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PRE STUDY OF CCS FOR A BIO FUELED CHP PLANT

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ABSTRACT

The environmental performance of a potential carbon capture and storage (CCS) installation at the bio fueled combined heat and power (CHP) plant in Lugnvik, Östersund was studied with screening life cycle assessment (LCA) methodology. CCS has lately been discussed for plants using bio fuels since it is one of few possibilities to actively decrease the concentration of carbon dioxide in the atmosphere. The most common process for carbon capture, absorption in MEA, was assumed. Transportation of the captured carbon dioxide to Norway for injection in natural gas fields was the considered storage option.

The impacts from transportation of the captured carbon dioxide indicate that alternatives should be investigated, e.g. possibilities for local storage or other types of utilization of the captured carbon. The comparatively high energy use for the MEA capturing process indicates that CCS for bio fueled plants must be carefully considered. Alternative technologies for carbon capture should be further investigated - e.g. if biological methods might give better performance over chemical absorption – as should the consequences of alternative handling of the captured carbon dioxide.

INTRODUCTION/PURPOSE

Could carbon capture and storage (CCS) be of interest for plants generating district heating in bio fueled combined heat and power plants (CHP)? CCS is discussed as one possible component in a set of actions to mitigate climate change, often in terms of making it possible to continue the use of fossil fuels and especially coal power. Lately CCS has also been discussed for plants using bio fuels since it is one of few technologies giving possibilities to actively decrease the concentration of carbon dioxide in the atmosphere, in contrast to just decreasing the emission of new carbon dioxide or other green house gases.

In this pre study Jämtkraft and the Echotechnology group at Mid Sweden University has initiated investigations of the environmental performance of implementing carbon capture and storage (CCS) at the CHP plant in Lugnvik, Östersund. We have made a screening life cycle assessment (LCA) study to model consequences.

The most common process for carbon capture, absorption in MEA, was assumed. Transportation of the captured carbon dioxide to Norway for injection in natural gas fields was the considered storage option.

STATE OF THE ART

The process of carbon capture and storage is known technology and to some extent used. For example carbon dioxide is separated from methane at natural gas fields in the North Sea and injected back in geological storage. The separation praxis has in this case the economic benefit of significantly decreased gas volumes to transport to shore. Post combustion capture at power plants has been practiced, mainly with the goal of achieving carbon dioxide for different uses, but is today not common. Post combustion capture of carbon dioxide for bio fuelled power of CHP plants is presently not in large scale use, but technically post combustion capture and storage would work similarly as for fossil fuelled plants [1]-[4].

For a retrofit situation of an existing plant, post combustion capture by absorption is the most commonly discussed method. For new plants pre combustion separation or oxy fuel solutions could also be considered. The most well known absorption chemical for post combustion capture of carbon dioxide is monoethanolamine (MEA), whereas the use of methyldiethanolamine (MDEA) and chilled ammonia as absorption chemicals represents technologies under development [5].

The Lugnvik plant contains of one CHP unit and two heat only units (used at peak heat demand and at summer service shut down of the CHP plant). The plant delivers district heating to the town of Östersund and some nearby municipalities. The main fuel types are sawmill residues and forest fuels, but peat and recycled wood are also used [6], [7].

METHODS

For this study a system model was created where the Lugnvik CHP plant was assumed to be retrofitted with a post combustion carbon capture facility using MEA absorption. Electricity needed for the capturing process was assumed to be covered by increased electricity production from the plant and it was assumed that the increased heat production could be delivered to the district heating network without limitations. The captured carbon dioxide was assumed to be transported to Norway and injected in the Sleipner field. This technical model was assessed using screening LCA methodology. LCA is a methodology to study environmental impacts over whole value chains, adding such as raw material extraction to use for a specified function. The parameters assessed were Global Warming Potential (GWP) and Acidification Potential (AP).

For this screening study we considered only the CHP plant (and not the heat only units also present at the Lugnvik site), assumed that all fuel utilized (also the peat) could be considered carbon neutral (of renewable origin), and regarding environmental impacts from fuel generation we only considered transports of the bio fuels to the plant. Environmental impacts from building and eventually decommissioning of the carbon capture facility was not considered.

We have assumed a carbon capture efficiency of 90% and that a third of electricity produced in the plant will be needed to run the carbon capture process [8]. The energy need might be underestimated for a CHP plant since the figure is based on facilities with power only production, but the approximation was considered sufficient for this screening study. We have modeled a corresponding increase in fuel transports, flue gas generation and ash transports. Flue gas and ash generation were based on the environmental data for the Lugnvik CHP plant of the year 2012 [6], [7]. For the MEA use, only transportation of the necessary make up due to losses [9] was considered, not the production of the chemical itself.

A pipeline transport of the captured carbon dioxide to Norway with subsequent injection in the Sleipner field was estimated based on data from a Vattenfall study [10], including emissions from constructing the pipeline over an assumed distance of 300 km. Electricity needed for pressure boosters etc is additional to the electricity needed for the carbon capture, and was assumed to be covered from the grid according to the Vattenfall study (not from increased production in the Lugnvik plant). An additional scenario estimating truck transports instead of pipeline transport (to avoid the need for building a pipeline over the mountain range) was based on emission factors for heavy truck transports [11].

Since this is a screening study with rough estimates, we have simplified by calculating the results per produced kWh, making no difference between electricity and heat. It should be noted that the production balance is skewed toward heat through the model assumptions.

RESULTS

The results for climate impacts as GWP in carbon dioxide equivalents are shown in Figure 1. As can be seen the emissions from running the Lugnvik CHP plant contributing to GWP increases significantly by implementing the CCS compared to the present situation, due to increased fossil fuel use by the increased transportation necessary (mainly by increased bio fuel and ash transports for the plant itself, and from transporting the captured carbon dioxide to storage). These increased emissions are however dwarfed compared to the avoided carbon dioxide emissions, shown as negative emissions in Figure 1.

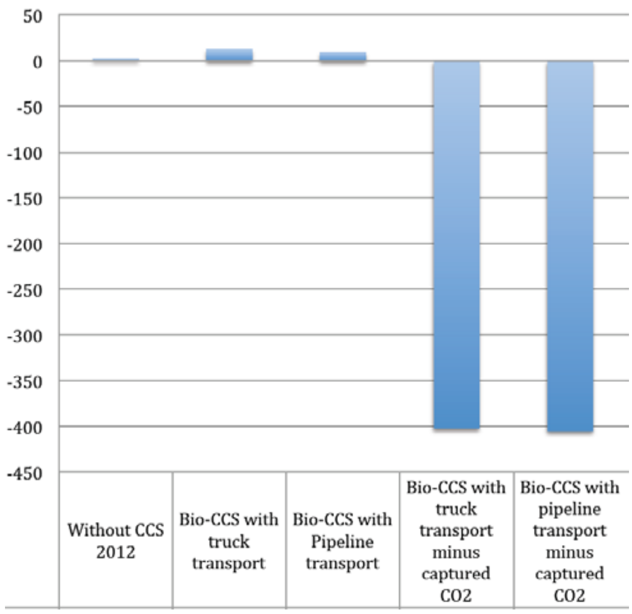

Fig. 1 The contribution to global warming for the CCS model of the Lugnvik bio fuelled CHP plant under two scenarios. Note that these results are from a screening study. The climate impact increases significantly from the present operations by introducing the CCS. The increased emissions are more than compensated for by the net withdrawal of carbon dioxide from the atmosphere through geological storage give, indicated by the large negative bars.

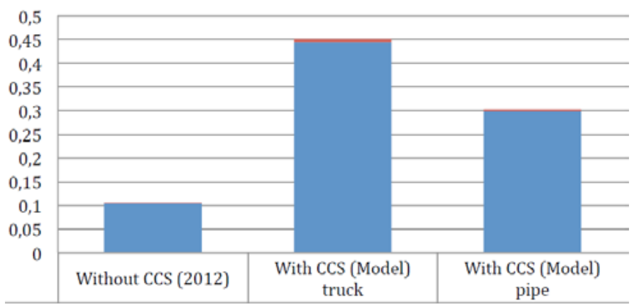

Fig. 2 The contribution to acidification, in sulphur dioxide equivalents, for the CCS model of the Lugnvik bio fuelled CHP plant under two scenarios. Note that these results are from a screening study. The acidification impact increases significantly from the present operations by introducing the CCS.

The results for acidification impacts as AP in sulphur dioxide equivalents are shown in Figure 2. For acidification the emissions and the impact only increase by the implementation of the CCS; for the parameter acidification there are no avoided impacts. Also for acidification the increased impact is to a large extent from increased transportations (and mainly to transport related NO_x emissions).

The pipeline transportation scenario would in this rough model give somewhat lower impacts compared to the truck transportation scenario.

DISCUSSION

The Lugnvik CHP plant is, compared to most coal power plants rather small, with comparatively small amounts of potentially captured bio-carbon dioxide.

This screening LCA study only gives a rough picture of the performance of the possible installation of a CCS facility in Lugnvik, but still clearly indicate that the reduction of carbon dioxide comes to a cost in form both increased use of bio fuels to deliver the same amount of benefits in form of heat and electricity, and in form of increased impacts to acidification from increased NO_x emissions The increased NO_x emissions originates from increased transports of fuels and ash due to increased incineration to cover the energy needed for the modelled absorption, and from transport of the captured carbon to the geological storage.

If the modelled technical solution should be implemented, it must be carefully studied from optimization point of view. Any increase in energy performance of the absorption process would be very beneficial. It should be investigated if alternative storage possibilities closer by could be utilized. Work must be put into further decreasing the flue gas NO_x emissions, when you implement a situation where you increase combustion of fuels without a significant increase of production.

The strongest indication from the study, however, is that for bio fuelled plants, alternative methods for both capturing and 'storage' of carbon should be considered. Biological absorption of carbon dioxide in flue gases by algae has been studied in small scale study by Jämtkraft and Ecotechnology in 2005 indicating a possible absorption rate of about 50% or above. If such biological processes could significantly reduce energy use in the absorption process the lower absorption rate might be acceptable for a bio fuelled plant. Alternatives to storage should also be investigated; for carbon dioxide from bio fuels perhaps secondary use as materials, bio oil, etc could be an as good option as long term geological storage, at least if the impacts from the storage / secondary use process would be significantly reduced. Other alternatives, as power to gas schemes, should also be studied and environmental and climate performances of the different alternatives carefully considered.

An issue not looked into here is risks of leakage in transportation or storage. Such considerations have been of high concern for the discussions of CCS for coal power plants in Germany.

OUTLOOK

Companies delivering district heat and other energy carriers based on bio fuels have a possibility to contribute to lowering the carbon dioxide concentration in the atmosphere. Before implementation such technologies must be further investigated regarding process optimization and how different options for both capture and storage or use of carbon will perform in environmental and energy systems perspective. Cost is also an issue which has not been looked into here.

CONCLUSIONS

The impacts from transportation of the captured carbon dioxide indicate that alternatives should be investigated, e.g. possibilities for local storage or other types of utilization of the captured carbon. The comparatively high energy use for the MEA capturing process indicates that CCS for bio fueled plants must be carefully considered. Alternative technologies for carbon capture should be further investigated - e.g. if biological methods might give better performance over chemical absorption – as should the consequences of alternative handling of the captured carbon dioxide – e.g. use for materials, bio oils, power to gas schemes etc.

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