Life Cycle Assessment case studies of Nuclear Waste disposal and Carbon Capture & Storage

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Abstract

A Life Cycle Assessment (LCA) of selected sites for nuclear waste geological disposal and carbon capture and storage (CCS) has been realized. The Swedish concept for nuclear waste management is compared to the Swiss one, while concerning CCS, the capture and storage of excess CO_2 present in the natural gas of the Sleipner natural gas reservoir as well as the oxyfuel and post-combustion units planned in Janschwalde lignite power plant are studied. The focus lies on the determination of the Life Cycle Inventory (LCI) data. Due to lack of precise information in the available literature, assumptions had to be made in both CCS and nuclear waste management modeling. Nevertheless, the assumptions were tested in the sensitivity analysis to make sure they were not major parameters in the final result.

The comparison of LCA results is realized performing Life Cycle Impact Analysis, using the methods Eco-indicator 99 Hierarchist perspective (average set), the CO_2 equivalent method (IPCC 2007, 100 years timeframe) and the Cumulative Energy Demand (CED). The impact method significantly influences the results of the LCIA. EI99 gives a relatively high weight to fossil fuel consumption, while the IPCC method emphasizes greenhouse gases emissions weighted by their global warming potential relative to CO_2, and the last one focuses solely on the energy consumption. The IPCC method obviously gives preferential results to CCS, since it reduces greenhouse gases emissions, while CED disadvantages CCS, due to the induced additional electricity use.

Concerning nuclear waste, the Swedish concept is studied in comparison with the Swiss one for the different categories of waste, as well as the impact of waste disposal on the nuclear electricity overall impact. The Swedish nuclear electricity is modeled using the Swiss PWR and BWR models, combined with the actual Swedish ratio of these reactors. The main parameter in the Swedish nuclear waste geological disposal is the electricity required during the final repository operation, though it appears that the reprocessing step in Switzerland presents a much higher impact than all the other steps, even though realized only during 40 of the 60 years of power plant operation modeled. Hence the impact would be even higher for a reprocessing of the totality of the waste. This being said, the impact of nuclear waste disposal in both countries is minor compared to the overall electricity impact. One can notice that even though storing a m^3 of Swedish spent fuel has a much higher impact than storing the same amount of LILW, this is outweighed by the fact that nine times more LILW is produced for a certain quantity of nuclear electricity produced, that is to say in the end the LILW storage has a higher share in the overall electricity impact than spent fuel. On the contrary, the oxyfuel and post-combustion units in Janschwalde both represent a significant share in the overall lignite electricity impact. The post-combustion process gives a higher impact than the oxyfuel one, independently from the method used for analysis. The main factors are the electricity for CCS and thus the efficiency loss, the MEA used for post-combustion and the CO_2 capture rate. In Sleipner the key factors are similar, even if the impact of CCS on the electricity is much smaller due to a smaller ratio of kWh used for CCS over the kWh produced. When comparing the electricity from a usual lignite power plant with the electricity produced in Janschwalde, CCS presents better results with all methods except the Cumulative Energy Demand, as expected.