

CCSP – Subtask 2.1.3 (case 3)

## Deliverable 242. Cost and CO2 evaluation toolkit for PCC in multi-fuel CHP plant

Scope

The goal was to investigate the effects of different post combustion capture ratios in different CHP-plant operation (condensing-, mixed- and CHP-modes) and energy market situations on techno-economic feasibility for a 315 MW<sub>fuel</sub> CFB-boiler using peat and biomass in retrofitted for PCC.

Approach for economic and environmental analyses

The economics of CCS are evaluated from investor's (local energy company) point of view including the effects on the existing energy system. Effect of CCS on operation economics of the CCS cases are compared to the reference system with varying parameters of operation. Regarding the GHG emissions, besides the site emissions, the main effects on global GHG emissions are also taken into account by using streamlined LCA and impacts on overall electricity production system.

In the study the whole CCS chain, including  $CO_2$  capture, processing, transport and storage, was included by utilising CCS plant economics toolkit (system model *CC-Skynet*<sup>M</sup> developed by VTT). In the toolkit, the profitability of each case can be analysed according to different market situations by adjusting plants operation and the most significant input values. In addition to plant and case specific technical inputs, the economic parameters can be varied, including interest rates, studied time frames, fuel taxes, subsidies and market prices for different fuels, electricity and  $CO_2$  emission allowances (in the EU ETS) as well as CCS related costs, for example required investment, transportation costs etc.

As there is no storage capacity in Finland the captured  $CO_2$  has to be transported and stored abroad. The storage phase in this study is evaluated according to Teir et al. (2011) <sup>1</sup>and the  $CO_2$  transportation including costs related are assumed according to Kujanpää et al. (2010)<sup>2</sup>.

## Main results

The main output is a Flash-based toolkit to visualise the costs and  $CO_2$  impacts with different inputs by selecting key variables using interactive menus. The toolkit was provided to Oulun Energia by VTT and it is not public.

From the study it was concluded that the required  $CO_2$  allowance price would need to be in range of 60-100  $\notin$ /tn to make the studied CCS solutions more economical than operation without CCS.

Example screens of the toolkit are shown in figures 1-4.



<sup>&</sup>lt;sup>1</sup> Teir, S; Arasto, A; Tsupari, E; Koljonen, T; Kärki, J; Kujanpää, L; Lehtilä, A; Nieminen, M; Aatos, S. Hiilidioksidin talteenoton ja varastoinnin (CCS:n) soveltaminen Suomen olosuhteissa. 2011. VTT, Espoo. VTT Tiedotteita - Research Notes : 2576

<sup>&</sup>lt;sup>2</sup> Kujanpää, L; Rauramo, J; Arasto, A. Cross-border CO2 infrastructure options for a CCS demonstration in Finland Proceedings of the International Conference on Greenhouse Gas Technologies (GHGT-10), 19-23 September 2010, Amsterdam, The Netherlands. Energy Procedia. Elsevier. Vol. 4 (2011), 2425-2431



COULUN ENERGIA VIT Reset values Income&cost CO2 breakeven prices CO2 emissions Streamlined LCA General variables Annual operating income and cost, M€/a CO2 price, C/tn 40 0 Electric. sys.price, C/MWb 60 0 📱 Capex 📙 Fuel(subsidy&tax) 📕 CO2-allow. 📕 CO2 transp&storage 📋 Other O&M 📗 DH income 📕 Electr. incon DH demand, GWh/a 1650 0 Price of DH, C/MWh 50 0 DH purch.price 1, C/MWh 20 0 DH purch.price 2, C/MWh 30 0 100 000000 Reference CO2 reduction scenario 80 0 0 38 Price of peat, C/MWh 13 0 Price of bio, C/MWh 20 0 Price of HFO, C/MWh 30 0 60 Price of bio, C/MWh 20 0 Price of HFO, C/MWh 30 0 MEA price, C/kg 2 0 40 16 14 Peat heat tax, C/MWh 3,9 0 HFO heat tax, C/MWh 19,4 0 Bio subsidy, C/MWhe 0 0 20 9 . \_ -12 Transp&stor sens.factor 0% 0 CCS CAPEX sens.factor 0% 0 -20 Time span, a 10 0 WACC for investment 5,0% -40 -7 Main results -60 CO2 BeP, C/t 77 -10 Profit, reference, MC/a 45 -80 Profit, scenario, MC/a 23 Captured CO2, Mt/a CCS-investment, MC 0,63 -100 
 Toppila II
 Toppila I
 DH purch.
 DH-boilers

 PROFIT
 31
 10
 4
 0
Toppila II Toppila I DH purch. DH-boilers 8 12 4 0 96 [MC/a] Transp.&storage, C/t 34 Condensing mode or biomass increase is feasible CCS Post combustion, 74% Toppila II Toppila I DH purch. DH-boilers Toppila II Toppila I DH purch. DH-b Peak load utilisation rat 6 300 % Share of condensing power productio 50% % Break-even electricity price for condensing por 57 Heat productio 943 540 153 7 000 0 4 500 0 1 800 0 [h/a] % of fuel usage] 55% [C/MWh] [GWh/a] 49 870 608 943 540 153 Net electricity production 699 Share of biomass of total fuel inpu 50% 629 270 [GWh/a] 240 
 Net electricity productio
 699
 240

 Share of biomass of total fuel inpu
 50%
 60%

 Break-even price (BeP) for biomass
 28
 27
50% 60% 27 28 [C/MWh]

Figure 1. Annual operating costs and overall profit of the case plants.



Figure 2. CO2 emissions of the case plants.





[C/MWh]

VIT COULUN ENERGIA Reset values Income&cost CO2 breakeven prices CO2 emissions Streamlined LCA General variables Breakeven price for CO2 allowances, C/t CO2 price, C/tn 40 0 Electric. sys.price, C/MWh 60 0 O CAPEX +50% O Default CAPEX O CAPEX -50% DH demand, GWh/a 1650 Price of DH, C/MWh 50 DH purch.price 1, C/MWh 20 DH purch.price 2, C/MWh 30 100 Price of peat, C/MWh Price of bio, C/MWh 20 Price of HFO, C/MWh 30 MEA price, C/kg 20 90 Peat heat tax, C/MWh 3,9 0 HFO heat tax, C/MWh 19,4 0 Bio subsidy, C/MWhe 0 0 Peat heat tax, C/MWh 3,9 80 Transp&stor sens.factor 0% 0 CCS CAPEX sens.factor 0% 0 70 Time span, a 10 0 WACC for investment 5,0% 0 60 Main results CO2 BeP, C/t 77 Profit, reference, MC/a 45 Profit, scenario, MC/a 23 CO2 BeP, C/t 50 Captured CO2, Mt/a CCS-investment, MC 0,63 24 36 48 60 72 84 96 96 34 Market price for electricity, C/MWh Transp.&storage, C/t Condensing mode or biomass increase is feasible CCS Post combustion, 74% Toppila II Toppila I DH purch. DH-be Toppila II Toppila I DH purch. DH-boilers Peak load utilisation rate 6 500 0 4 000 0 1 800 0 7 000 0 4 500 0 1 800 0 [h/a] [% of fuel usage] 55% 49 870 608 Break-even electricity price for condensing proc 57 Heat production 943 540 [C/MWh] 15 153 153 Wh/a] Net electricity pr duction 699 240 629 270 [GWh/a] Share of biomass of total fuel inpu Break-even price (BeP) for biomast 28 60% 27 60% 27 50% [9/6]

## Figure 3. Breakeven prices for CO2.



Figure 4. CO2 emissions including streamlined LCA.

