ton:
- Biomass in recovery boilers
- Biomass in peat power plants
- CCS in bio/NG production
- Biofuels
- CCS in iron & steel
- CCS in coal-fired power plants
- CCS in peat power plants
- CCS in recovery boilers
- BiocNG
Sectoral approach to 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 2G BtL (Biomass to Liquids) production (+ C1 chemistry)

- Gasification and synthesis 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…
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.ijgcc.2014.09.004  
http://dx.doi.org/10.1016/j.ijgcc.2012.08.018  
http://dx.doi.org/10.1016/j.ijgcc.2012.08.017
Towards negative CO₂ emissions with Oxy-CFB technology

- **Fossil**
  - Low solids
  - High solids
  - High plant efficiency
  - Fossil CO₂ emissions
  - *Higher OPEX* and CAPEX than without capture

- **Fossil with CO₂ capture**
  - 8...10 %-pts eff. penalty in CCS
  - Up to 95% CO₂ capture rates

- **Bio/Multi**
  - Agro
  - Wood
  - Good plant efficiency
  - Zero (biogenic) CO₂ emissions
  - *Higher OPEX* and CAPEX than with fossil fuels

- **Bio/Multi with CO₂ capture**
  - Efficiency penalty similar to fossil
  - "Negative" CO₂ emissions
  - *Highest OPEX* and CAPEX

* without CO₂ allowances
Hydrogen enhanced synthetic biofuels - More than twofold increase in biofuel output

- Economically attractive over non-enhanced designs when the average cost of low-GHG hydrogen falls below 2.2-2.8 €/kg, depending on the process configuration.

- If all sustainably available wastes and residues in the European Union were collected and converted only to biofuels, using maximal hydrogen enhancement, the daily production would amount to 1.8 - 2.8 million oil equivalent barrels displacing up to 41 - 63 per cent of the EU’s road transport fuel demand in 2030.
Integration of P2G with biomass fired CHP plant

Case study conducted in NEO-CARBON ENERGY project:

- Case: 300 MW\textsubscript{fuel} BFB boiler cofiring peat and forest residues, 10 MW PtG integration
- OxyBoost 5 m-% of secondary and tertiary air during the highest electricity prices
- Profitability of PtG investment with OxyBoost (SNG production, benefits from by-product O\textsubscript{2}, excess steam/heat utilisation, different scenarios, for example electricity prices and incomes from grid service)
- More flexibility; could be used also to enable cheaper (low quality) fuels
Conclusions
Conclusions across technologies and sectors

- Bio-CC(U)S is primarily a systemic issue
- Bio-CCS can lead to carbon negative impact e.g. remove CO$_2$ from the atmosphere
  - Bio-CCS can offset emissions across sectors and historical emissions
  - 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
  - Bio-CCU prolong of use of carbon molecule (circular economy) and pave the way for technology deployment. Not generally resulting in direct large GHG emission savings, however it can be an enabler to a systemic change
- Bio-CCS is the only carbon negative solution that can technically be deployed in large scale in near future
- In general, bio-CCS is not a solution to possible sustainability issues related to biomass. However it will have an impact on the greenhouse gas balance of biomass use
TECHNOLOGY FOR BUSINESS

More information:

http://www.cleen.fi/en/program_overviews/ccsp_carbon_capture_and_storage_program
http://www.vtt.fi/proj/ccsfinland/
http://www.vtt.fi/sites/flexiburncfb/