CCS feasibility improvement in industrial and municipal applications by heat utilisation

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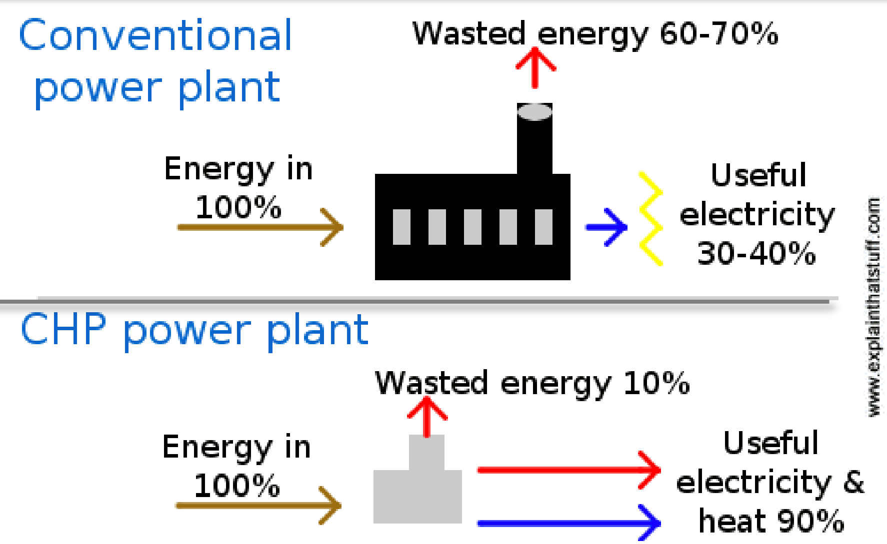
Introduction

- 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.
- On the other hand, heat can be recovered from the existing industrial processes in high enough temperatures for CCS processes, for instance solvent regeneration.

The impact of CCS:

Several estimations available under public domain

Lower break-even price due to heat utilisation?



Conducted conceptual case studies on CCS feasibility

	Steel mill	CHP-plant	CHP-plant
Location	northern Finland	western Finland	southern Finland
Fuel power	-	500 MW	1000 MW
Capture potential	2.5 Mt/a	1.4 Mt/a	1.3 Mt/a
Combustion tech.	-	CFB	GTCC
Capture tech.	PCC	oxy	PCC
Fuel	process gas	cofiring/biomass/peat	natural gas
Type	retrofit/rebuilt	greenfield	retrofit

- Based on real industrial plants and operational environments in Finland
- Process modeling of the plants with and without CCS applied
- Techno-economic evaluation of the overall feasibility (including transportation and storage) and emission reduction from the investor's point of view
- Impacts on the case specific plant and the surrounding energy system

Business from technology

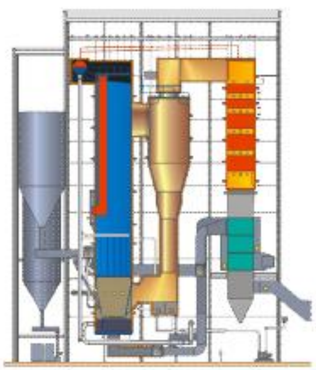
Feasibility of Bio-CCS in CHP production

- *Case Study of Biomass Co-firing Plant in Finland*

Towards negative CO_2 emissions with CFB technology

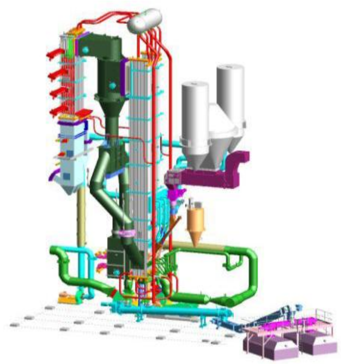
Fossil

•Low solids
•High solids



- High plant efficiency
- Fossil CO_2 emissions

Fossil with CO_2 capture

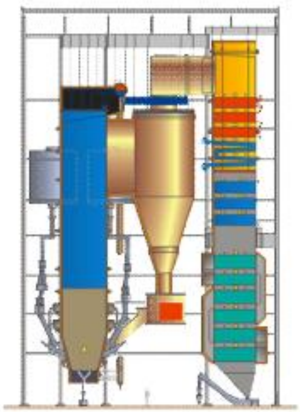


- 5…10 %-pts eff. penalty in CCS
- Up to 95% CO_2 capture rates

Higher OPEX* and CAPEX than without capture

Bio/Multi

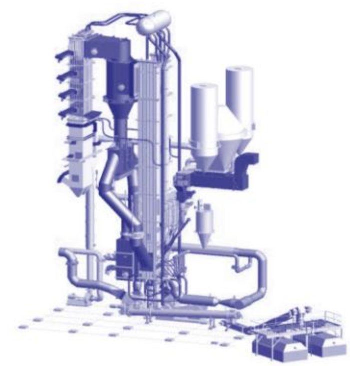
•Agro
•Wood



- 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

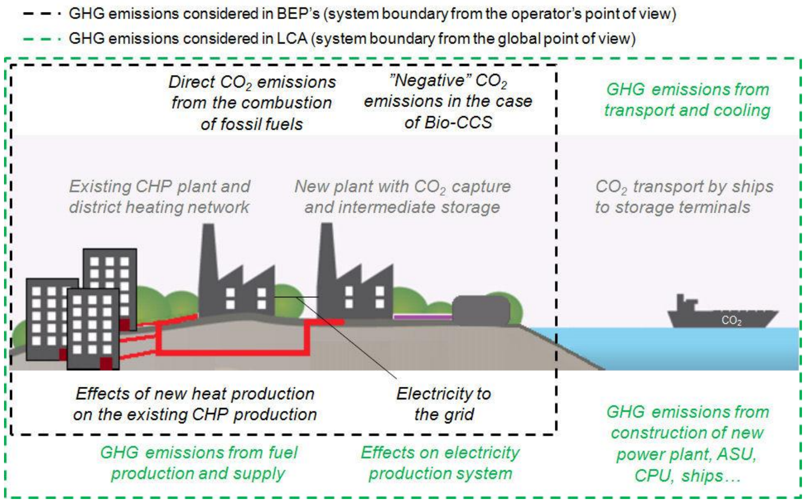
* without CO_2 allowances

metso

FOSTER WHEELER

Case study introduction

- Greenfield 482 MW_{fuel} CHP-plant (air/oxy CFB-boiler).
- The studied fuel-shares were pure biomass, pure peat and biomass-peat co-firing. Note! Assumed that the economic incentive for negative CO_2 emission is included in EU ETS.
- The plant is connected to the existing district heating network where other CHP plant (fired with 50 % peat and 50 % biomass) already exists.
- The other plant and limited district heat consumption in the area limits the benefits obtained from CCS heat recovery.



Modelled energy balance for plant operation with 100 % peat

	without CCS		with CCS	
Operation mode	CHP	Power	CHP	Power
Fuel input, MW[1)]	576	576	576	576
Power, MW_{net}	165	213	125	163
District heat, MW	272	0	352	0
from turbine	272	0	266	0
from ASU&CPU	0	0	86	0
Overall net efficiency[1)]	76 %	37 %	83 %	28 %
Power net efficiency[1)]	29 %	37 %	22 %	28 %

1) Fuel thermal input is based on fuel HHV

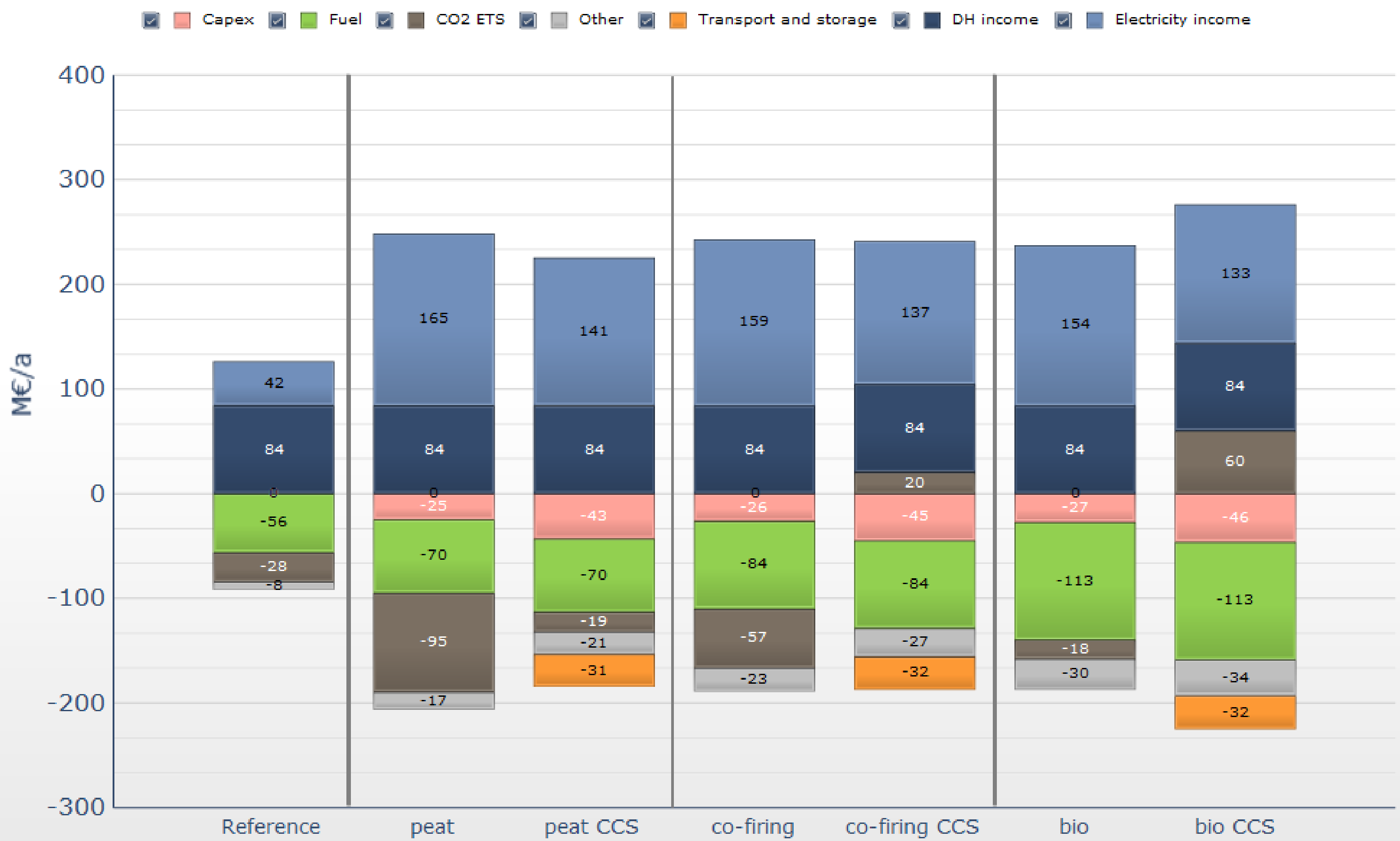
- 7 %-pts - 9 %-pts

- Very high overall process efficiency is achievable if process heat can be utilized in district heating.
- If flue gas condensers are utilized (as typically in CCS applications) the overall process efficiencies on a LHV basis can exceed even 100% with wet fuels such as biomass and peat (moisture content about 50 %).

GHG emissions | Annual costs | Profit and BeP | ?

Annual operating costs and income, M€/a

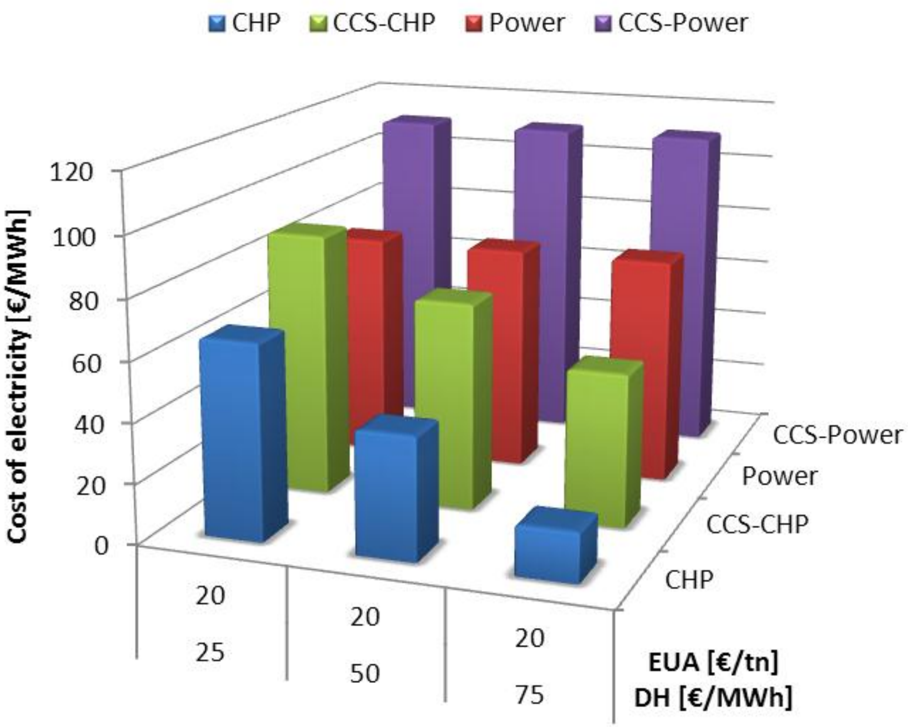
Electricity, €/MWh 90
EU-ETS, €/tn 60

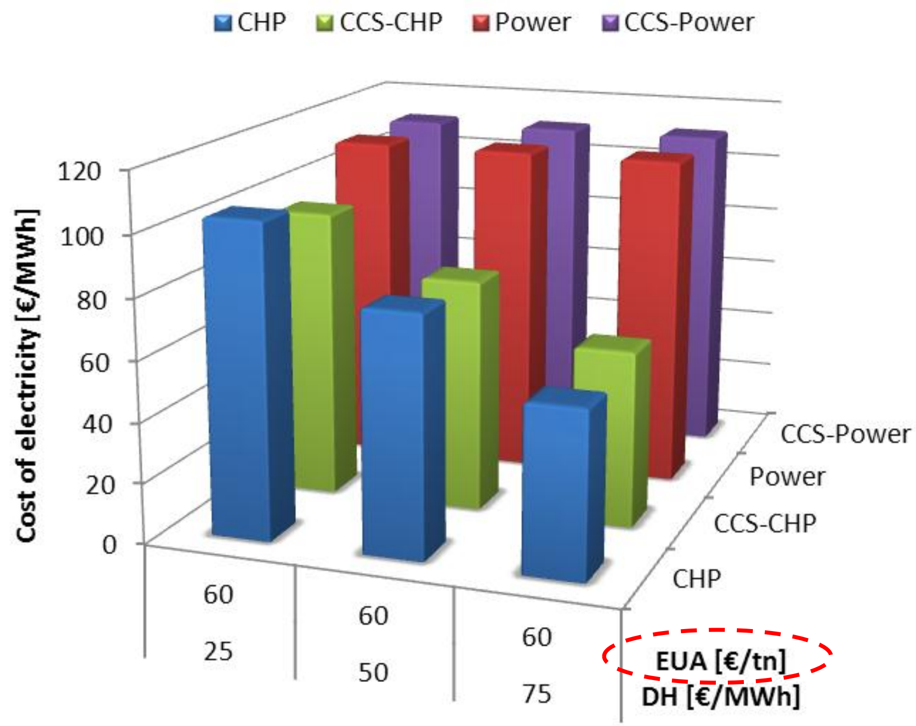


Net profit:	Reference	peat	peat CCS	co-firing	co-firing CCS	bio	bio CCS
	34	42	41	54	54	50	52

Benefits of CHP in the CCS system

The electricity production costs of **CCS CHP** are more competitive than with **CCS power only** as seen in figure with different EUA and district heat prices in the peat fired cases.





Business from technology

Feasibility of CCS in CHP production

- *Case Study of Natural Gas Fired GTCC Plant*

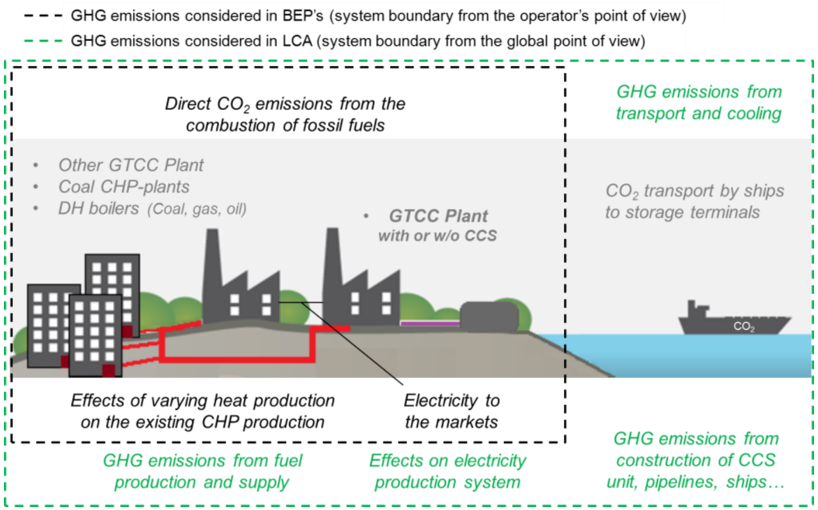
Helsingin Energia

Case study introduction

- Retrofit of about 1000 MW_{fuel} natural gas fired GTCC plant with **post combustion capture** technology using MEA.

- Part of relatively large district heating network including also other CHP units in the same network:
  - other GTCC plant
  - coal fired CHP plants
  - district heating boilers (heat production by coal, oil and gas).

- Retrofitting of CCS changes e.g.
  - maximum electricity and heat output
  - utilisation rates of the GTCC plant and the **other** plants.



Modelled energy balance for MEA solvent

	without CCS		with CCS	
Operation mode	CHP	Power	CHP	Power
Fuel input, MW (HHV)	1 020	1 020	1 020	1 020
Power, MW_{net}	412	519	367	397
District heat, MW	443	0	325	0
from turbine	443	0	302	0
from capture&CPU	0	0	23	0
Overall efficiency	84 %	51 %	68 %	39 %
Power	40 %	51 %	36 %	39 %

- 4 %-pts - 12 %-pts

Break-even prices > 100 €/tn_{CO2} (very sensitive to key parameters)

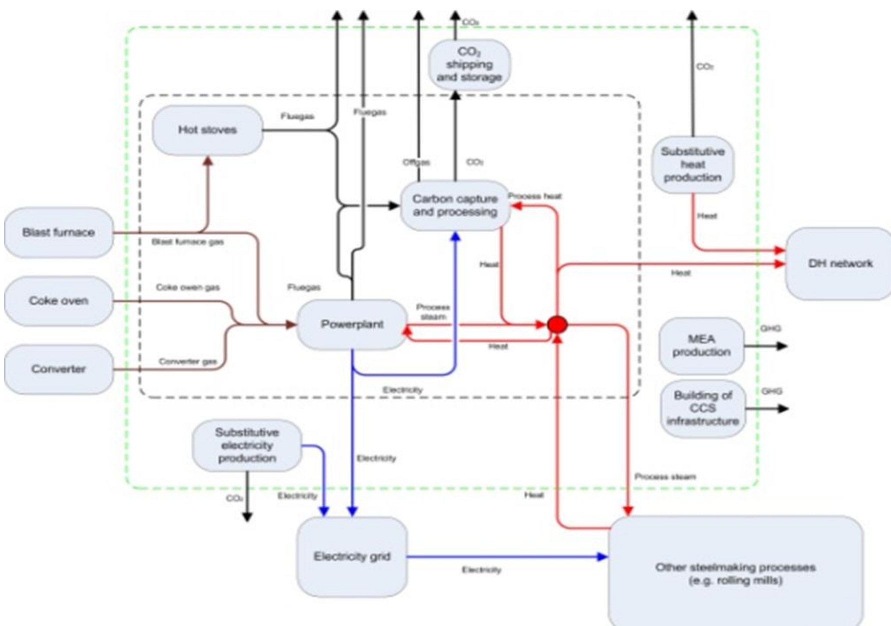
- **Heat recovery from CCS is not sufficient to compensate the lost in DH production from turbine**
- **Potential for future improvements: Optimisation of heat integration and use of advanced solvents**

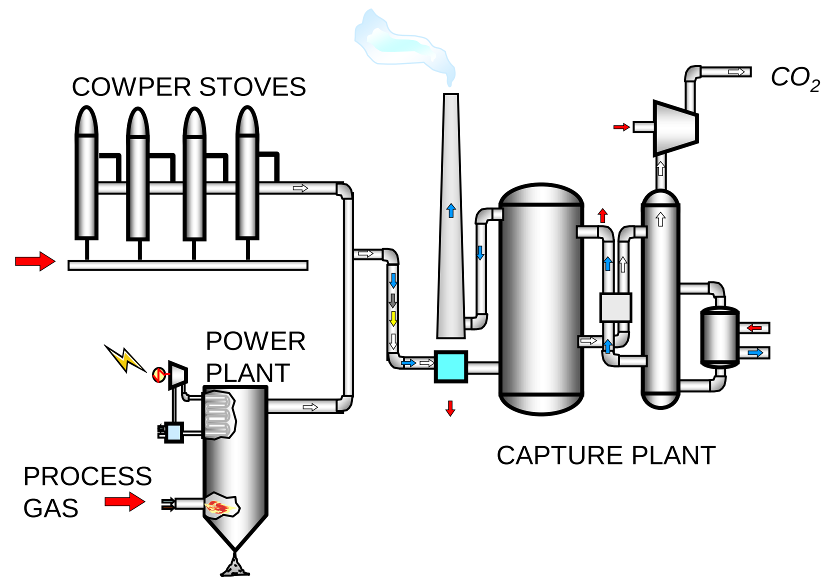
Business from technology

Feasibility of CCS at an integrated steel mill

Case study introduction

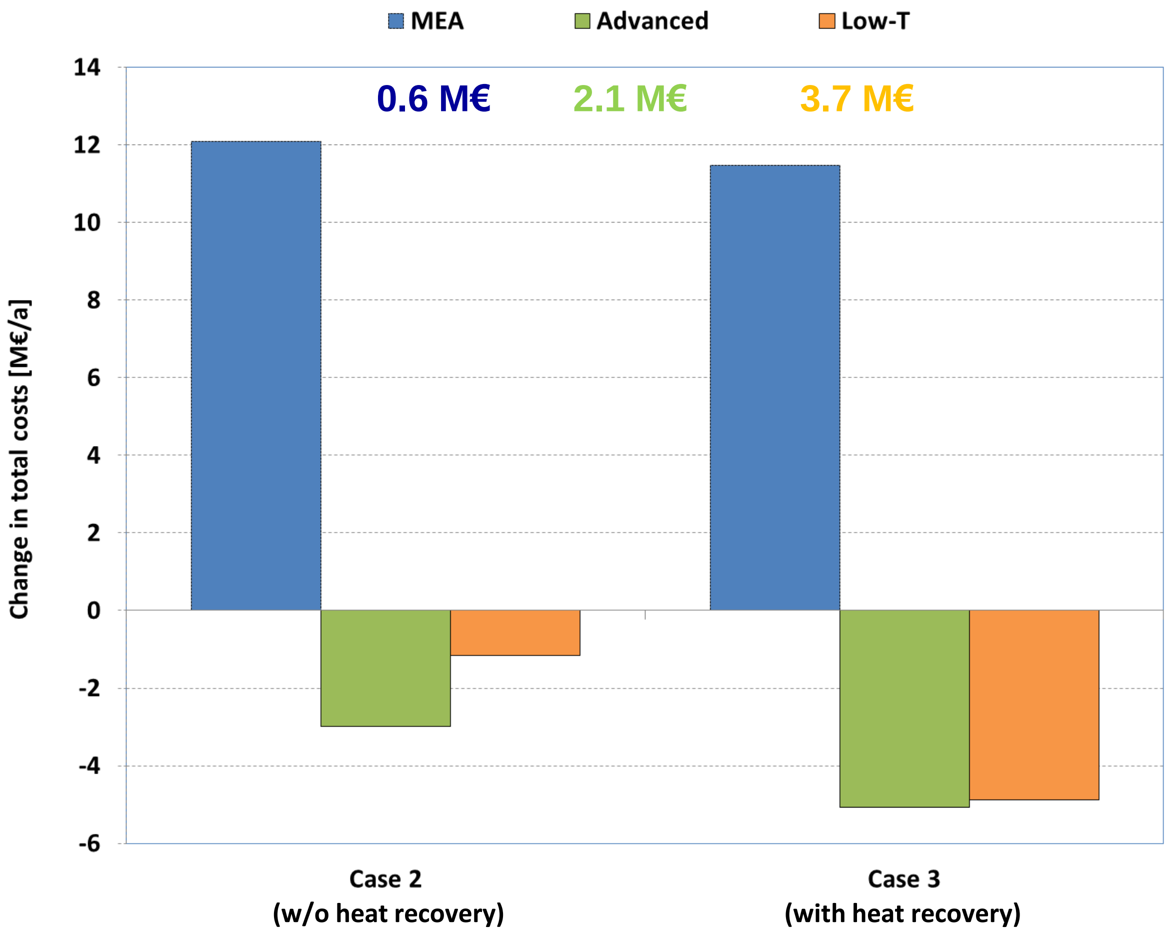
- Based on Ruukki Metals Oy's Raahe steel mill, which is the largest integrated steel mill in the Nordic countries producing hot rolled steel plates and coils.
- It is also the largest CO_2 point source in Finland emitting approximately 4 Mton / year (in 2011).
  - 60% from cowper stoves and power plant





Post-combustion capture process

Impact of process heat utilisation on annual operation costs



- The economic benefit of heat recovery from steel mill processes is few millions of euros annually, depending on e.g. the solvent (the difference between case 3 and 2).
- Process heat available in liquid phase was mapped roughly – the potential may be significantly higher.
- → "Low-T" solvent, which could be regenerated using low temperature (> 80 °C) process heat, would probably bring benefits in the overall economics.

Assumed situation:

- EUA price 60 €/tn and electricity price of 80 €/MWh
- Three different solvents with specific properties

Conclusions

- In CHP plants, improvements can be achieved with heat integration in terms of overall efficiency and feasibility of CCS.
  - oxy-combustion seems to provide higher potential than PCC
- The costs for CCS are heavily dependent not only on the characteristics of the facility but especially in the CHP applications also on the operational environment and the chosen system boundaries and assumptions.
- Economical benefits can be achieved in the cases where heat from CCS plant is utilized in district heating network and the plant can be operated also in condensing mode to achieve high utilisation rates.
- The studied impact of heat recovery from steel mill processes to solvent regeneration can result economic benefit of few millions of euros annually.

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/