Business from technology

Bio-CCS in power and CHP production with high biomass shares

Workshop: Biomass with CCS - Removing CO_2 from the Atmosphere, 19.6.2012, Brussels

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Biomass combustion in power and CHP plants

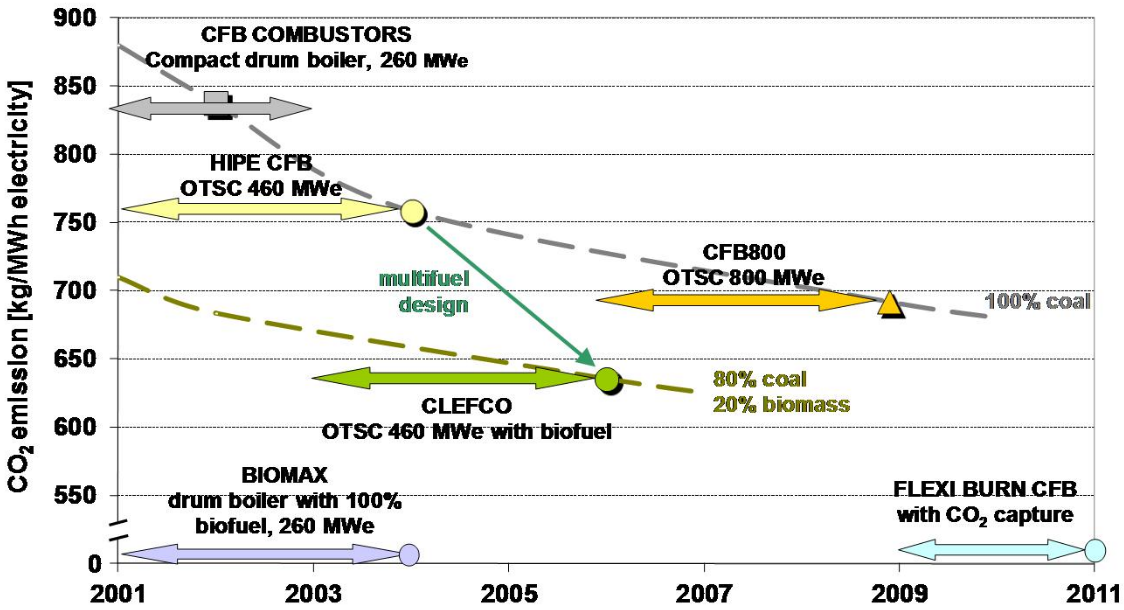
Different co-firing technologies in PC

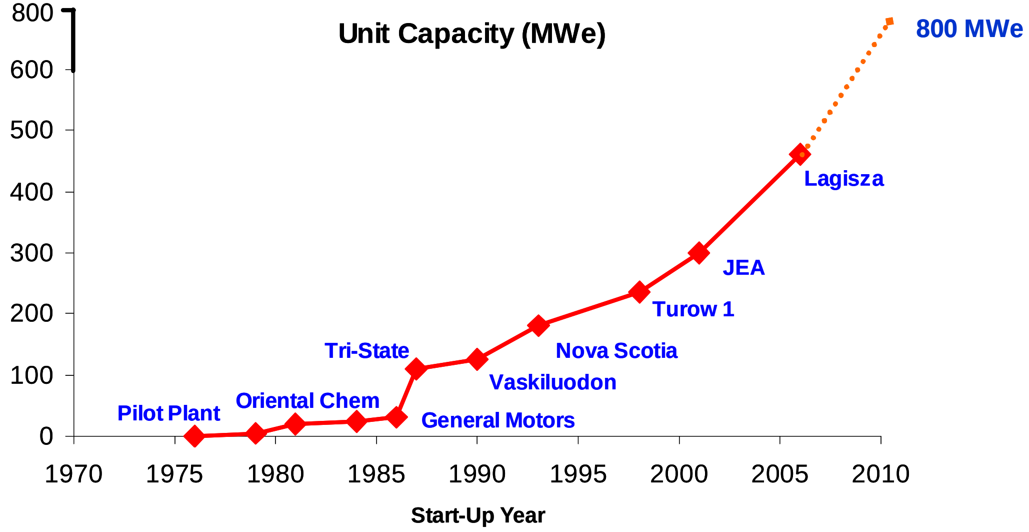
- direct co-firing (mixing of biomass with coal or separate biomass feeding)
- indirect co-firing (gasification, pyrolysis, separate biomass boiler with integrated steam cycle)
- biomass shares relatively small (especially in direct co-firing)

Dedicated/high-share biomass plants

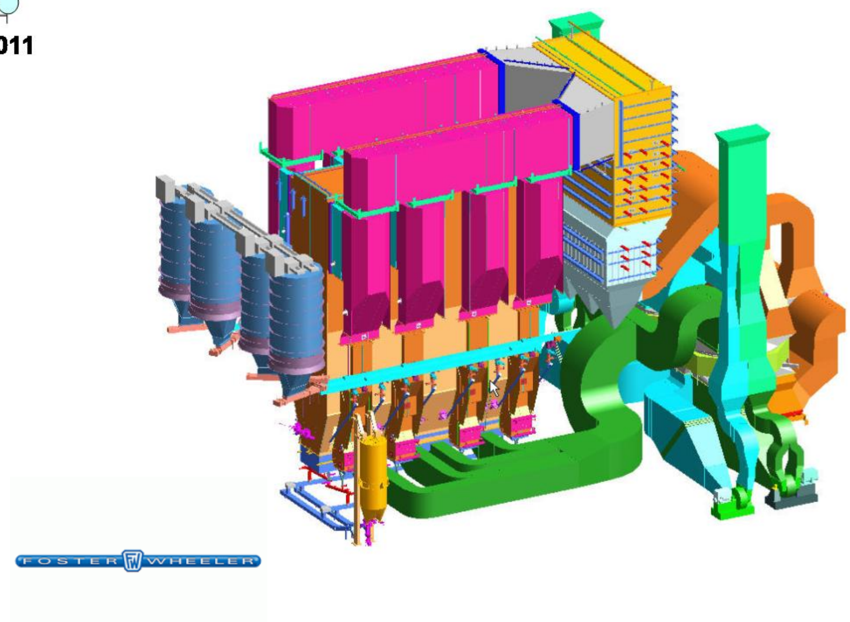
- grate combustion in small scale
- **fluidised bed combustion** has become the dominant technology in larger plants
- typical size of dedicated biomass power and CHP plants is smaller than PF coal plants (mainly due to fuel availability)

Development of CFB technology under EU programs





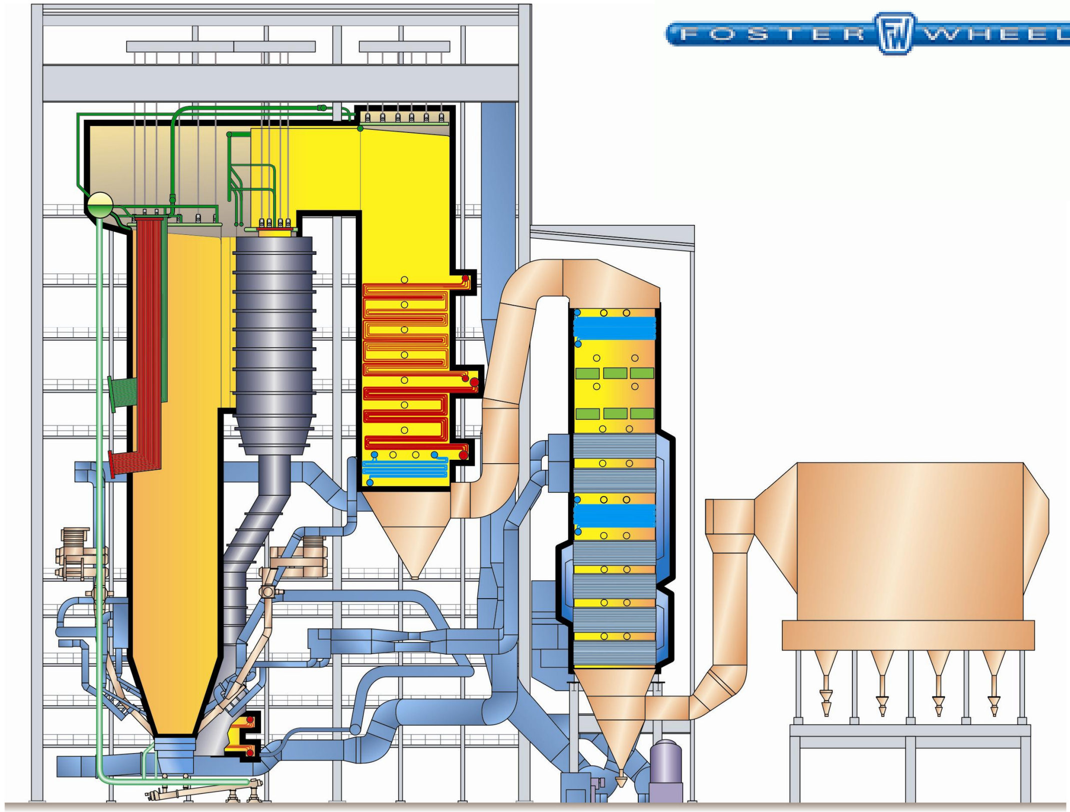
FP5: CFB Combustor, HIPE CFB, BIOMAX
RFCS: CLEFCO, CFB800
FP7: FLEXI BURN CFB, O2GEN



The World's largest 100% biomass CFB

GDF Suez Energia Polska S.A.
Połaniec
Poland

Steam	447 MW_{th}
	153/135 kg/s
	128/20 bar
	535/535 °C
Fuels	
Wood	0 – 100 %
Agro	0 – 20 %
	straw, sunflower pellets, dried fruit (marc), and palm kernel
Start-up	2012

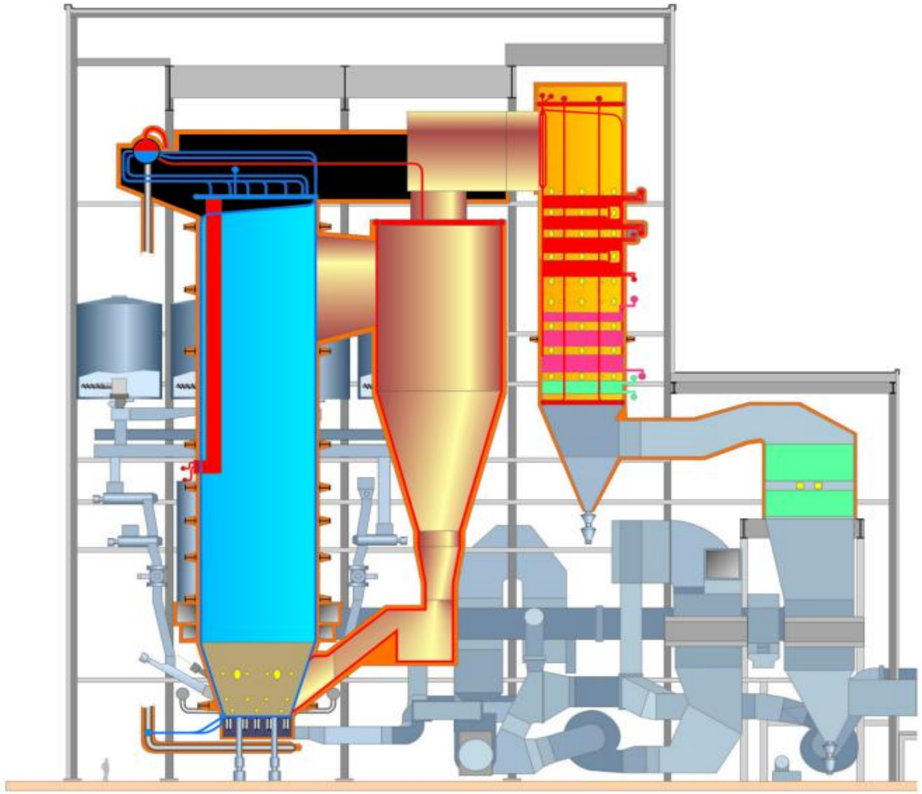


Possibility to utilise 100% biomass in co-fired CFB

Alholmens Kraft,
Pietarsaari, Finland

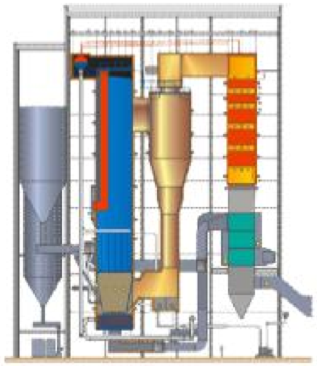
CFB technology:

- **550MW$_{th}$**
- **194kg/s, 165bar, 545°C**
- Uses 40 % peat, 20 % coal, 30 % of biomass (forest residues, industrial wood and bark etc.) and 10 % SRF.
- The design of the plant allows great fuel flexibility, the boiler is able to combust all mixtures from **100 % biomass** to 100 % coal.



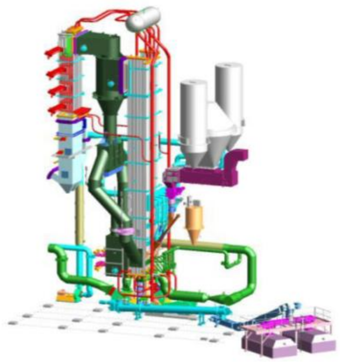
Towards negative CO_2 emissions with CFB technology

Fossil
•Low solids
•High solids



- High plant efficiency
- Fossil CO_2 emissions

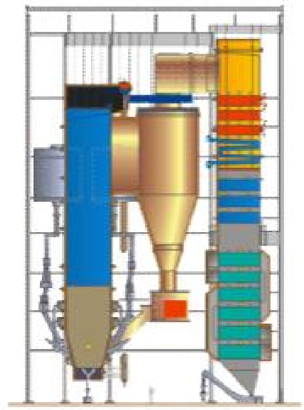
Fossil with CO_2 capture



- 5…10 %-pts eff. penalty in CCS
- Up to 95% CO_2 capture rates

Higher OPEX and CAPEX than without capture

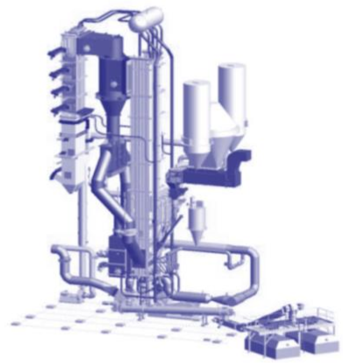
Bio/Multi
•Agro
•Wood



- 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

metso

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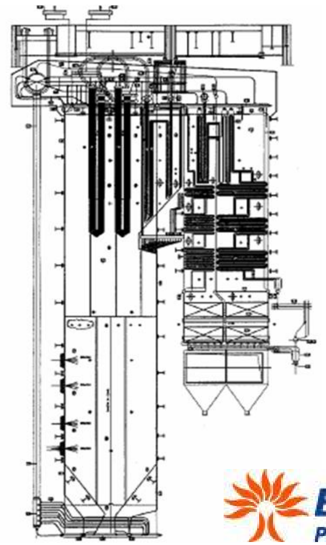
The advantages of CFB technology compared to PC in oxy-combustion

- Competition between PC and CFB in oxygen-firing is somewhat similar to the air-firing case, with differences in fuel and process flexibility, emissions with or without flue gas cleaning equipment ash streams, etc.

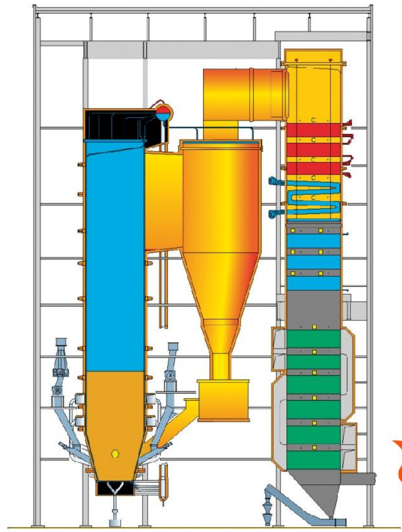
- The **flexibility of CFB under varying load conditions** offers benefits in retaining more uniform furnace temperature profiles (in air-firing as well as oxygen-firing).
  - **Lower NOx emissions** compared to PC
  - Enables more extensive process optimisation possibilities with **higher O_2 concentrations** which results in smaller furnace size and therefore improves economy of oxy-CFB vs. oxy-PC.

- Limestone addition into the furnace for sulphur capture can **ease separation of CO_2 from flue gas**. In the case of large biomass shares, the additional SO_x removal investment is not needed.

- CCS always reduces the overall power plant efficiency, irrespective of the technology. However, high fuel flexibility offers an additional benefit for CFB technology to **compensate the costs of CCS by applying low-quality fuels**.



Enel Produzione

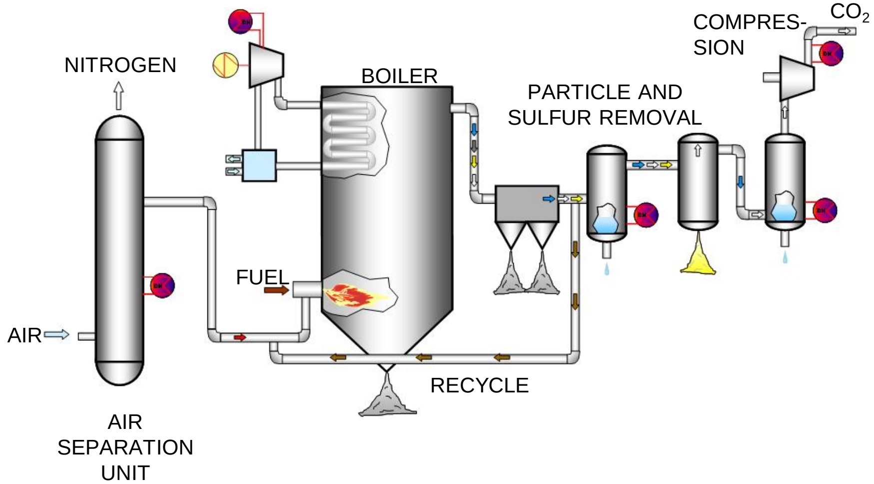


metso power

CO_2 capture options for biomass (co-)fired boilers (CFB/PC)

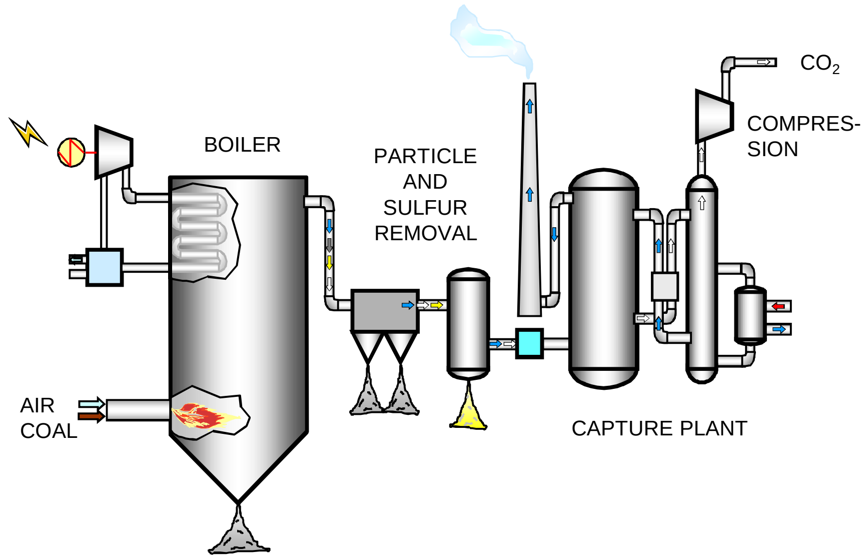
Oxyfuel combustion

- More suitable for greenfield plants (challenges with air ingress in retrofit)
- Main energy penalty due to ASU electricity consumption
- Flexiburn concept for air or oxy-fired operation modes (in CFB)
- Possible challenges with boiler design due to flue gas properties (e.g. enrichment of impurities)



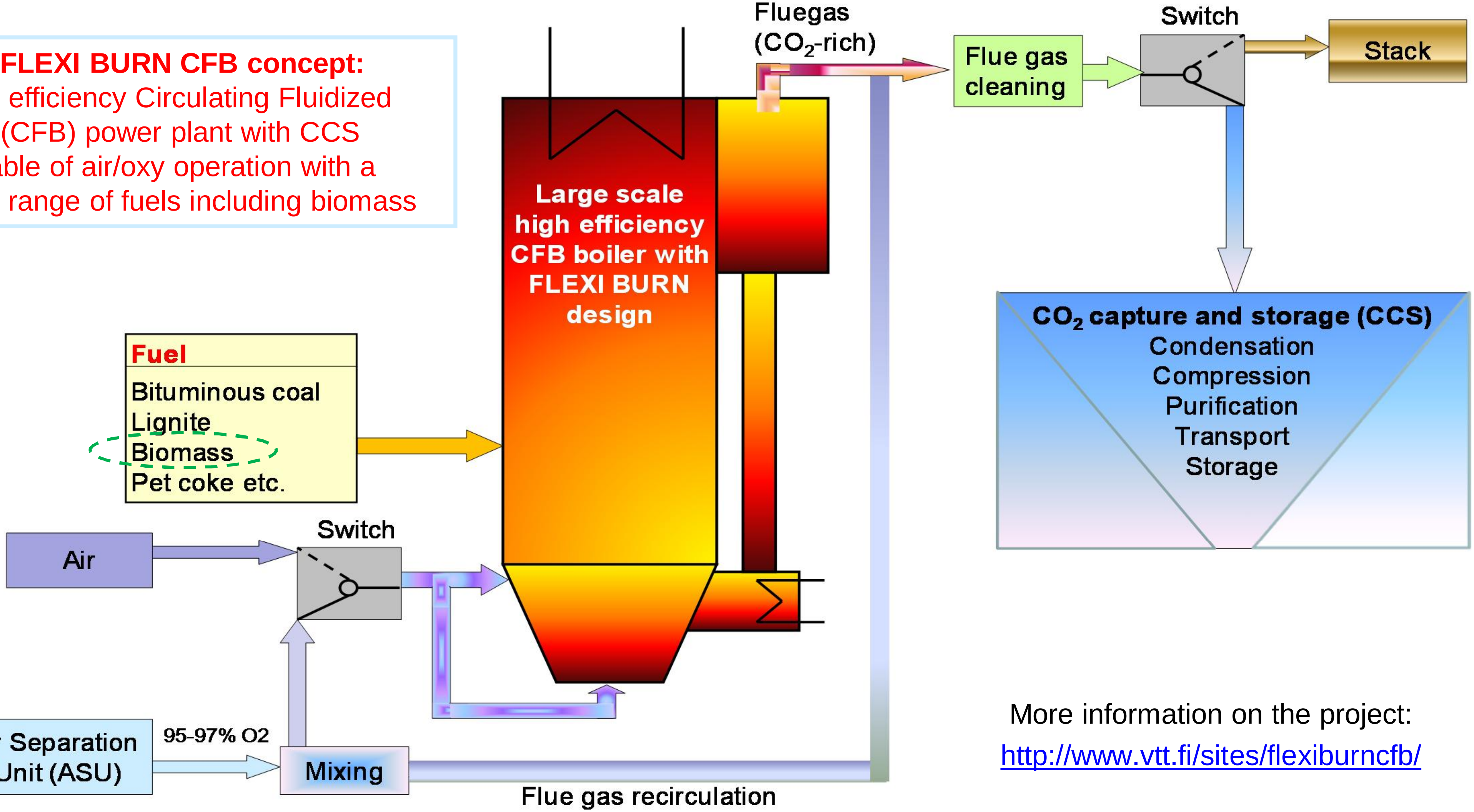
Post combustion

- Suitable also for retrofit (challenges with on-site space requirements)
- Main energy penalty due to steam need for solvent regeneration
- Possibility to by-pass the capture plant during profitable market conditions
- Possible challenges with solvent related emissions (e.g. nitrous amines) and waste disposal



FLEXI BURN CFB allowing operation under normal air-firing as well as oxygen-firing with CCS

The FLEXI BURN CFB concept:
High efficiency Circulating Fluidized Bed (CFB) power plant with CCS capable of air/oxy operation with a wide range of fuels including biomass

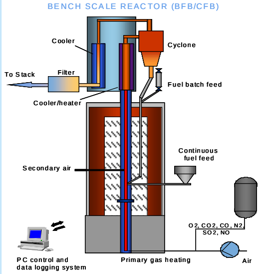


More information on the project:
http://www.vtt.fi/sites/flexiburncfb/

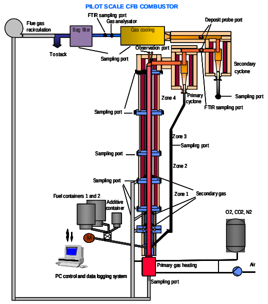
FLEXI BURN CFB – Demonstration steps

Demonstration scales

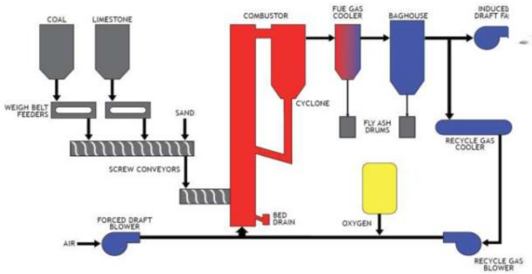
VTT 0.3kW



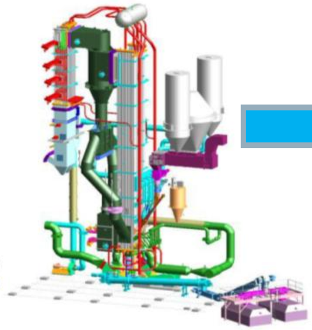
VTT 0.1MW



CANMET 1MW



CIUDEN 30MW



Concept for 300 MW$_e$

Aim: to develop and demonstrate FLEXI BURN CFB concept enabling to reach the target of near zero emission power plants

Post-2020 target:
Full 800 MW$_{e, gross}$ commercial plant

Completed

In progress

2009 Time 2012

OXY-CFB-300 Compostilla Project
CCS Value Chain

CAPTURE TECHNOLOGY

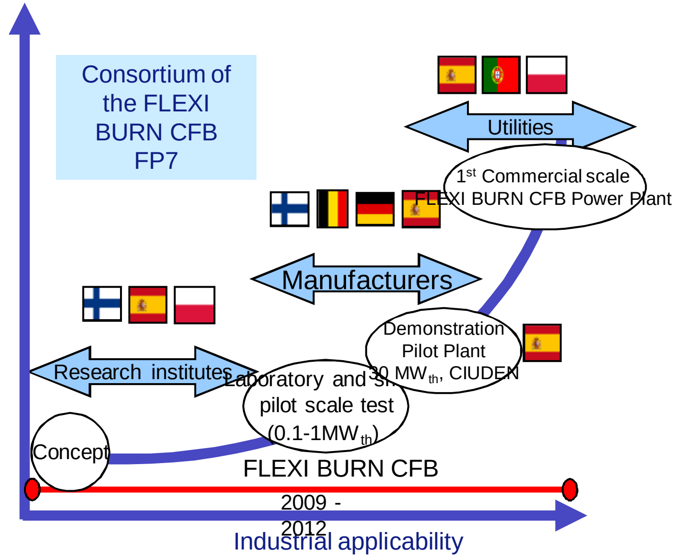
- OXY-CFB supercritical boiler; wide design fuel range (domestic and imported), including biomass.

CO_2 TRANSPORT

- 12” / 16” underground pipeline; 135 km.
- 5,500 ton/day; ~ 120 bar

CO_2 STORAGE

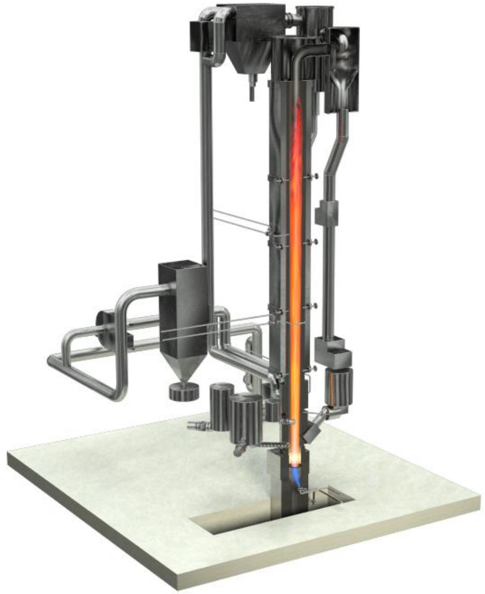
- Deep saline formation
- Duero basin (optional: Ebro basin)



Co-financed by the European Union
European Energy Programme for Recovery

Flexiburn: Pilot scale CFB experiments (0.1MW) under air- and oxygen-firing conditions

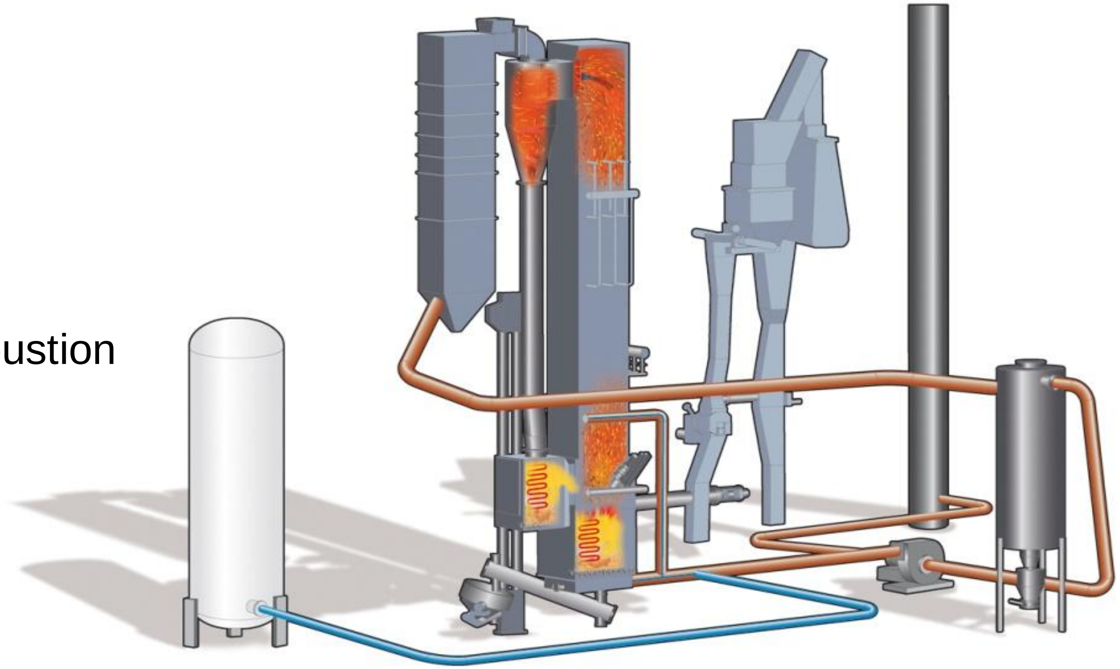
- Combustion tests have been carried out with pilot scale and bench scale test rigs at VTT in Finland
- Tests provide a base for development and validation of the design tools needed in the concept development
- Also some **biomass fuels** have been tested (straw pellet and good quality wood chips)



Fuels	Mixture ratio on energy basis (LHV wet)	Mixture ratio on mass basis (wet)
Anthracite + Pet-coke	55/45	70/30
Anthracite	100	100
Bituminous coal (Polish)	100	100
Lignite (Spanish) + South African coal	55/45	70/30
Anthracite + wood	90/10	85/15
Bituminous coal (Polish) + straw pellet	80/20	75/25

Successful CFB Oxy-combustion Pilot Project

- Oxy-combustion CFB boiler
  - Location in Metso test plant in Tampere
  - *Preliminary tests at VTT*
- Project participants
  - Metso and Fortum
- Target
  - To scale up CFB oxyfuel combustion from laboratory to pilot scale
- Test figures
  - Size $4MW_{th}$
  - 5 weeks test runs in 2010
  - Two fuels tested



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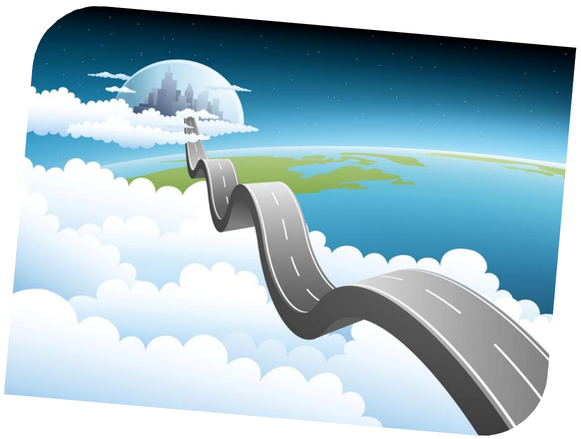
Feasibility of Bio-CCS in CHP production
- *Case Study of Biomass Co-firing Plant in Finland*



Fortum

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Conceptual CCS case studies by VTT (conducted & upcoming)

	Power plant	CHP-plant	Steel mill	CHP-plant	CHP-plant	Steel mill	CHP-plant	CLC-plant
Location	western Finland	central Finland	northern Finland	western Finland	southern Finland	northern Finland	northern Finland	western Finland
Fuel power	1300 MW	500 MW	-	482 MW	919 MW	-	300 MW	482 MW
Capture potential	3 Mt/a	1.5 Mt/a	2.5 Mt/a	1.4 Mt/a	1.3 Mt/a	2.5 Mt/a	1 Mt/a	?
Combustion tech.	PF	CFB	-	CFB	GTCC	-	CFB	CFB
CCS tech.	PCC	oxy/PCC	PCC	oxy	PCC	OBF	PCC	oxy (CLC)
Fuel	coal	peat	process gas	cofiring/ biomass/peat	natural gas	process gas	peat/biomass	?
Type	retrofit	greenfield	retrofit/ rebuilt	greenfield	retrofit	retrofit/ rebuilt	retrofit	greenfield

- Based on real industrial plants and environments
- Modeling of the plants with and without CCS applied
- Techno-economic evaluation of the overall feasibility (including transportation and storage)
- Costs and emission reduction from the investor's point of view

Economic trade-off for CO_2 capture plant investor

- Feasibility of CCS is very sensitive for CO_2 allowance and electricity prices
  - Interaction between CO_2 allowance and electricity price
  - Sensitivities also for fuel prices, efficiencies, investments etc. need to be clarified

- System model CC-Skynet™ has been developed at VTT to evaluate the most critical questions with focus on the impacts on the case specific plant and the **surrounding energy system**

Case study introduction

- The case study for economic and environmental implications of Bio-CCS is based on greenfield 482 MW_{fuel} CHP-plant situated on the coast of the Gulf of Bothnia and emitting approximately 1.5 Mton CO_2 / year. The plant is equipped with a modern **CFB-boiler** which is using **oxy-fuel technology** in the CCS applications.

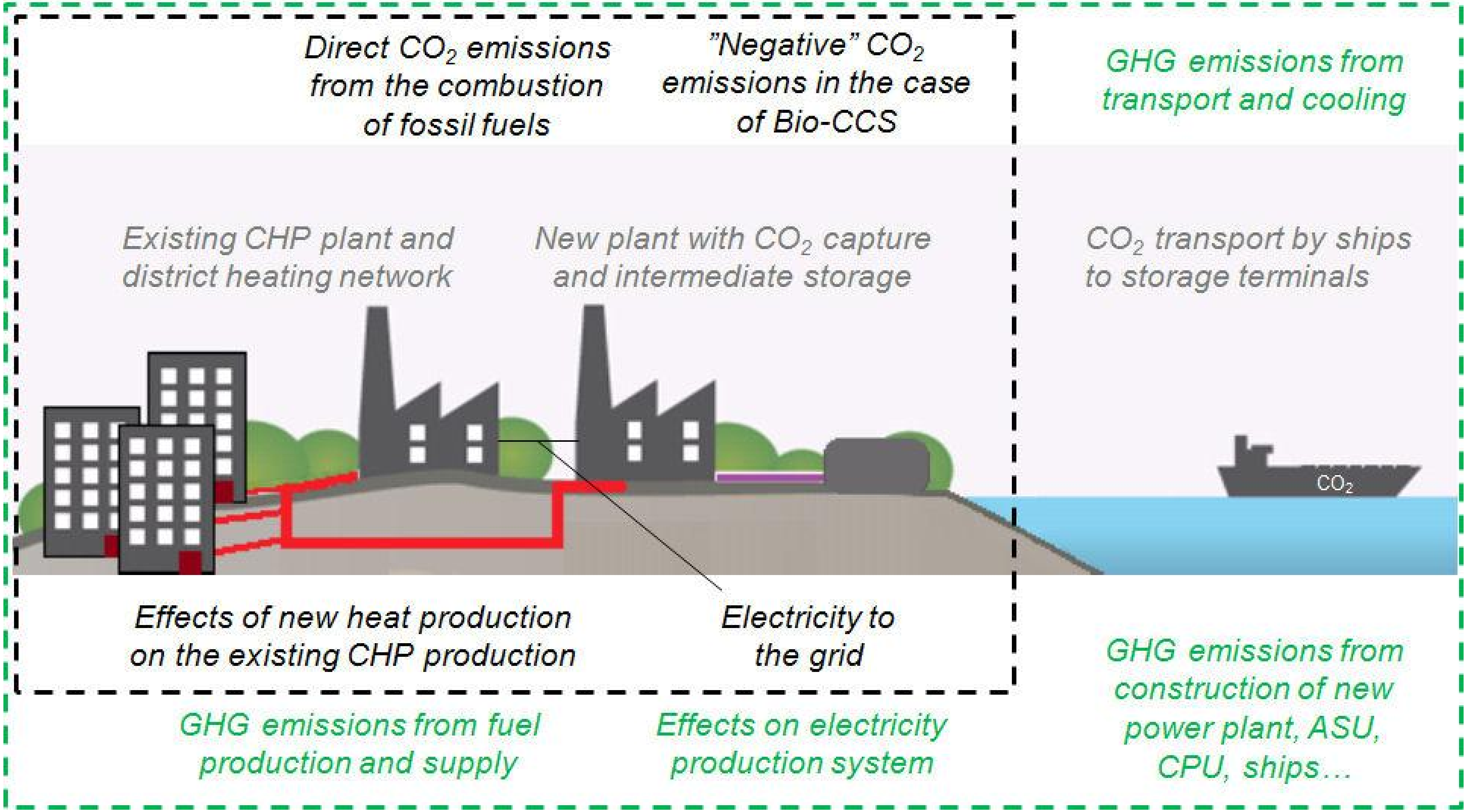
- The economics of CCS were evaluated from investor's (local energy company) point of view including the effects on existing energy system

- In the study it is assumed that **the economic incentive for negative CO_2 emission is included in EU ETS**.

- In the studied system **existing CHP-plant** and the new plant produce district heat and back-pressure electricity with given utilization rates and condensing electricity is produced **at the new plant** depending on the given utilization rates.

Studied system and selected boundaries

- GHG emissions considered in BEP's (system boundary from the operator's point of view)
- GHG emissions considered in LCA (system boundary from the global point of view)



The studied cases are named as follows

1. **Reference**: No new plant. The existing CHP-plant produces district heat and back-pressure electricity with maximum load (utilization rate 6000 h/a) and number of heavy-oil fired district heating plants provide the additional heat needed within the system.

2. **peat w/o CCS**
3. **peat with CCS**

} The new plant is fired with 100 % peat

4. **co-firing w/o CCS**
5. **co-firing with CCS**

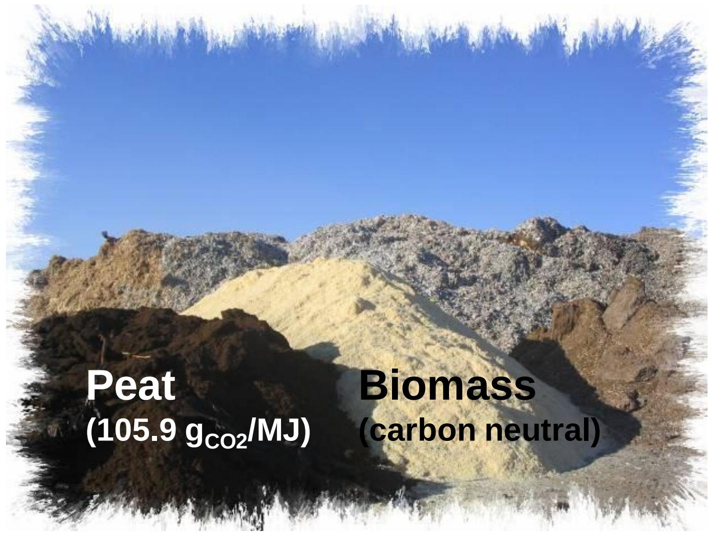
} The new plant is fired with 50 % peat and 50 % biomass

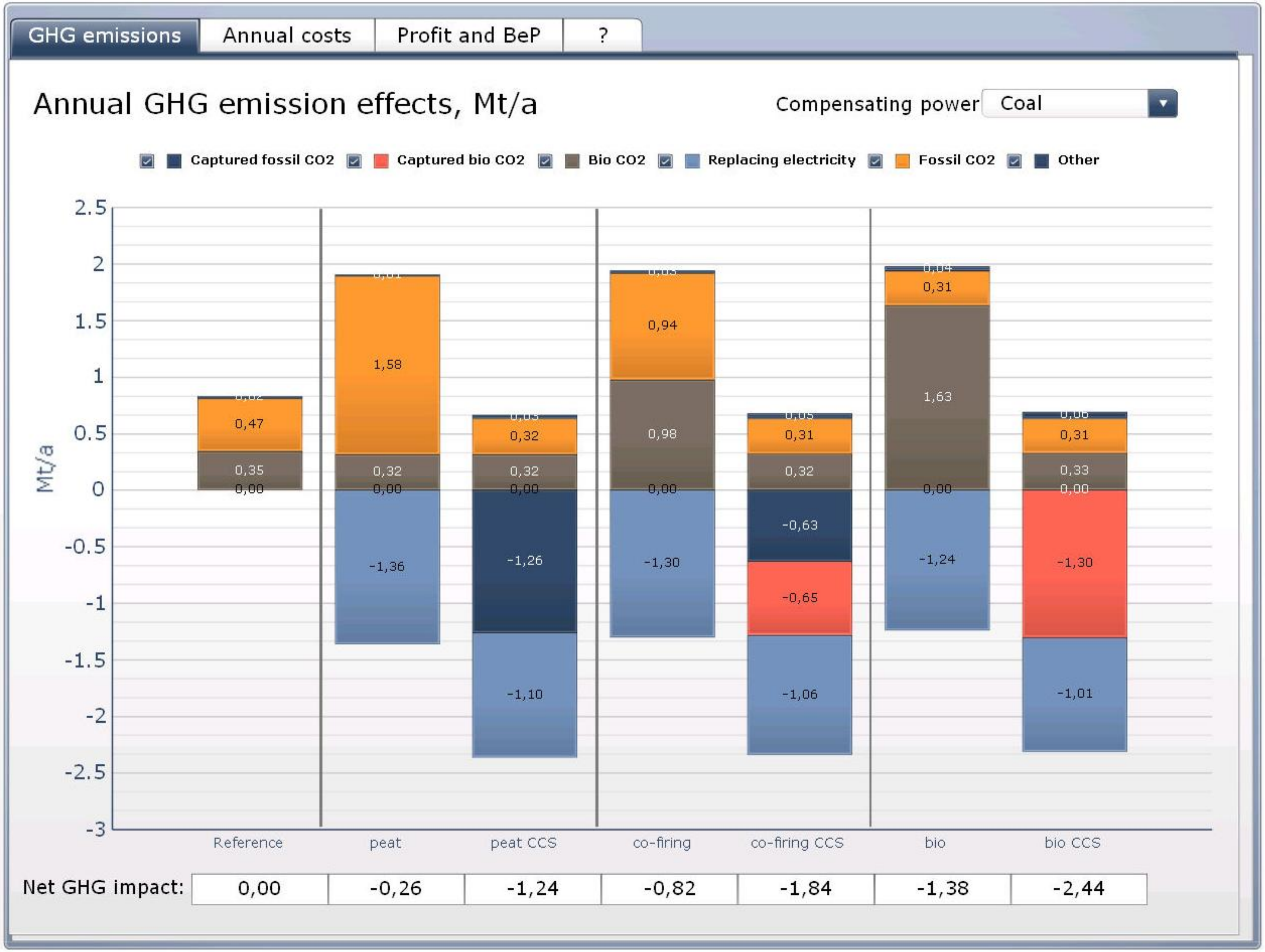
6. **bio w/o CCS**
7. **bio with CCS**

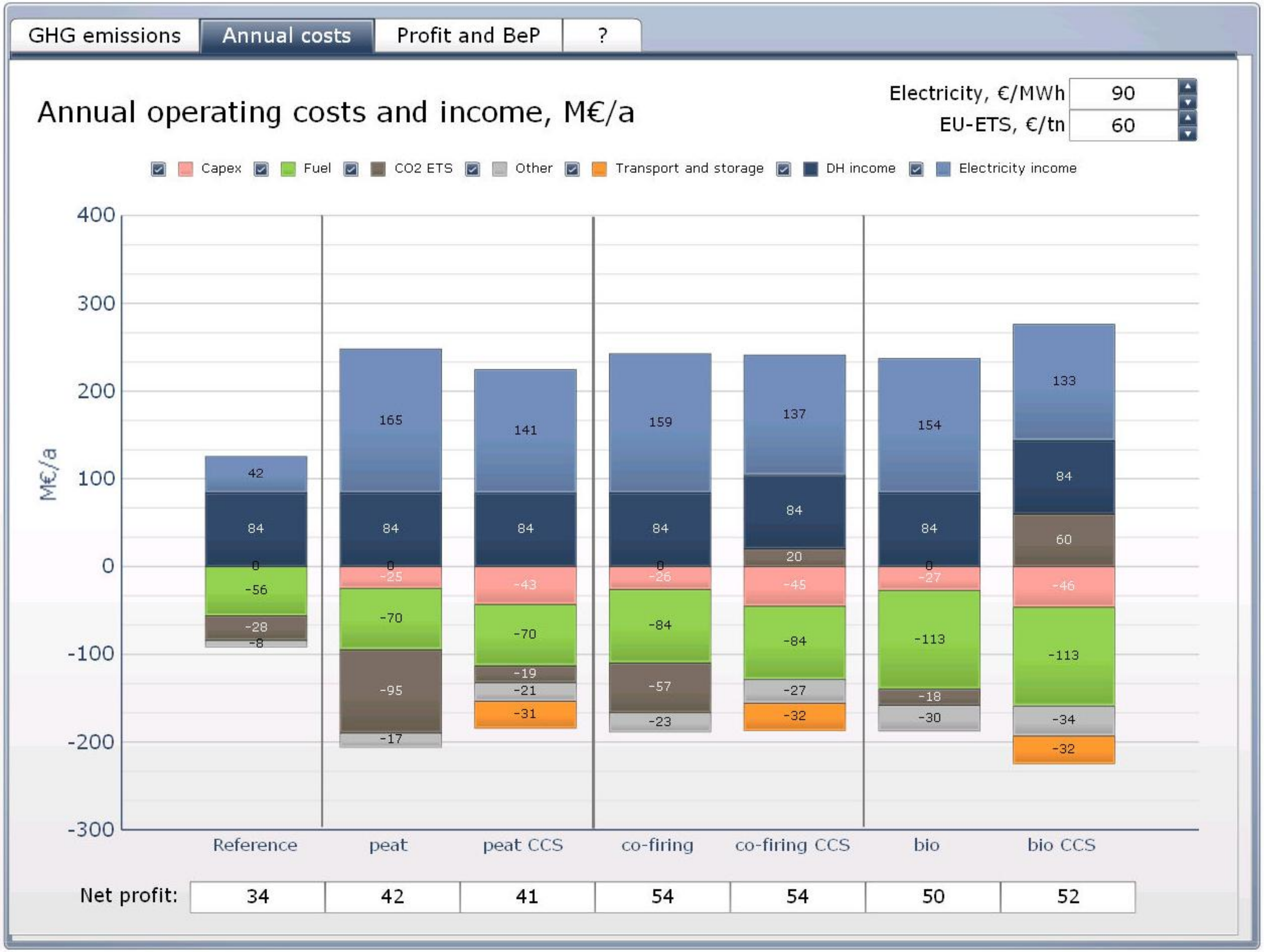
} The new plant is fired with 100 % peat

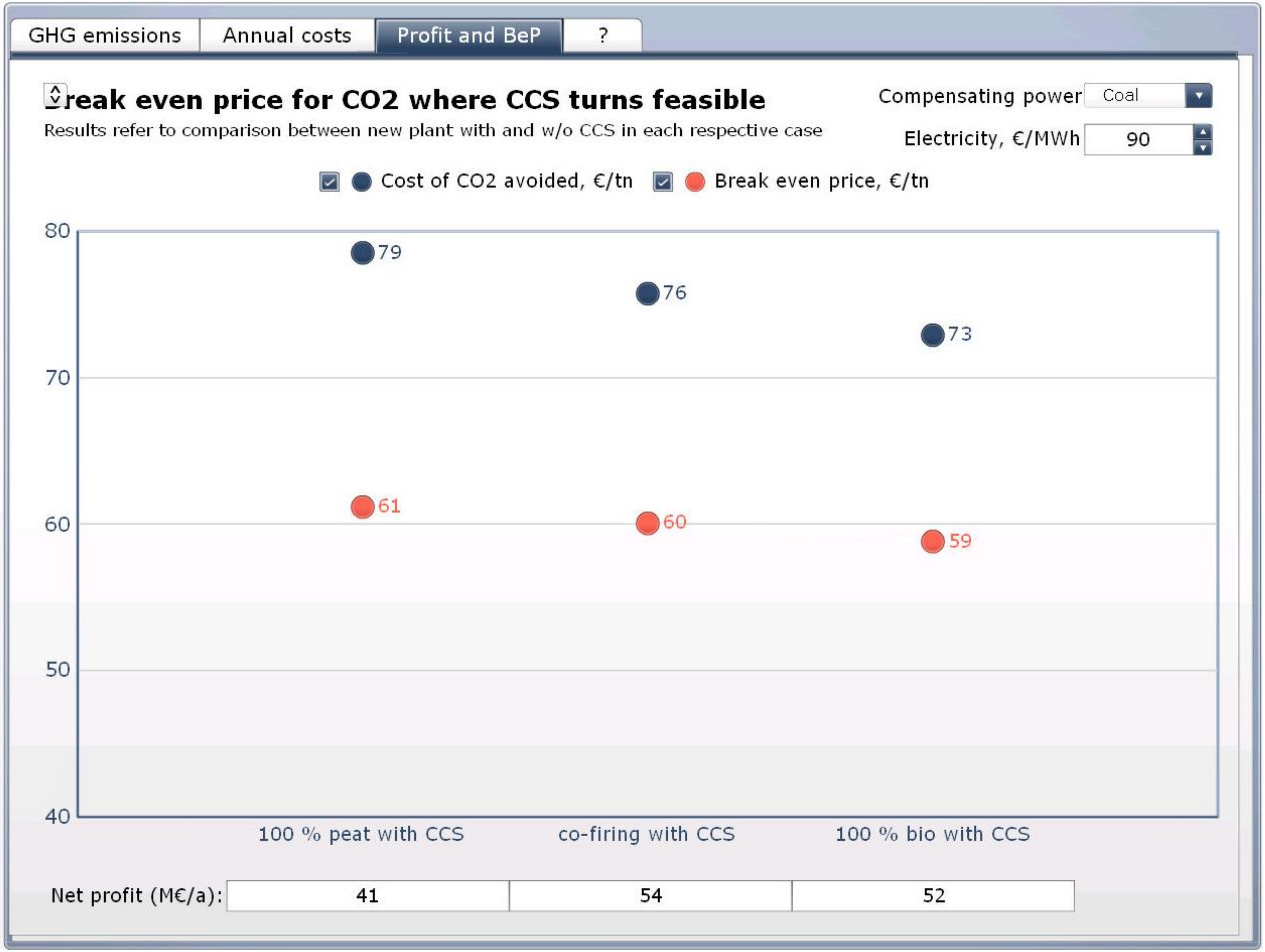
In every case the existing CHP-plant is fired with 50 % peat and 50 % biomass.

Biomass prices are case-specific due to (possible) price increase with higher volumes




GHG emissions
Annual costs
Profit and BeP
?
Annual GHG emission effects, Mt/a
Compensating power
Coal
Captured fossil CO2
Captured bio CO2
Bio CO2
Replacing electricity
Fossil CO2
Other
Mt/a
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0,47
0,35
0,00
1,58
0,32
0,00
-1,36
0,32
0,32
0,00
-1,26
-1,10
0,94
0,98
0,00
-1,30
0,31
0,32
-0,63
-0,65
-1,06
0,31
1,63
0,00
-1,24
0,31
0,33
0,00
-1,30
-1,01
Reference
peat
peat CCS
co-firing
co-firing CCS
bio
bio CCS
Net GHG impact:
0,00
-0,26
-1,24
-0,82
-1,84
-1,38
-2,44


GHG emissions
Annual costs
Profit and BeP
?
Annual operating costs and income, M€/a
Electricity, €/MWh 90
EU-ETS, €/tn 60
Capex
Fuel
CO2 ETS
Other
Transport and storage
DH income
Electricity income
M€/a
400
300
200
100
0
-100
-200
-300
Reference
peat
peat CCS
co-firing
co-firing CCS
bio
bio CCS
42
84
0
-56
-28
-8
165
84
0
-25
-70
-95
-17
141
84
-43
-70
-19
-21
-31
159
84
0
-26
-84
-57
-23
137
84
20
-45
-84
-27
-32
154
84
0
-27
-113
-18
-30
133
84
60
-46
-113
-34
-32
Net profit:
34
42
41
54
54
50
52


GHG emissions
Annual costs
Profit and BeP
?
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
Compensating power
Coal
Electricity, €/MWh
90
Cost of CO2 avoided, €/tn
Break even price, €/tn
80
70
60
50
40
79
76
73
61
60
59
100 % peat with CCS
co-firing with CCS
100 % bio with CCS
Net profit (M€/a):
41
54
52

Conclusions on the case study

- The costs for CCS are heavily dependent not only on the characteristics of the facility and the operational environment but also on the chosen system boundaries and assumptions.
- In the case of Bio-CCS the investment and operational costs (excluding CO_2 emission allowances) are probably higher than in the case of fossil fuels. However, increasing CO_2 prices benefit Bio-CCS faster than other CCS options.
- Feasibility of Bio-CCS is strongly dependent on the CO_2 allowance price shift into biomass prices. In general, feasibility of CCS is dependent significantly on the CO_2 price shift into electricity price.
- The current EU ETS do not recognize negative emissions, and thus the economical incentive is not available for capturing CO_2 from biomass installations.

Thank you for your attention!

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/

Tekes FOSTER WHEELER metso Fortum