TECHNOLOGY FACTSHEET

PRE-COMBUSTION CO2 CAPTURE ADD-ON FOR POWER PLANTS - SOLID FUELS

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Sector	CCS
ETS / Non-ETS	ETS
Type of Technology	CCS
Description	In this factsheet a generic solution to capture CO2 before combustion of solid fuels such as coal, solid biomass or municipal solid waste (MSW) in power plants is considered. Reference technology is integrated gasification combined cycle (IGCC) plant, where syngas (a mix between CO, CO2 and H2) is produced from which CO2 can be captured before the syngas is combusted in a combined cycle plant. Depending on the fuel used, there are different requirements for syngas cleaning in preparation for CO2 capture (dust filters, NOx removal, sulphur scrubbers, etc.), which will impact performance and costs. The performance and cost ranges are considered to be sufficiently close for the variety of solid fuels to group them together in a single factsheet. The focus of this factsheet is solely on CCS for IGCC plants. The reference is IGCC plants without CCS and all reported data is relative to the reference plant (e.g. investment costs are additional costs for CCS and exclude investment costs for the IGCC plant, such as the gasification unit). There are a variety of techniques that can be used to separate CO2 from the syngas, including using sorbents/solvents, membranes and distillation machinery (IEA, 2013). After gasification the CO2 concentration in the syngas is 8-20 %, which is potentially higher than the concentration after combustion (12-14%) (IPCC, 2005). Physical solvents, such as Selexol, are the most commonplace technique for pre-combustion capture for IGCC power plants (Rubin et al., 2015a), therefore they are considered the default for this factsheet. Similar to chemical solvents, CO2 is attached to the physical solvents in an absorber after which the solvents are separated and regenerated using steam to release the CO2 and enable reuse of the solvent (IEAGHG, 2014a). Compression and dehydration are part of the CO2 capture process. Reports on CO2 pressure after capture vary 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) (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
TRL level 2020	TRL 9 Benchmark IGCC plants with pre-combustion CCS are reported to be TRL 9, even though there are several lower TRL options that can improve performance but require further development (IEAGHG, 2014b). The capture technology is similar to processes used in ammonia production, a well established process (IEAGHG, 2014b).

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	Mton CO2/year		4.00								
			3.00			-			6.00		
Potential	EU	Gton CO2	Current			2030			2050		
			300.00			-			-		
			300.00	–	300.00	*Min*	–	*Max*	*Min*	–	*Max*
Market share	0	%	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Capacity utlization factor	-										
Full-load running hours per year	7,500.00										
Unit of Activity	Mton/year										
Technical lifetime (years)	30-40 (IPCC 2005)										
Progress ratio	0.8-0.975 (Rubin et al 2015b)										
Hourly profile	No										

Explanation	Annual capture capacity depends on many factors such as type of feedstock (more CO2 in flue gas of coal power plant than natural gas power plant), size of power plant, capture rate, etc. Value and range given here are solely to give an impression of typical scale, for power plants of a common size (500 MW - 1 GW). 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). Full-load running hours per year are determined by the power plant running hours, typically aroun 7,500 hours per year. Progress ratio is based on Rubin et al (2015b) learning rate projections of 2.5-20% for coal IGCC with CCS. No estimates are given in the study for biomass with CCS.

COSTS

	Euro per Functional Unit	Current			2030			2050		
Year of Euro	2015									
Investment costs	€ / kWe	1,150.00			1,350.00			1,350.00		
		850.00	–	1,600.00	1,200.00	–	1,600.00	1,200.00	–	1,600.00
Other costs per year	€ / kWe	-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Fixed operational costs per year (excl. fuel costs)	€ / kWe	57.50			56.00			56.00		
		57.50	–	57.50	56.00	–	56.00	56.00	–	56.00
Variable costs per year	€ / MWh	1.00			1.00			1.00		
		0.50	–	1.20	0.50	–	1.20	0.50	–	1.20

Costs explanation	Costs are given in terms of additional costs per kWe of power production capacity, such as the CO2 capture unit. The investment and operational costs of the existing plant are not included. The reference plant is a coal or lignite IGCC plant without CCS. Costs based on coal and lignite IGGC plants with pre-combustion CCS as there is more data available on these types of plants than other solid fuel plants. Costs for biomass and MSW are expected to be higher than average costs for coal and lignite plants due to additional requirements for flue gas cleaning (e.g. SOx and NOx removal) to prevent rapid solvent degradation. It was not possible to clearly identify what the additional costs consist of, as some sources do not elaborate and others compare costs to pulverised coal plants and not IGCC. Additional investment costs at least include CO2 compression unit (IEAGHG, 2014a). Additional fixed O&M costs are expected to include additional maintenance costs, labour costs, insurance costs and taxes (IEAGHG, 2014a). Variable O&M costs include additional costs for chemicals and catalysts (ZEP, 2011; IEAGHG, 2014a). Costs per ton CO2 captured are estimated by Rubin et al. (2015a) at 21-31 €/ton. Costs per avoided ton CO2 generally range from 28-44 €/ton CO2 (Rubin et al. 2015a, IEA, 2013; ZEP 2011). IEAGHG (2014a) reports significantly higher CO2 avoidance costs: 70-75 €/ton CO2. Some sources use supercritical pulverised coal plants without CCS as a reference instead of IGCC without CCS, which are less costly and therefore lead to a higher calculated cost of avoided CO2. Note that all these sources report costs for new coal-fired IGCC power 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	1.10			-			-		
			0.18	–	1.14	*Min*	–	*Max*	*Min*	–	*Max*
	Heat	PJ	0.10			-			-		
			0.10	–	0.18	*Min*	–	*Max*	*Min*	–	*Max*
		PJ	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Energy in- and Outputs explanation	The energy penalty for CO_2 capture is estimated at 20-35% (% more input/MWh) (Rubin et al. 2015; IPCC, 2005; IEA, 2013). The energy penalty for IGCC plants with CCS is partially determined by energy required to operate pumps and compressors and the regeneration of the solvent. In addition to that there is a potential loss in power output due to changes in the performance of the plant (Rubin et al., 2015a; IEAGHG, 2014b). It is assumed half the required energy is electric energy for compression and pumps and half is heat for the thermal regeneration of solvents. Additional energy required for capture and compression are estimated to be 0.17-0.3 MWh/ton CO_2 captured, based on Rubin et al. (2015a) data.										

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	CO_2	ton/MWh	-0.90			-			-		
			-1.10	–	-0.75	*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 CO_2 emissions from a plant. Reference is a supercritical pulverised coal power plant with no CCS. A 80-90% CO_2 emissions reduction is assumed (Rubin et al., 2015a). CO_2 emissions from flue gas before capture (including CO_2 from additional fuel use for energy required for CO_2 capture) ranges from 0.85-1.25 ton CO_2/MWh (Rubin et al., 2015a; JRC, 2014). Emissions to the atmosphere after capture are 0.09-0.28 ton CO_2/MWh (Rubin et al., 2015a; JRC, 2014). Emissions in coal IGCC plants without CCS are in the range of 0.75-0.9 ton/MWh (Rubin et al. 2015a; JRC, 2014; Manrtipragada, 2019)										

OTHER

Parameter	Unit	Current			2030			2050		
Capture rate	% CO_2 captured	0.85			-			-		
		0.80	–	0.90	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Explanation	Some reports indicate higher capture rates are technically and economically feasible in some specific applications (IEAGHG 2014b).									

REFERENCES AND SOURCES

IEA (2013) - Technology Roadmap: Carbon Capture and Storage

IPCC (20015); Kelly, Thambimuthu, Soltanieh, Abanades et al - Special Report on Carbon dioxide Capture and Storage

Rubin, Davison and Herzog (2015a) - The cost of CO_2 capture and storage

IEAGHG (2014a) - CO_2 capture at coal based power and hydrogen plants

IEAGHG (2014b) - Assessment of Emerging CO_2 Capture Technologies and their Potential to Reduce Costs

IOGP (2019) - The Potential for CCS and CCU in Europe

Rubin, Azevedo, Jaramillo and Yeh (2015b) - A review of learning rates for electricity supply technologies

JRC (2014) - Energy Technology Reference Indicators

ZEP (2011) - The cost of CO_2 capture

Mantripragada, Zhai and Rubin (2019) - Boundary dam or Petra Nova - Which is a better model for CCS energy supply?