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Carbon Capture and Storage Program

Overcoming non-technical barriers

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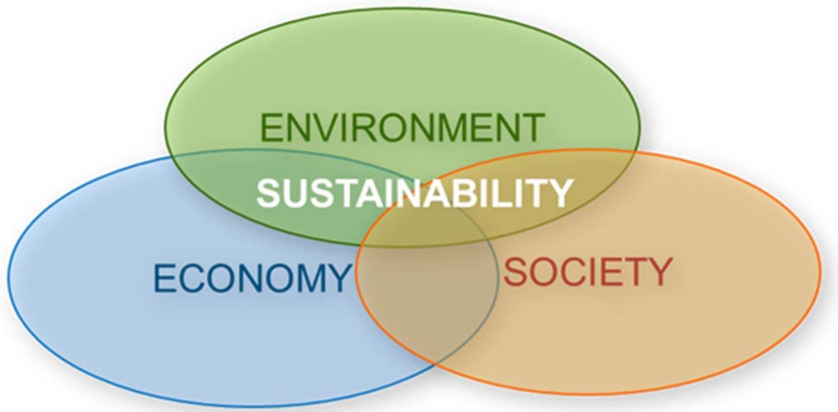
WP1 results

"non-technical barriers from sustainability point of view"

- **<u>Integrated sustainability assessment</u>**
  - Environment: LCA case studies, dispersion modelling
  - Economy: General cost data and operational environment
  - Society: Legislation & acceptability



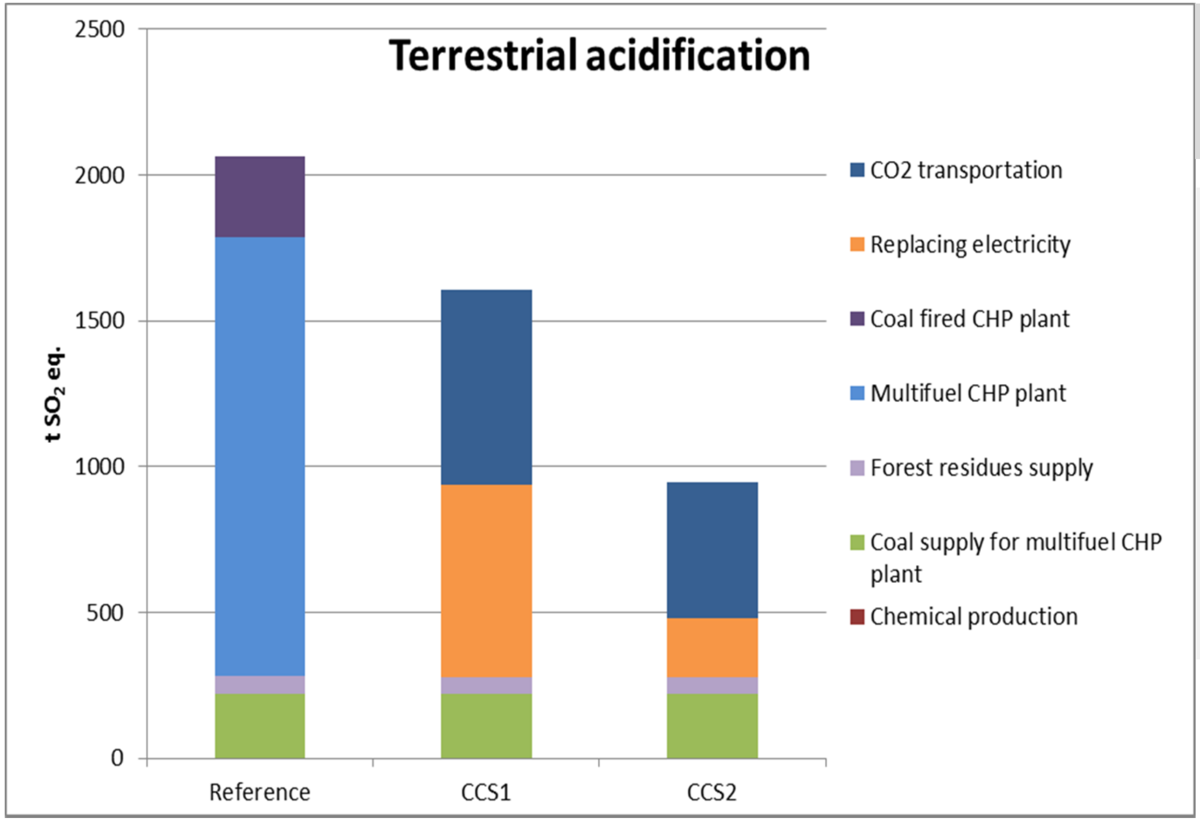
ENVIRONMENT

Life cycle assessments (LCA)

- Three case studies conducted in WP1 of CCSP
- Generally known that CO_2 decreases
  - Even “negative” CO_2 emissions by bioCCS
  - Overall impact mostly dependent on the impacts of energy penalty (replacing electricity in system level and consequent life cycles)
    - Multifold in comparison to, for example, CO_2 emissions from ship transportation of CO_2
- Focus on other environmental impacts

Acifidification

Case example: Greenfield oxy-CFB combustion (CHP)



Annual production
- 1058 GWh electricity
- 2353 GWh heat

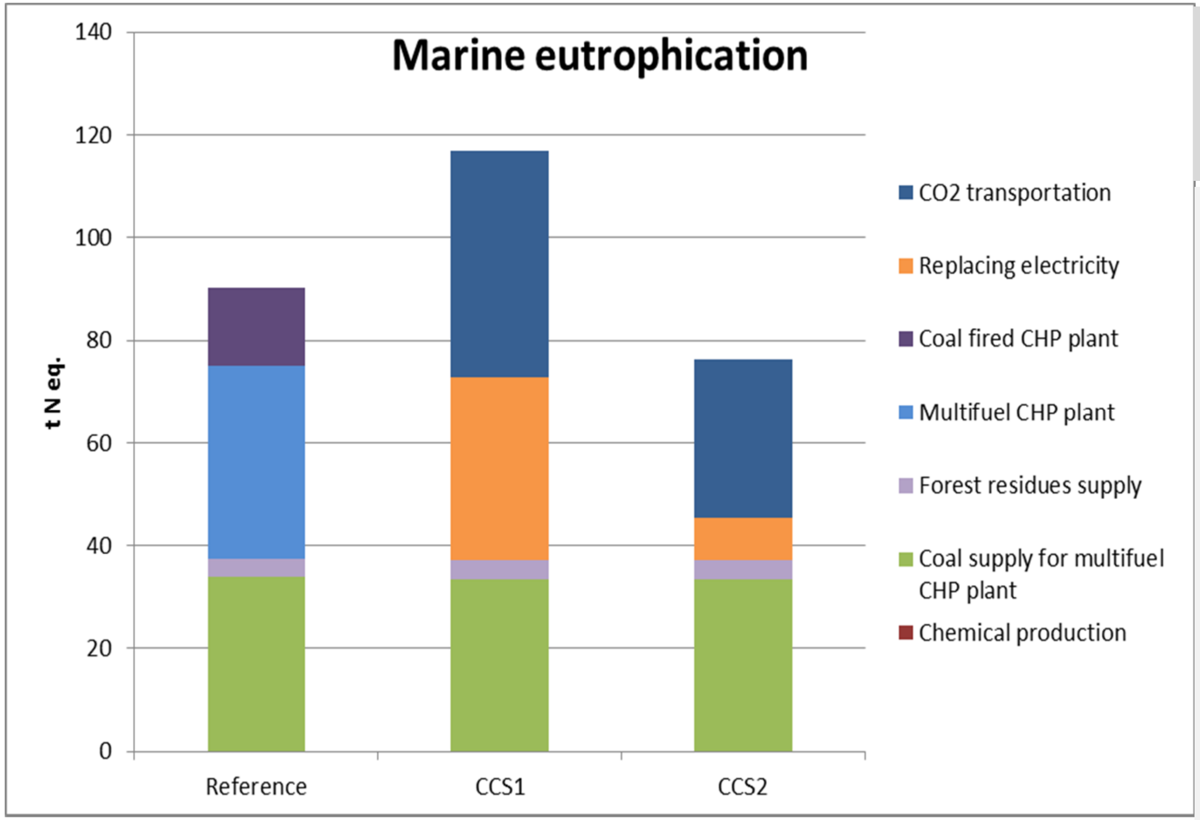
Results are very sensitive to assumptions regarding

- the reference case
- the assumed energy profile for replacing electricity
- ship transport (distance, fuel, size of the vessel)

Applied impact assessment method ReCiPe Midpoint (2012)

Eutrophication

Case example: Greenfield oxy-CFB combustion (CHP)



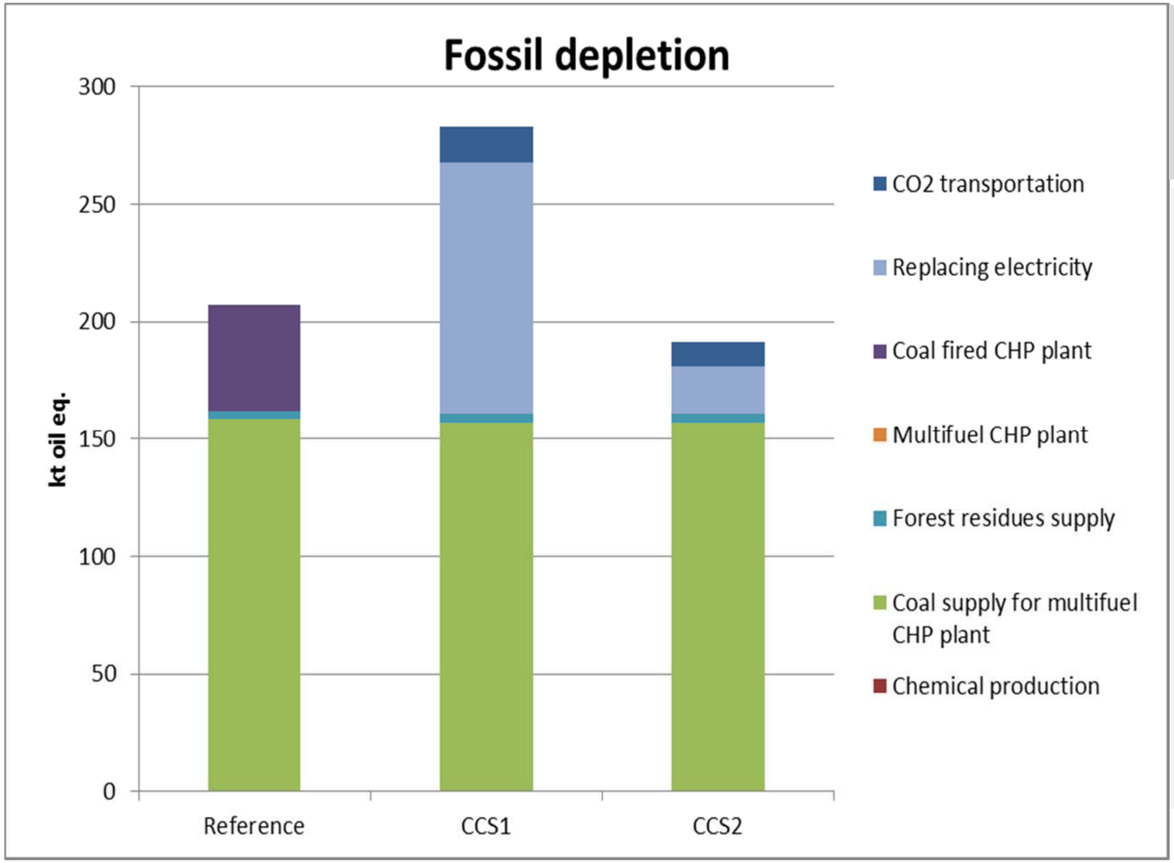
Annual production
- 1058 GWh electricity
- 2353 GWh heat

- Emissions from the Multifuel CHP plant decrease due to CCS implementation
- Increase occurs due to ship transport of captured CO_2 and due to replacing electricity
- Further savings are possible if distance of ship transport can be shortened (e.g. until Dalders)

Applied impact assessment method ReCiPe Midpoint (2012)

Fossil resources depletion

Case example: Greenfield oxy-CFB combustion (CHP)



Annual production
- 1058 GWh electricity
- 2353 GWh heat

CCS1:
- Replacing electricity (514GWh) produced with coal
- Transport of CO_2 with 10 000 m^3 ship.

CCS2:
- Replacing electricity (514GWh) produced with Finnish average fuel profile
- Transport of CO_2 with 20 000m^3 ship

Applied impact assessment method ReCiPe Midpoint (2012)

Dispersion modelling and amines (post-comb.)

- Dispersion models suggest potential exceedance of nitrosamine+nitramine concentration of 0.3 ng/m^3
- A chemical box model (Onel *et al*. 2015) estimated that
  - in an overcast day scenario the resulting sum was less than 0.004 ng/m^3
  - a clear day or clear night scenario may result in nitramine+nitrosamine concentration 0.5–1.0 ng/m^3
- Puff model with amine chemistry module (Fowler and Vernon 2012a)
  - optimistic scenario: sum of all harmful species 14% of 0.3 ng/m^3
  - pessimistic scenario: sum of all harmful species exceeded 0.3 ng/m^3
- Ramboll has developed tools for modelling

Conclusions - Environment

- In addition to CO_2, also the SO_2, NOx and N_2O emissions from the assessed power plants decrease due to CCS implementation.
  - Increases occur due to ship transport and need for compensating energy
  - Not a barrier, but due to ambiguous nature of LCA, also contradictive results are published in international literature and risk for disinformation exists.
    - Requires foreseeable development of power system and regulation of emissions from ships

- Dispersion modelling tools developed → modelling capability not a barrier
  - Carcinogenic emissions such as nitrosamines may become a barrier even if amounts are small (limits vs. technology specific emissions)

ECONOMY

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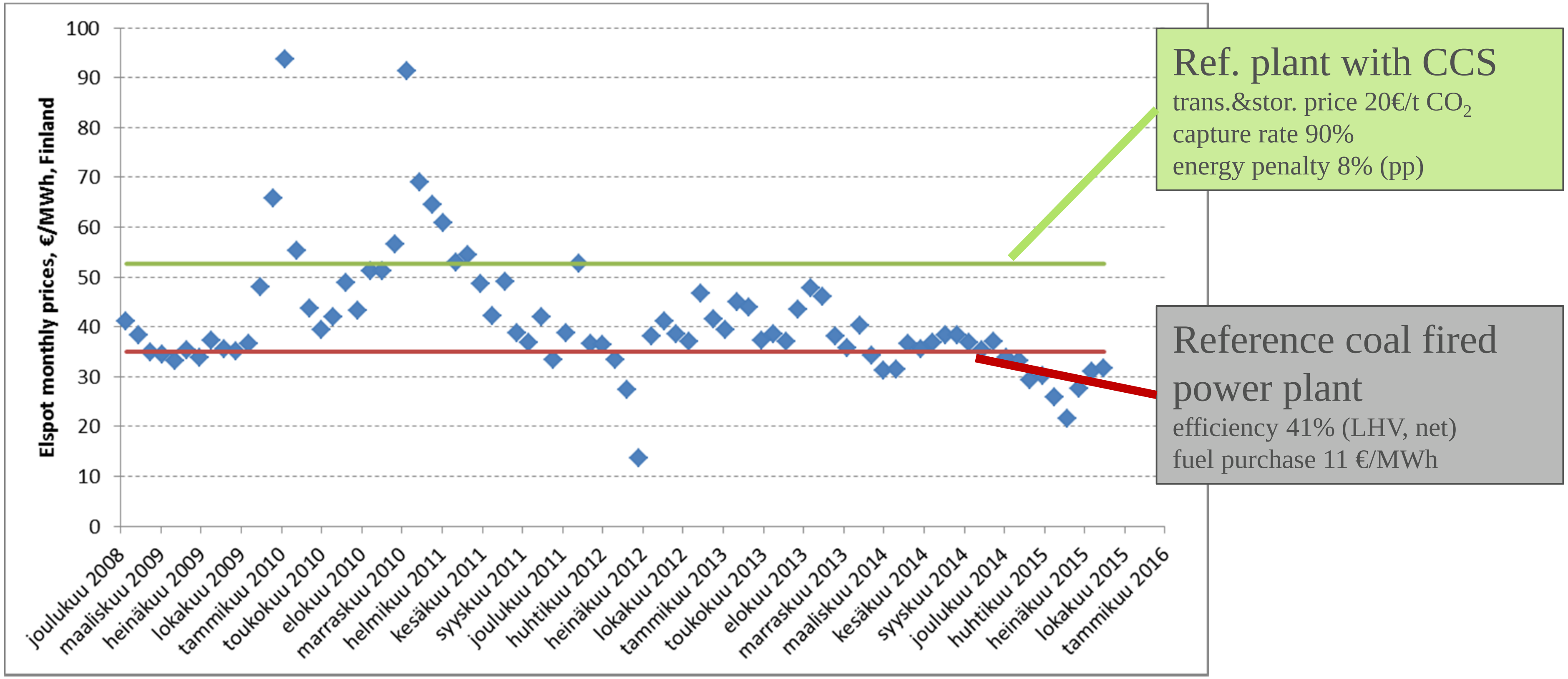
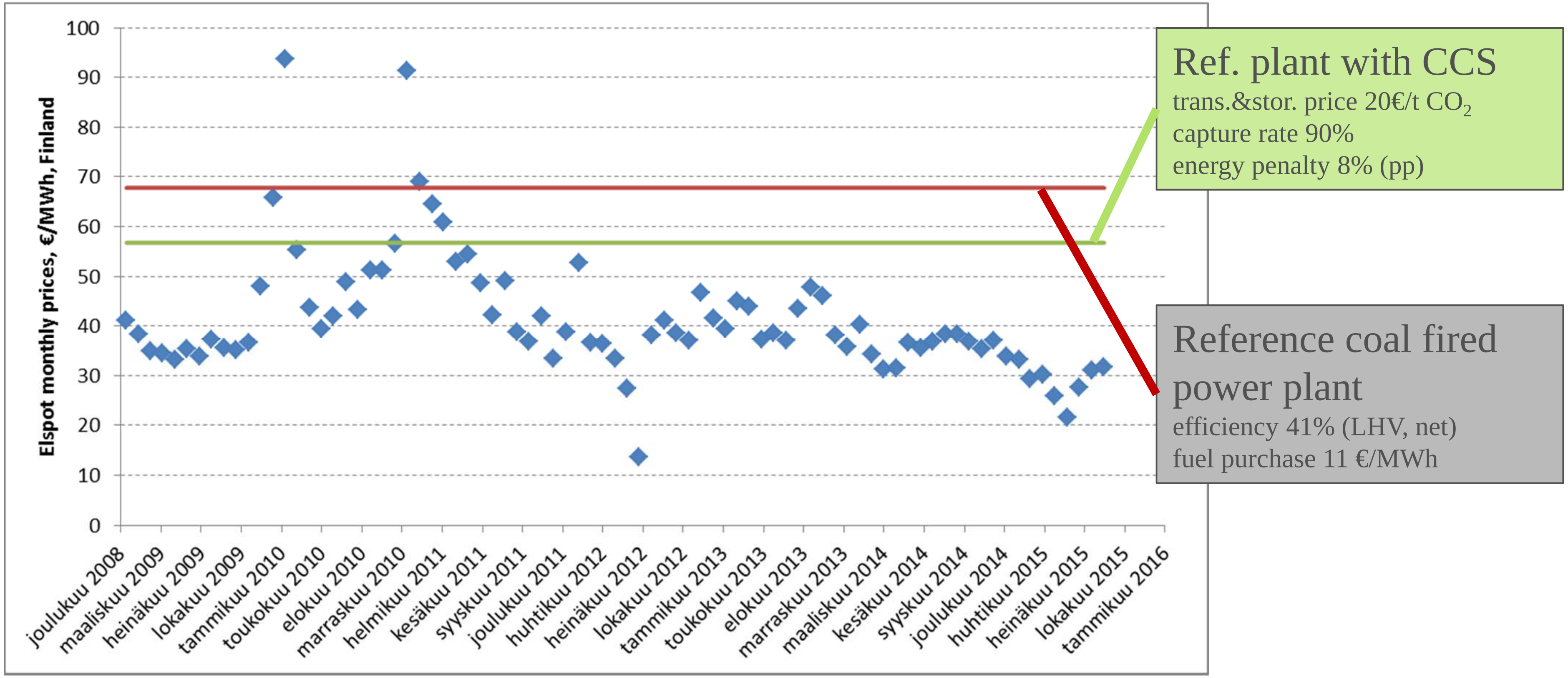
Fuel+CO_2 costs vs. Elspot monthly prices

Emission allowance price in EU ETS 10€/t



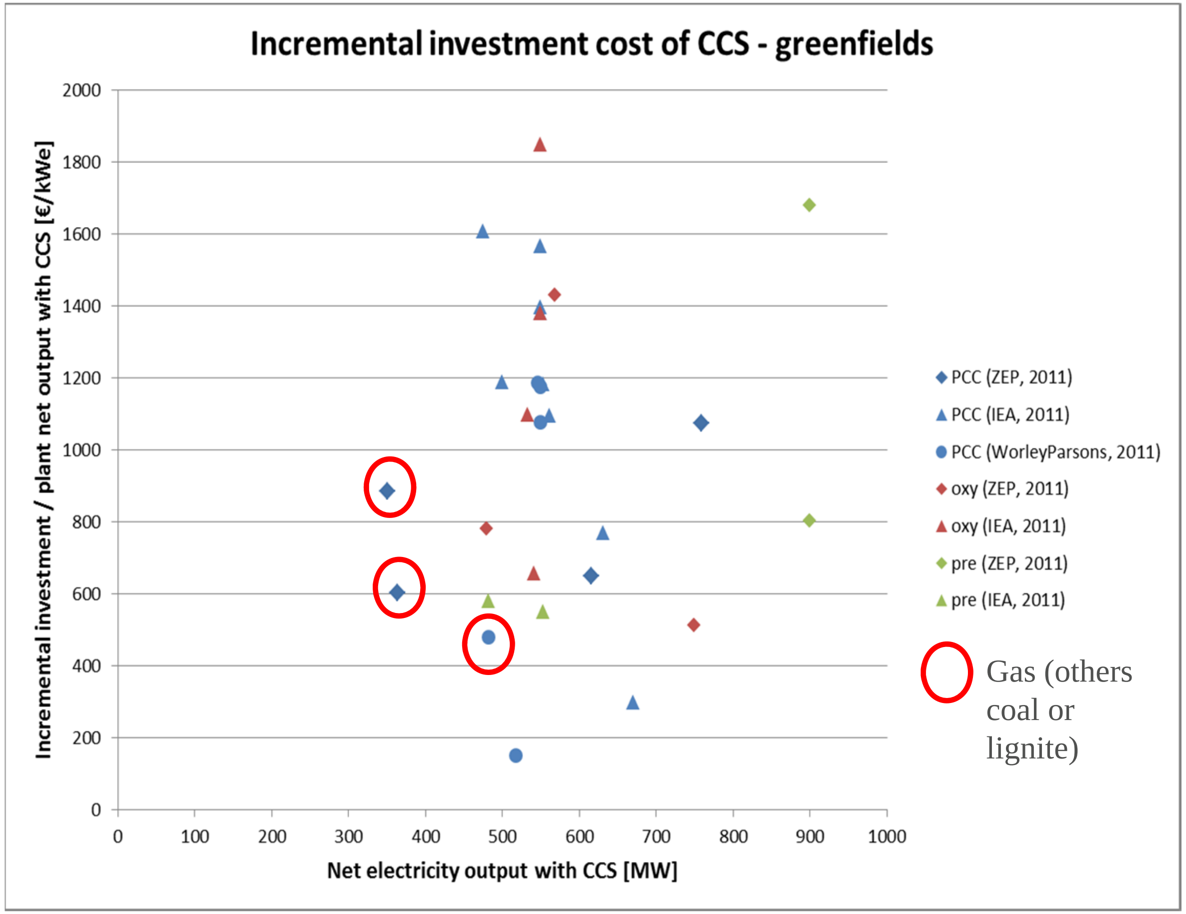
Fuel+CO_2 costs vs. Elspot monthly prices

Emission allowance price in EU ETS 50€/t



Incremental investment cost of CCS

- No trend in incremental investment costs can be found
- The average incremental investment for GTCC CCS is below average



For comparison: Investment for Boundary Dam project (FOAK, retrofit) ~ 10 000 €/kWe

- incl. boiler and turbine improvements

How to overcome the economic barriers?

- Improved technologies (e.g. CLC)
  - Non-technical and technical barriers are interlinked
- Applications for ”low hanging fruits” (e.g. Slag2PCC, biodiesel, Ca-cycles)
- Profitability from other markets than electricity spot-price
  - capacity markets
  - other products than electricity (heat, biofuels, CCU, etc…)
  - waste management, industry, negative emissions!
- Who will take the risk with FOAK plants
  - subsidies required?
  - uncertainty still remains with NOAK plants
    - costs, potential for mushrooming?

SOCIETY

Safety

- There are several legal environmental, health and safety (EHS) requirements an operating industrial (power) plant must fulfill.
- Introducing carbon capture to these plants would not (at least in most of the cases) substantially increase or tighten the legal requirements. Carbon capture would be a new process unit, whose safety should be ensured.
- EHS-issues and risks related to processing CO_2 is not a new topic, but the amounts of CO_2 in CCS value chain are. A major release of CO_2 has a potential to become a major accident hazard.
- The risks related to carbon capture should be compared with other risks in a facility and to assess whether the existing safety measures and other risk reducing measures are sufficient.

EU ETS

Negative emissions

Article 49

Transferred CO_2

1. The operator shall subtract from the emissions of the installation any amount of CO_2 originating from fossil carbon in activities covered by Annex I to Directive 2003/87/EC, which is not emitted from the installation, but transferred out of the installation to any of the following:

(a) a capture installation for the purpose of transport and long-term geological storage in a storage site permitted under Directive 2009/31/EC;

Ship transportation

(b) a transport network with the purpose of long-term geological storage in a storage site permitted under Directive 2009/31/EC;

Utilisation and mineral carbonation

(c) a storage site permitted under Directive 2009/31/EC for the purpose of long-term geological storage.

Article 3

Definitions

(52) 'CO_2 transport' means the transport of CO_2 by pipelines for geological storage in a storage site permitted under Directive 2009/31/EC;

For any other transfer of CO_2 out of the installation, no subtraction of CO_2 from the installation's emissions shall be allowed.

http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R0601&from=EN

How to overcome the legislative barriers (1/3)

Negative emissions:

- Proposal: Income from gained CO_2 allowances
  - several possibilities, for example NER400
    - Scientific approach: monitoring at storage site only
    - Proposals outlined (journal article)

- CCS in biomass co-firing probably already possible until net zero CO_2 emissions?

- Liquid biofuels: benefits in required life cycle emission reductions?
  - RES directive, Fuel Quality directive, forthcoming regulations…

How to overcome the legislative barriers (2/3)

Ship transportation:

- Monitoring could be based on the existing requirements for documentation (Bill-of-Laden, BoL)
  - Possible solutions to be presented in two papers (GHGT + journal?)

- Preparations to include ship transportation in EU ETS
  - May overcome some barriers

- London Protocol: Transboundary amendment for CO_2 export needs 30 countries to ratify
  - until 2014 only 2 (UK and Norway) had ratified!
  - Finland is not a party of London Protocol → not a barrier for Finland (directly)

How to overcome the legislative barriers (3/3)

Utilisation

- Economic benefit from the product CO_2, not from saved CO_2 allowances
  - Increased economic value of replaced CO_2 emissions in other sectors improves profitability
  - Potential incoherencies in some cases (need for research and dissemination)

Mineral carbonation

Communication and commenting

- MEE, EU and national regulation
- International collaboration (conferences, IEA, IEA GHG, EERA, ZEP…)

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Public acceptance

Greenpeace, CCS - False Hope - fact sheet

www.corporateeurope.org

kn-online.de

www.dw.de

www.linksfraktion.de


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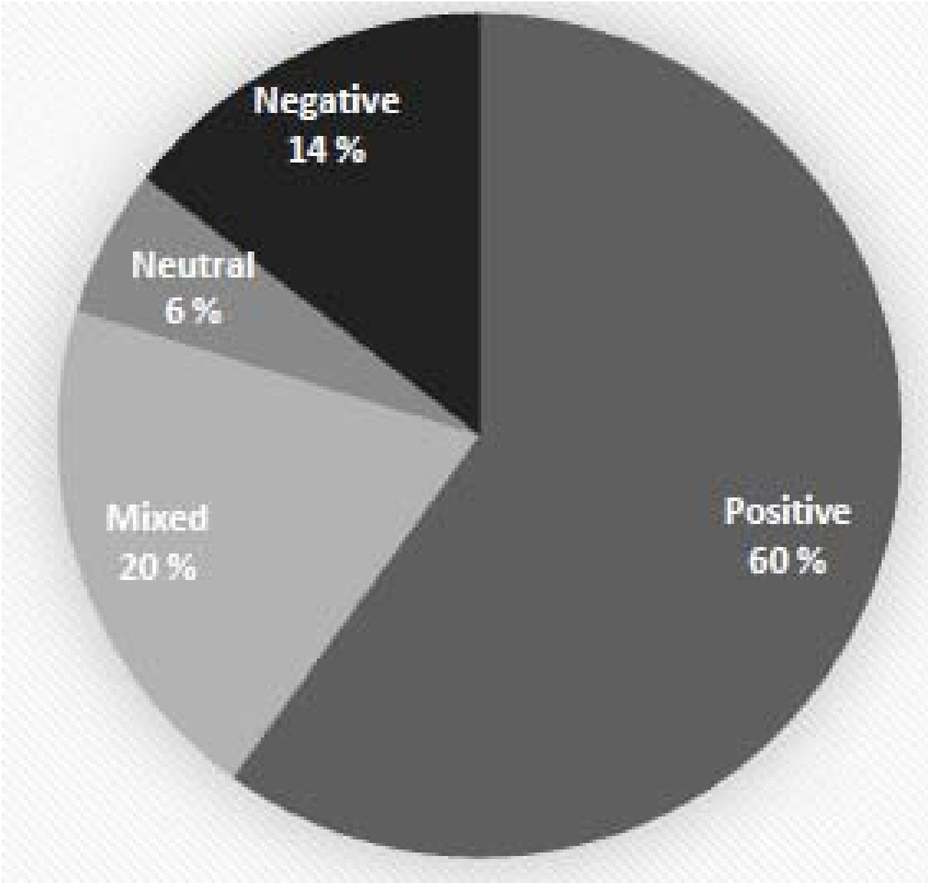
Vattenfall withdraws from German CCS project

07 December 2011 16:32 Source: ICIS

http://www.icis.com

Tone of the articles (N=282) in the Finnish print media data

(Kojo & Innola, CCS in the Finnish Print Media)



TOP-5 arguments regarding CCS in Finnish print media

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TOP-5 positive arguments:

- Reduces emissions / Slows down climate change
- EU / Other countries are investing in CCS
- Technology already exists / is tested / is in use
- CCS is an important means among others
- Consumption of fossil fuels will continue / increase

also used as a negative argument

TOP-5 negative arguments

- CCS is expensive
- Problematic/unsolved final storage
- Not profitable/deployable in decades
- Technology still in planning stage/not used
- Lessens plant-efficiency/requires more energy

Tentative conclusions related to acceptance

- Probably not a significant barrier in Finland
  - In general, difficulties mostly with geological storage → no storage sites in Finland
  - Uncertain due to lack of full scale projects
    - Currently CCS is not on agenda of media in Finland
      - Should it be for instance to foster awareness and debate on climate change mitigation options?
      - Who will be the talking heads media will refer to in the future?

- The same options presented from economic perspective may help also in terms of acceptability
  - Communication needed regarding final storage (excl. CCU)

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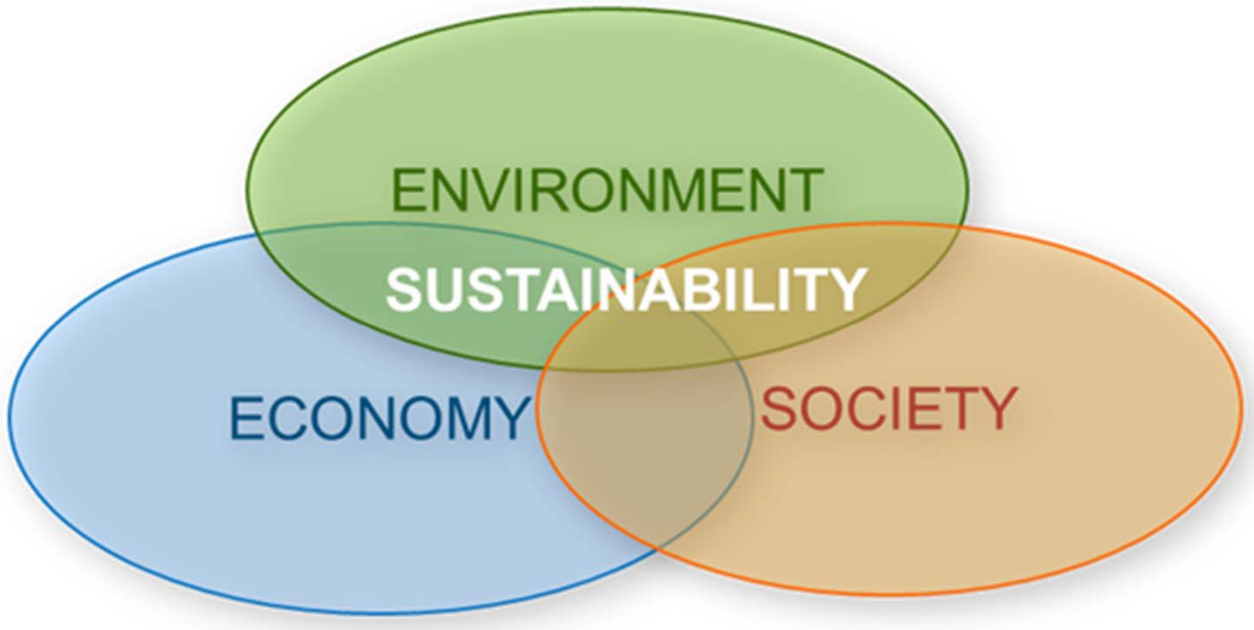
Some examples of published guidelines

- Ashworth et al. (2011) *Communication/Engagement Toolkit for CCS Projects*. CSIRO. 50 pages.
- Bellona (2009) *Guidelines for public consultation and participation in CCS projects*. 10 pages.
- Jammes et al. (2012) *Social Site Characterisation & Stakeholder Engagement*. Global CCS Institute. 132 pages.
- NETL/US DoE (2009) *Best Practices for Public Outreach and Education for Carbon Storage Projects*. National Energy Technology Laboratory. 62 pages.
- World Resources Institute (2010) *Guidelines for Community Engagement in Carbon Dioxide Capture, Transport, and Storage Projects*. 100 pages.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SUSTAINABILITY
ECONOMY
SOCIETY

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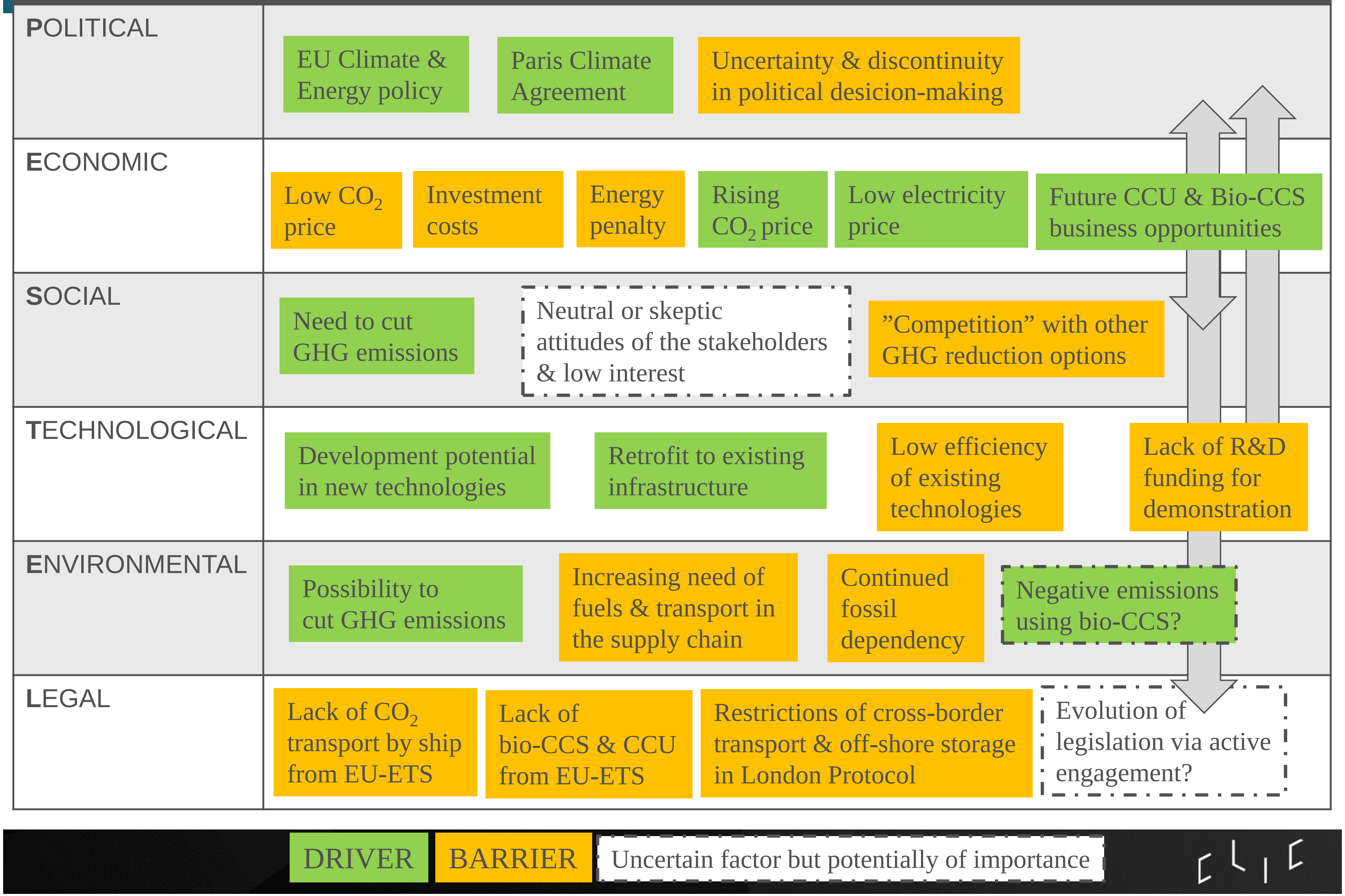
PESTEL analysis for integrating the results

- PESTEL framework categorizes environmental influences of the operational environment into six main categories: **P**olitical, **E**conomic, **S**ocial, **T**echnological, **E**nvironmental and **L**egal.
- PESTEL can be used for
  - analysing the macro-environment
  - for providing an overview of most important factors
  - for identifying key drivers of change
- In this case, PESTEL framework was applied for identifying key drivers and potential barriers for implementation of CCS technologies in Finland.

Identified Drivers & Barriers for CCS in Finland



Conclusions

- Lack of profitability probably the most important barrier
  - Difficult to overcome in many cases
  - Some ”low-hanging-fruits” available for CCU
  - Business cases vs. national economy and balance of trade (e.g. domestic transportation fuels)
- Several legislative barriers
  - Negative emissions, ship transportation, CCU
  - Easy to overcome (in principle), but actions required
- Uncertain acceptability
  - Significant resistance in some regions/cultures/against companies
  - Fully tested if projects are realised → public engagement and active communication and interaction