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MULTI-CRITERIA ASSESSMENT MODEL FOR CARBON CAPTURE AND STORAGE SYSTEMS

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ABSTRACT

A flexible and transparent multi-criteria model is being developed to evaluate the sustainability of carbon capture technologies and chains: to guide policy makers, investors and technology developers on important challenges and opportunities. The model is built with a techno-economic and a GHG assessment with a hybrid LCA approach. The model has demonstrated important benefits from combination of economic and process data, such as making the analysis more efficient and how a GHG assessment can expand the scope and of a techno-economic assessment.

INTRODUCTION

Carbon Capture and Storage (CCS) is considered to be one of the most promising alternatives for reducing anthropogenic greenhouse gas emissions (Rochelle, 2009). To bring CCS closer to commercial realization, its sustainability must be explored by multi-criteria assessments that take into account economic, environmental and social aspects (J. P. Jakobsen et al., 2011; J.P. Jakobsen, Roussanaly, Tangen, & Mølnvik, 2012; J. P. Jakobsen, Tangen, Nordbø, & Mølnvik, 2008).
This project is part of the international CCS research center BIGCCS (Aarlien, 2009) and its aims are to develop a model that

- Is flexible and cover several types of technologies, governing parameters (e.g. varying energy and CO_2 quota prices) and sustainability aspects

- Is transparent, coherent and efficient. The model should provide decision makers with clear and applicable information.

CCS technologies have been studied with LCA for more than ten years, but it is still a challenge to make LCA thinking and results an operational part of CCS development.

METHODS

The model is built as a set of building blocks (modules) that each model a specific part of CCS chains, such as capture, transport and storage technologies. These modules can be

combined to study different CCS chains. Each module cover a wide range of economic and environmental key performance indexes, such as: net present value of costs, potential climate impact, initial investment amount, and utilities (water, electricity and fuel) consumption. So far modules for amine based post-combustion capture and two different transport technologies are developed: onshore pipeline and shipping between harbors. The technologies that are covered are under continuous expansion.
Each module contains a techno-economic assessment and a GHG assessment based on inputs from process modeling and data found in literature. The economic assessment methodology is presented in the article "Techno Economic Evaluation of Amine based CO_2 Capture: Impact of CO2 Concentration and Steam" (Husebye, Brunsvold, Roussanaly, & Zhang, 2012).

The GHG assessments cover materials and energy used in operational and capital expenses, and is performed as a hybrid-LCA by combining physical processes data with economic data from the techno economic assessment (figure 1). A hybrid LCA approach has advantages as it ensures consistency between the economic and environmental assessments and it can compensate for the incomplete system boundaries, and underestimation of net environmental impact, that can be the result of a purely process based LCA (Lenzen, 2000; Suh, 2004). Combining data is also efficient with regards to necessary resources to perform the studies and makes it easier to build a clear and transparent model.
The process data is modeled with data from Ecoinvent 2.2 (EcoInvent, 2012) and the economic data is modeled with an environmentally extended input output database published by Carnegie Mellon University (eiolca.net, 2008).

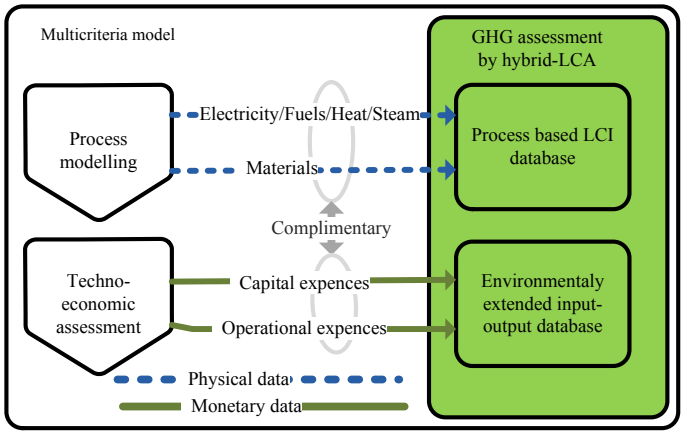

Figure 1 Illustration of hybrid-LCA GHG assessment

RESULTS AND CONCLUSIONS

The project demonstrates that cooperation between experts in CCS technology, techno-economic assessment and LCA can build a robust and efficient multi-criteria assessment model. The use of the model has also demonstrated that a multi criteria model can increase

the scope and precision of each of the assessments within the model through internal exchange of data.
To study the use of the assessment model it was applied on two cases: one looking at amine post capture from flue gas with different CO_2 concentrations (Husebye, et al., 2012; Roussanaly, Brunsvold, Hognes, Jakobsen, & Zhang, 2013) and one case comparing different technologies to transport CO_2 from capture to storage (Roussanaly, Hognes, & Jakobsen, 2013). The first case study demonstrated the expected correlation between CO_2 concentrations: capturing at very low concentrations is costly both in terms of economy and GHG emissions. More interesting was to study how the results of the GHG assessment could be fed back to the economic assessment: The results of the GHG assessment was used to estimate what could be the future price of the operational and capital expenses if the GHG emissions they cause are reflected in their price: That their external climate costs are integrated into their price. Figure 2 illustrates how the cost per unit of CO_2 avoided decrease as the CO_2 concentration in the flue gas (the exhaust into the capture process) increase. The grey part is what is captured with a regular techno-economic assessment. The black part illustrates what could potentially be added if the GHG emissions caused by the capital and operational expenses of the capture process are reflected in their price.

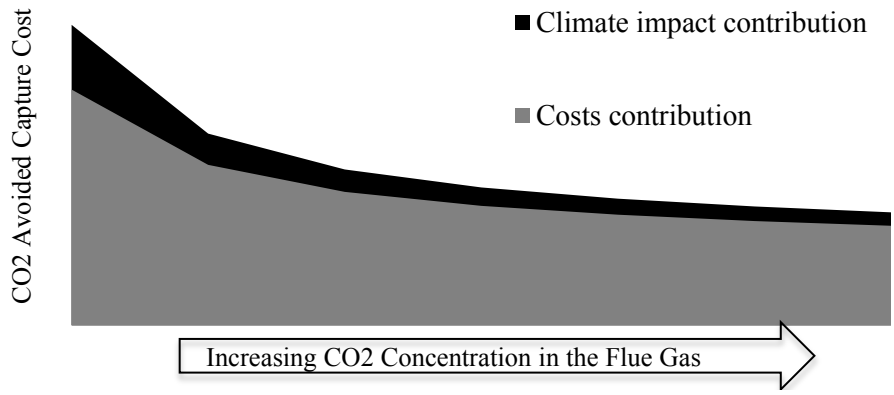

Figure 2 Illustration of the cost per unit of CO2 avoided with post amine capture for increasing CO2 concentration in the flue gas (Roussanaly, Brunsvold, et al., 2013).

DISCUSSION

Decision makers among energy producers and CCS technology developers have welcomed the model. New case studies are now being planned: To study the use of the model and how it can expand the understanding of CCS technologies and provide applicable information.
The model and its modules and assessments are under continuous expansions and improvement. The hybrid-LCA aims at expanding the selection of environmental impacts it includes. Already water consumption is partly included (Roussanaly, Hognes, et al., 2013), but the goal is to expand to a more complete range of impact assessment methods. In this phase the availability of public environmentally expanded input-output databases are challenging. Especially it is challenging to understand how and if different databases like

ecoinvent and the Carnegie Melon database can be combined for different environmental impacts. They are not applicable for the exact same impact assessment methods, thus one might end up combining apples and bananas. Expansion of publically available environmentally expanded input output data is not within the scope of this project, but there are several promising initiatives to make such databases publically available, and hopefully in formats that makes it easier to combine them with the established process based LCA databases.

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