ccsp

Carbon Capture and Storage Program

Techno-economic feasibility of different CCS applications in Finland

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CCSP – FINAL RESULTS SEMINAR

13TH OCTOBER 2016, HELSINKI

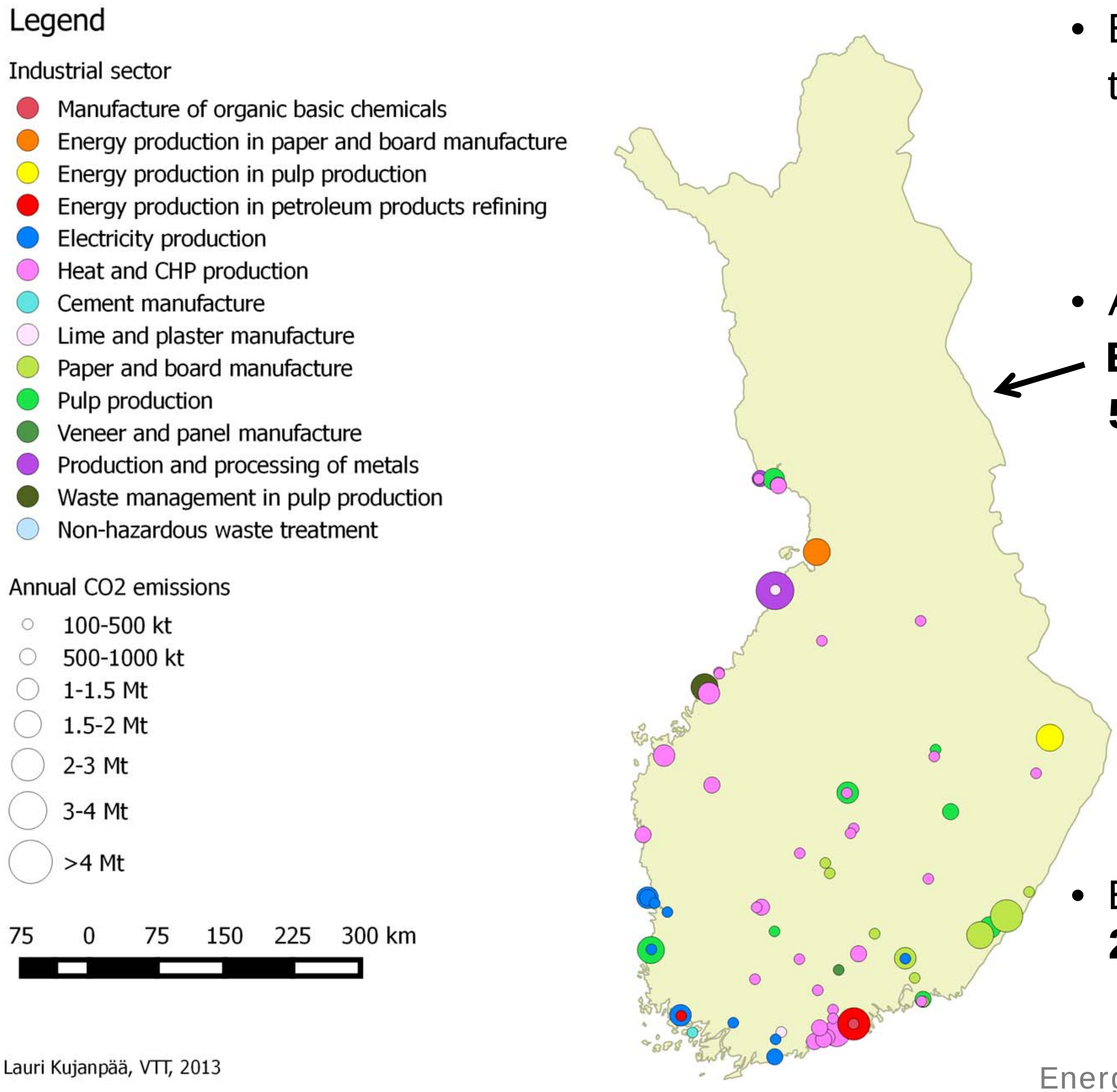
Introduction - Aim of the WP2 work in CCSP

- The potential of applying different CCUS concepts to different industrial applications in Finland has been evaluated
  - both from the economic performance and process integration point of view
  - based on real industrial plants and their environments in Finland

- Analysed application areas have included for example:
  - electricity and combined heat & power (CHP) production
  - pulp & paper
  - oil refining
  - hydrogen production by steam methane reforming (SMR)
  - steel industry



Largest CO_2 emission sources in Finland 2013



- Emissions under the emission trading scheme were **31,5 Mt**
  - 28,8 Mt in 2014
  - 588 facilities (in 2014)
- All CO_2 emissions reported to **E-PRTR** database amounted to **52,5 Mt** (77 facilities >0,1 Mt)
  - 0,4 Mt Chemical industries
  - 28,8 Mt Energy sector (including oil refining)
  - 4,3 Mt Production of metals
  - 0,9 Mt Mineral industry
  - 2,0 Mt Waste management
  - 16,1 Mt Paper and wood
- Estimated biogenic emissions **24 Mt** (2013, >0,1 Mt)

Source: European Environment Agency,
Energy authority (Finland) & Statistics Finland
VTT estimation

This slide includes an on-line Flash visualization which can be shown only at: http://ccspfinalreport.fi/#/

Presentation order of the on-line tools

Cost & potential

Summary	Summary graph	Bio-CCS in a CHP-system	CLC power plant	GTCC in a CHP-system	CCS in steelmill
	5	1	2	3	4

VTT has conducted several techno-economic concept studies for CCUS applicability within energy production and carbon intensive industry in Finland based on real industrial plants and their environments. An illustrative summary graph was developed in the following toolkit (see Summary graph) in which the potential and costs of CCUS in different applications and market conditions in Finland can be visualised. The main research questions answered are:

- What are the most profitable CCUS applications in Finland in different market situations (e.g. prices of electricity, CO2 allowances, etc.)
- What CO2 price is required to turn these CCUS cases feasible over the respective reference cases without CCUS?
- What is the estimated potential for these different applications (in Mt/a of CO2)?

Additionally, interactive case-specific toolkits have been prepared for different application areas - see tabs for examples from biomass-CHP, CLC power plant, GTCC CHP and steel mill.

In the toolkits, 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 as well as CCS related costs, for example required investment and CO2 transportation costs.

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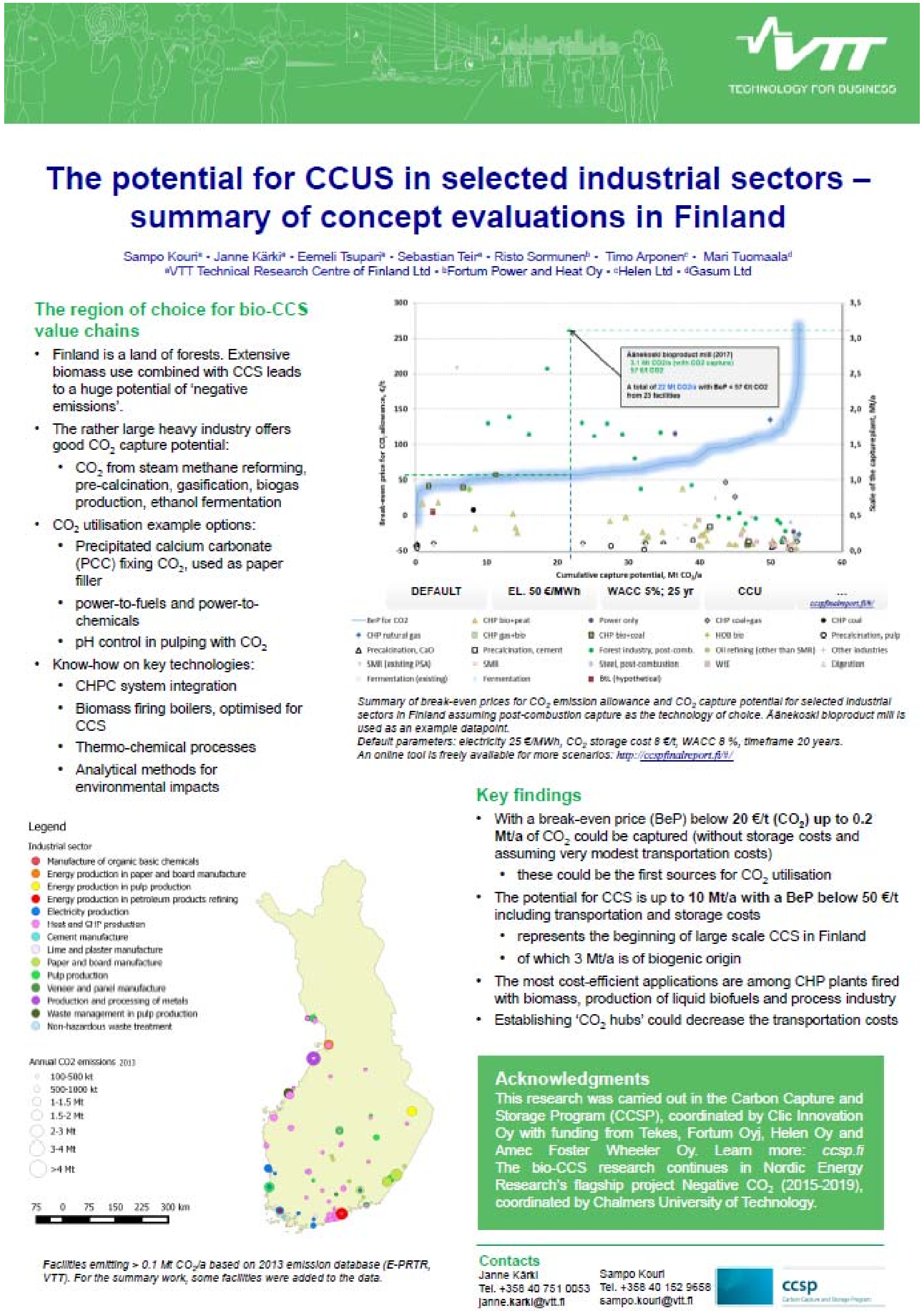
Key findings of the summary work

- With a break-even price (BeP) below **20 €/t (CO_2) up to 0.2 Mt/a** of CO_2 could be captured (without storage costs and assuming very modest transportation costs)
  - These could be the first sources for CO_2 utilisation
- The potential for CCS is up to **10 Mt/a with a BeP below 50 €/t** including transportation and storage costs
  - This represents the beginning of large scale CCS in Finland
  - Of which 3 Mt/a is of biogenic origin
- The most cost-efficient applications are among **CHP plants fired with biomass, production of liquid biofuels and process industry**
  - However, this requires that "negative" emissions from bio-CCS are acknowledged and included in the EU emission trading system → the opportunities as well as the challenges of bio-CCS/bio-CCU are very relevant for Finland
  - Depending on the CO_2 demand, the economic potential for bio-CCU may be larger than for bio-CCS because of the typically small unit sizes and inland locations of biomass fired CHP plants and pulp mills
- CCS does not provide a simple solution to reduce CO_2 emissions in Finland as there are no suitable formations for CO_2 storage
  - CO_2 export would be required
  - Establishing 'CO_2 hubs' could decrease the transportation costs

More info around our poster in this seminar

Note! Poster includes *old-school* interactive elements



Carbon Capture and Storage Program

CCS in a large-scale CHP system - Bio/coal-CCS in multifuel CHP plant

Timo Arponen / Helen Ltd

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Combined heat, power and cooling system in Helsinki

One of the most developed combined heat, power and cooling (CHPC) systems in the world exists in Helsinki and is operated by Helen Ltd

- 4 CHP Power plants producing heat and power
  - 2 Natural gas (CCGT)
  - 2 Coal + Pellets (0-10 %) (PC)
- Heat-only boilers
  - Natural gas, Oil, Coal
- Heat pumps: District Heat and Cooling using purified sewage water, district cooling water and electricity
- Absorption chillers using district heat
- Free cooling (sea water)

Questions of the research

Scenario: Multifuel CHP plant replaces one coal+pellet –fired plant

Main Questions

- How to integrate a CO_2-capture plant into a multifuel CHP plant?
- How does the multifuel plant with CO_2-capture fit into the energy system and what are the impacts to the whole system?
- Is it profitable to invest in CCS technology?

Multifuel CHP plant and CO_2-capture plant 1 / 2

- Multifuel power plant
  - CHP: District Heat and Electricity
  - CFB-boiler (Circulating Fluidised Bed)
  - 0-80 % biomass (forest residues), 20-100 % coal
- CCS
  - Possibility to utilize the process waste heat for district heating, which would make it possible to compensate for the energy losses
  - Post combustion capture, Plug-In (as power plant already exists)
  - 50 % flue gases treated in the capture plant
  - 90 % CO_2-removal efficiency

Multifuel CHP plant and CO_2-capture plant 2 / 2

BIO 80 % COAL 20 %	Base [MW]	With CCS [MW]	Diff.
Fuel	746	746	0 %
Electricity	242	195	-20 %
District Heat	414	529	+28 %
Efficiency(*	88 %	97 %	+9 %-p
COAL 100 %	**Base [MW]**	**With CCS [MW]**	**Diff.**
Fuel	717	718	0 %
Electricity	243	205	-16 %
District Heat	414	466	+12 %
Efficiency(*	92 %	93 %	+1 %-p

(* total efficiency including electricity and district heat

CCS includes flue gas condenser. Most of the heat is recovered from the condenser. *Investment in the flue gas condenser solely would be possible and profitable also without an investment in CO_2-capture.*

Approach

Prices and other variable costs

- Fuels, CO_2 emission allowances, taxes, transport and storage costs of CO_2, other variable costs
  - The scenario published by Ministry of Employment and the Economy (2015) was used as a basis for the prices of coal, natural gas, oil and electricity.
    The values for year 2030 were used (given in the source as 2014 money)
    (http://tem.fi/documents/1410877/2148188/Skenaariokehikko+%28luonnos+14.6.2016%29.pdf/51c1e381-6892-41b4-a37c-d3aa7e5f52f5)

➔ Optimization of the production:

- Feasibility of four different cases for new multifuel plant were compared (co-firing vs. coal, with and without CO_2-capture)
- The most feasible merit orders were calculated
  (The plants are taken into operation starting from the plant for which the operation costs are the lowest)

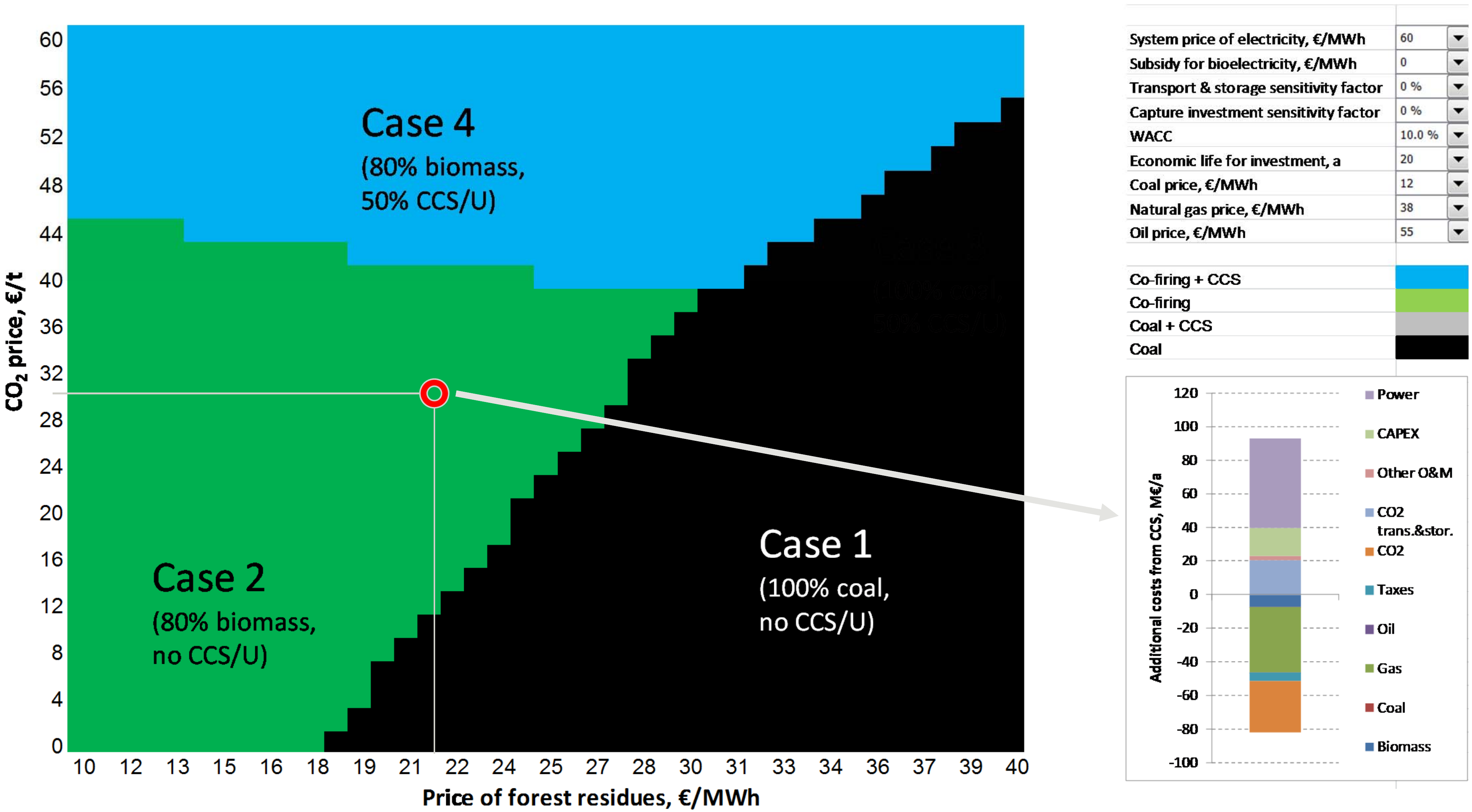
→ Fuels, emissions, costs, incomes (electricity)

➔ Overall operation costs of the whole system

- Investment costs (Carbon capture plant, 140 M€) → CAPEX

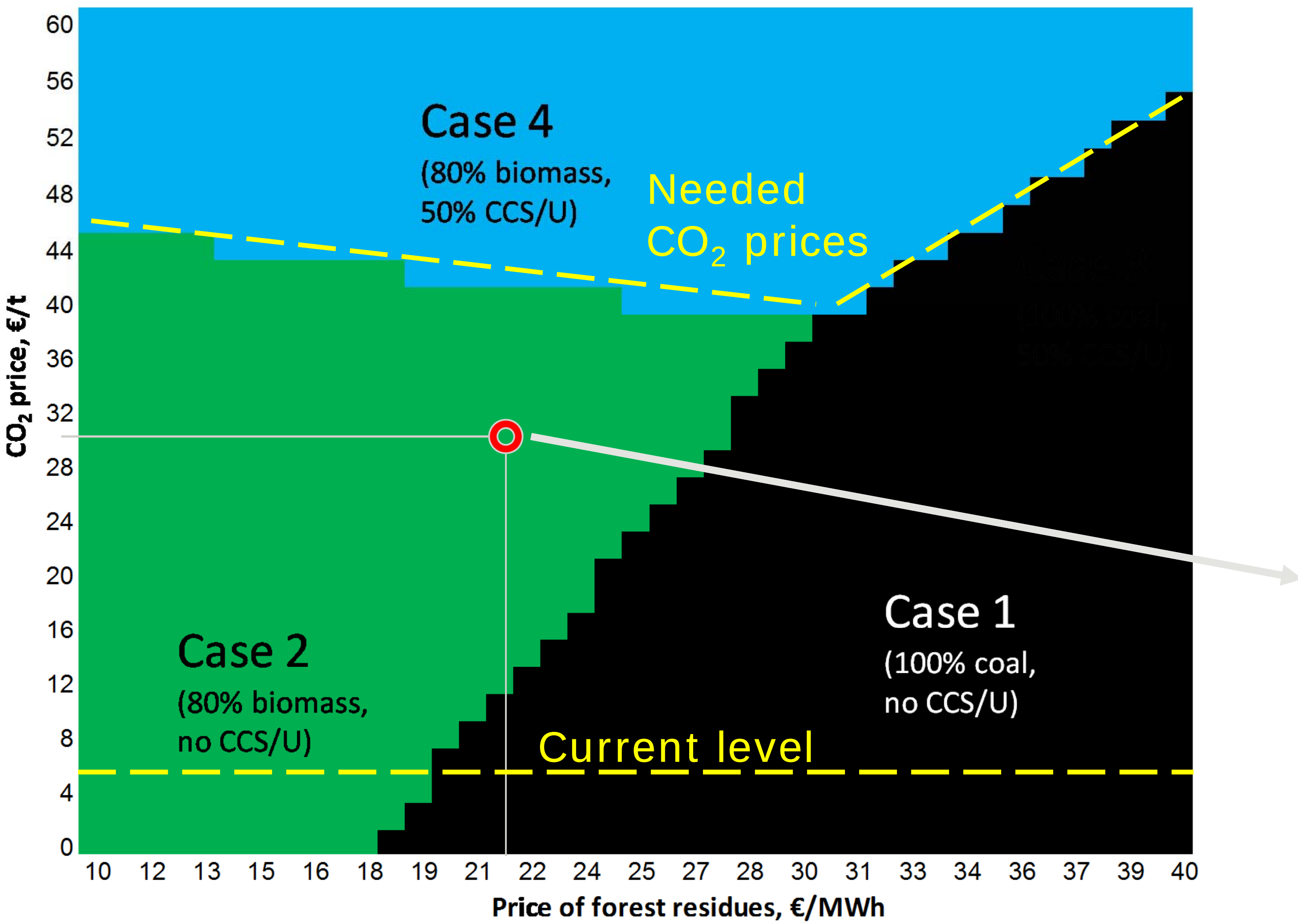
➔ Profitability of the CCS-investment

The profitability of the CCS investment

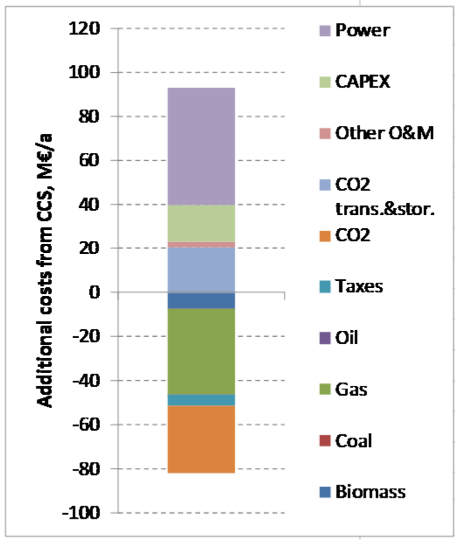


The profitability of the CCS investment

Break-even price for CCS is in the range of 40-45 €/t

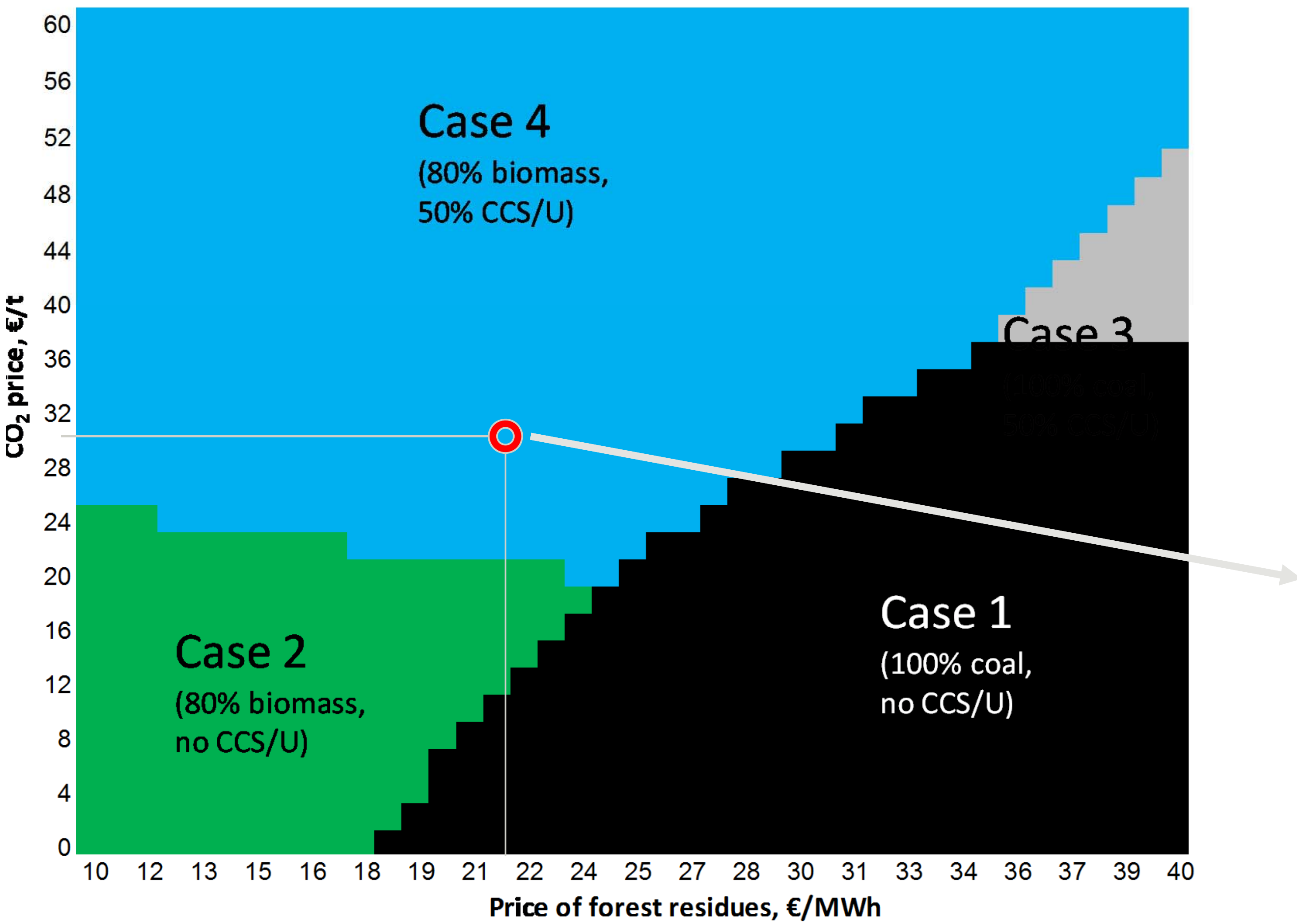


System price of electricity, €/MWh	60
Subsidy for bioelectricity, €/MWh	0
Transport & storage sensitivity factor	0 %
Capture investment sensitivity factor	0 %
WACC	10.0 %
Economic life for investment, a	20
Coal price, €/MWh	12
Natural gas price, €/MWh	38
Oil price, €/MWh	55
Co-firing + CCS	
Co-firing	
Coal + CCS	
Coal	



The profitability of the CCS investment
No transportation / storage costs
(e.g. CO_2 utilisation)

Break-even price for CO2-capture is over 20 €/t



System price of electricity, €/MWh	60
Subsidy for bioelectricity, €/MWh	0
Transport & storage sensitivity factor	-100 %
Capture investment sensitivity factor	0 %
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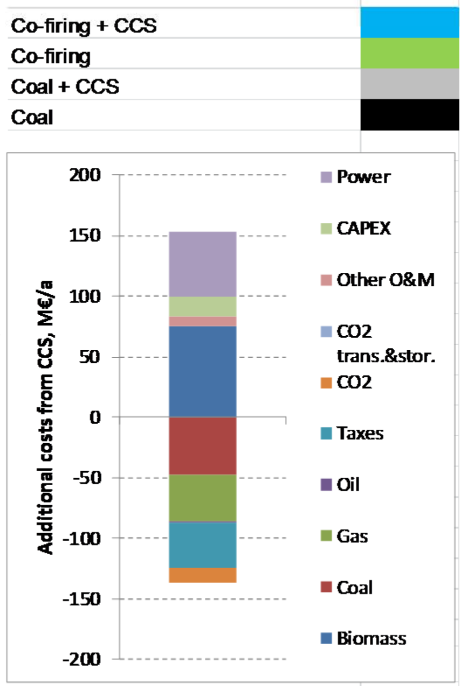

Key messages

- Result pictures show the most feasible cases in relation to prices of CO_2-emission allowances and biomass purchase
  - Including investments in CO_2-capture
- CCS with biomass seems to be more feasible than with coal, but still not profitable
  - CO_2 allowance price level 40-45 €/t needed for bio-CCS
  - Coal-CCS needs much higher CO_2 prices and/or high biomass prices

  - *Assuming that bioenergy is carbon-neutral and capturing biogenic CO_2 is acknowledged in the EU ETS as ”negative emissions”*
  - *Investment in the flue gas condenser solely would be possible and profitable also without an investment in CO_2-capture.*