**TECHNOLOGY FACTSHEET**

# POST-COMBUSTION CO2 CAPTURE ADD-ON FOR POWER PLANTS - GASEOUS FUELS

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| Date of factsheet | 12-8-2020 |
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| Sector | CCS |
| ETS / Non-ETS | ETS |
| Type of Technology | CCS |
| Description | In this factsheet, a generic end-of-pipe solution to capture CO2 from power plant flue gases after the combustion of carbon-rich gaseous fuels such as natural gas, gasified solid fuels, biogas or industrial waste gases is considered. Low-carbon gases such as hydrogen are not considered. The reference technology is a combined cycle gas turbine (CCGT). Post-combustion capture is also applicable to large scale gas boilers, but these are not a core focus of this factsheet. There are different requirements for flue gas cleaning in preparation for CO2 capture (dust filters, NOx removal, sulphur scrubbers, etc.) which will influence performance and costs. The performance and costs ranges are considered to be sufficiently close for the variety of gaseous carbon-rich fuels to group them together in a single factsheet.<br><br>Post-combustion capture can be attached to an existing power plant or incorporated in the design of a new plant, the latter with potential for increased efficiency and lower total costs. The focus of this factsheet is add-on capture for a stand-alone plant, regardless of age or feedstock, and therefore does not take into account potential efficiency gains or cost reductions from integrated design of new plants.<br><br>Post-combustion CCS generally entails capture from flue gases with low CO2 concentrations. In the case of gaseous fuels, concentrations are generally below 10% (IPCC, 2005; IEAGHG, 2013). There are a variety of techniques that can be used to separate CO2 from the flue gas, including the use of sorbents/solvents, membranes and distillation machinery. Chemical solvents, such as Mono-Ethanolamine (MEA), are the most commonplace technique for post-combustion capture for power plants (IPCC 2005), therefore they are considered the default for this factsheet.<br><br>Compression and dehydration of CO2 is part of the capture process. CO2 pressure after capture varies from 8 MPa to 20 MPa in the studies cited here. At these pressure levels it is possible to transport the CO2 through low-pressure pipelines (maximum pressure of 4.8 MPa) or high-pressure pipelines (minimum of 9.6 MPa; see IPCC, 2005) with minimal additional (de)compression required. It is therefore assumed that no additional compression step is required after capture to prepare the CO2 for pipeline transport. If CO2 is transported in liquid state, then additional compression will be required. |
| TRL level 2020 | TRL 9<br>Commercial post-combustion CO2 capture solutions have been available for several decades (IPCC, 2005). As of 2019 there are two operational commercial coal power plants with post-combustion capture (Mantripragada et al., 2019). There are no CCGT plants with CCS, as the cost of CO2 abatement for CCGT+CCS is higher than for coal power plants. The same capture technology applied at coal power plants can be applied at CCGT plants as well, which makes this a mature technology also for CCGT plants. |

## TECHNICAL DIMENSIONS

| | Functional Unit | | Value and Range | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Capacity | Mton CO2/year | | 1.25 | | | | | | | | |
| | | | 0.70 | | | - | | | 1.80 | | |
| | | | **Current** | | | **2030** | | | **2050** | | |
| Potential | EU | Gton CO2 | 300.00 | | | - | | | - | | |
| | | | 300.00 | – | 300.00 | *Min* | – | *Max* | *Min* | – | *Max* |
| Market share | 0 | % | - | | | - | | | - | | |
| | | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |

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| Capacity utlization factor | - |
| Full-load running hours per year | 7,500-8,000 |
| Unit of Activity | Mton/year |
| Technical lifetime (years) | 30-40 (IPCC 2005) |
| Progress ratio | 0.93-0.98 (Rubin et al 2015b) |
| Hourly profile | No |
| Explanation | Annual capture capacity depends on many factors such as the size of power plant, capacity factors, capture rate, etc. Value and range are given here solely to give an impression of typical scale, for power plants of a common size (400-800 MW).<br><br>Capture potential is dependent on number of deployed power plants and the CO2 capture rates - and therefore difficult to assess. A potential limiting factor can be the available storage capacity, which is estimated at (at least) 300 Gton CO2 in the EU and 10,000 Gton CO2 globally (IOGP 2019).<br><br>Full-load running hours per year are determined by the power plant running hours, typically between 7,500 and 8,000 hours per year.<br><br>Progress ratio is based on Rubin et al (2015b) learning rate projections for natural gas CCGT with CCS (2-7%). No estimates are given for biobased fuels with CCS. |

## COSTS

| | |
|---|---|
| Year of Euro | 2015 |

| | Euro per Functional Unit | Current | | | 2030 | | | 2050 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Investment costs | € / kWe | 650.00 | | | 650.00 | | | 650.00 | | |
| | | 450.00 | – | 950.00 | 550.00 | – | 800.00 | 550.00 | – | 800.00 |
| Other costs per year | € / kWe | - | | | - | | | - | | |
| | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| Fixed operational costs per year (excl. fuel costs) | € / kWe | 16.00 | | | 16.00 | | | 16.00 | | |
| | | 16.00 | – | 16.00 | 16.00 | – | 16.00 | 16.00 | – | 16.00 |
| Variable costs per year | € / MWh | 2.00 | | | 2.00 | | | 2.00 | | |
| | | 1.40 | – | 2.00 | 1.40 | – | 2.00 | 1.40 | – | 2.00 |

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| Costs explanation | Costs are given in terms of additional costs per kWe of power production capacity, such as additional costs for flue gas preparation and the amine CO2 capture plant. The investment and operational costs of the existing plant are not included.<br>Natural gas CCGTs are used as reference plant. Any additional flue gas cleaning steps required to prevent rapid degradation of the solvent when using other gaseous fuels will increase the costs. If the (bio)gas used is fed into the CCGT at natural gas standards, the costs of capture are likely to be the same as for natural gas CCGTs.<br>Additional investments are mostly investments for CO2 capture and compression (IEAGHG, 2012). Additional fixed O&M costs include additional maintenance costs for the CO2 capture and compression units (IEAGHG, 2012). Variable O&M costs include additional chemicals, cooling water fee and waste disposal costs (ZEP, 2011; IEAGHG, 2012). The evolution of solvent and waste disposal costs contains high levels of uncertainty (ZEP, 2011).<br>For natural gas CCGTs with post-combustion costs per ton CO2 captured reported range between 30-65 €/ton (IPCC, 2005; Rubin et al. 2015a). For the same CCGTs the cost of avoided CO2 is reported in the range of 35-95 €/ton CO2 avoided (IPCC, 2005; Rubin et al. 2015a; IEA, 2013; ZEP, 2011). Note that all these sources report costs for new natural gas plants with CCS. The cost of add-on CCS is expected to be higher due to project specific costs, such as construction challenges due to limited space, integration of existing plant with new capture plant and lower economies of scale at smaller existing plants (Rubin et al. 2015a). |

| ENERGY IN- AND OUTPUTS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Energy carrier** | **Unit** | **Current** | | | **2030** | | | **2050** | | |
| Energy carriers (per unit of main output) | *Main output:* Electricity | PJ | | -1.00 | | | - | | | - | |
| | | | -1.00 | – | -1.00 | *Min* | – | *Max* | *Min* | – | *Max* |
| | Electricity | PJ | | 1.08 | | | - | | | - | |
| | | | 1.07 | – | 1.09 | *Min* | – | *Max* | *Min* | – | *Max* |
| | Heat | PJ | | 0.08 | | | - | | | - | |
| | | | 0.07 | – | 0.09 | *Min* | – | *Max* | *Min* | – | *Max* |
| | | PJ | | - | | | - | | | - | |
| | | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| Energy in- and Outputs explanation | The energy penalty for CO2 capture is estimated at 13-18% (% more input/MWh) (Rubin et al., 2015a; IPCC, 2005; IEA, 2013). Additional energy is required as electricity for pumps and compression and as heat, mostly for the regeneration of the solvent used for CO2 capture. The ratio of additional electricity and heat required depends on the plant design. It is here assumed that 50% of additional energy requirement is electricity and 50% heat (based on IEAGHG, 2013).<br>The additional heat and electricity required for capture is approximately 0.46 MWh/ton CO2 captured, half of which heat and half electricity (IEAGHG, 2013). | | | | | | | | | | |

| MATERIAL FLOWS (OPTIONAL) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Material** | **Unit** | **Current** | | | **2030** | | | **2050** | | |
| Material flows | | | | - | | | - | | | - | |
| | | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| | | | | - | | | - | | | - | |
| | | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| Material flows explanation | | | | | | | | | | | |

| EMISSIONS (Non-fuel/energy-related emissions or emissions reductions (e.g. CCS) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Substance** | **Unit** | **Current** | | | **2030** | | | **2050** | | |
| Emissions | CO2 | ton/MWhe | | -0.29 | | | - | | | - | |
| | | | -0.32 | – | -0.29 | *Min* | – | *Max* | *Min* | – | *Max* |
| | | | | - | | | - | | | - | |
| | | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| | | | | - | | | - | | | - | |
| | | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| | | | | - | | | - | | | - | |
| | | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| Emissions explanation | The inclusion of CCS reduces CO2 emissions from a plant. Reference is a natural gas CCGT plant, with 83-88% capture rate (Rubin et al., 2015a). CO2 emissions from the flue gas before capture (including CO2 emission from additional fuel consumed due to CO2 capture) ranges from 0.35-0.65 ton CO2/MWh (Rubin et al., 2015a; IEAGHG, 2013). Emissions to the atmosphere after capture are 0.04-0.14 ton CO2/MWh (Rubin et al., 2015a; IEAGHG, 2013; JRC, 2014).<br>Emissions without CCS are in the range of 0.34-0.37 ton/MWh (Rubin et al., 2015a; JRC, 2014). | | | | | | | | | | |

| OTHER | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **Current** | | | **2030** | | | **2050** | | |
| Capture rate | % CO2 captured | | 0.90 | | | - | | | - | |
| | | 0.85 | – | 0.95 | *Min* | – | *Max* | *Min* | – | *Max* |
| Solvent consumption | kg/ton CO2 | | 0.90 | | | - | | | - | |
| | | 0.20 | – | 1.60 | *Min* | – | *Max* | *Min* | – | *Max* |
| | | | - | | | - | | | - | |
| | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| | | | - | | | - | | | - | |
| | | *Min* | – | *Max* | *Min* | – | *Max* | *Min* | – | *Max* |
| Explanation | According to Rubin et al. (2015), there have not been significant developments in CO2 capture rates since the IPCC Special Report on CCS from 2005, which reported a range of 85-95% at the time. Some reports indicate that higher capture rates are technically and economically feasible in some specific applications (IEAGHG 2014).<br><br>The performance of solvents declines over time and therefore requires replacement and recovery. This leads to the consumption of solvent of 0.2-1.6 kg/ton CO2 captured (IPCC, 2005). | | | | | | | | | |

**REFERENCES AND SOURCES**


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