TECHNOLOGY FACTSHEET

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OXYFUEL COMBUSTION CO2 CAPTURE 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 from flue gases after the combustion of solid fuels such as coal, solid biomass and municipal solid waste (MSW) mixed with high purity oxygen in power plants is considered. The combustion with high purity oxygen makes for a high concentration of CO2 in the flue gas (>80%), from which the remaining water vapour is removed by cooling and compressing the gas stream resulting in high purity CO2 (IPCC, 2005). The main cost component is therefore not in the CO2 capture, but in the cryogenic air separation for oxygen production. There may be different requirements for flue gas cleaning depending on the fuel used (dust filters, NOx removal, sulphur scrubbers, etc.) which will influence 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 one factsheet. The focus of this factsheet is solely on oxyfuel combustion CCS at power plants operating on solid fuels. Solid fuel power plants without CCS are used as a reference (super)critical coal/lignite, solid biomass power plant, etc.) and all reported data is relative to the reference plants (e.g. investment costs are additional costs for oxygen production and carbon capture, the reported data does not include investment costs for the power plant itself). Plants can be retrofitted with oxyfuel CCS technology (JRC, 2014). Compression and dehydration are part of the CO2 capture process. Reports on CO2 pressure after capture vary from 11 MPa to 15 MPa (Rubin et al., 2015a; IPCC, 2005). 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) without any additional compression required. If CO2 is transported in liquid state, then additional compression will be required. Transport by pipeline is considered the default option and compression costs and energy requirements are therefore not included in the factsheet.
TRL level 2020	TRL 7 Oxyfuel power pilot plants with thermal power of 15 and 30 MWth are being tested. Cryogenic air separation units are a mature technology. (Kotowicz et al., 2019; IEAGHG, 2014a)

TECHNICAL DIMENSIONS

Capacity	Functional Unit		Value and Range								
	Mton CO2/year		3.90								
			3.00			-			5.50		
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	7,500-8,000										
Unit of Activity	Mton/year										
Technical lifetime (years)	30-40 (IPCC 2005)										
Progress ratio	0.99-0.80 (Rubin et al 2015b)										
Hourly profile	No										

Explanation

Annual capture capacity depends on many factors such as size of power plant, capture rate, etc. Value and range given here are for oxyfuel coal power plants (500MW-1GW (ultra)supercritical pulverised coal plants) to give an impression of typical scale. Smaller solid biomass and MSW plants will have lower capacity.

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 between 7,500 and 8,000 hours per year.

Progress ratio is based on Rubin et al (2015b) projections for coal power plants (pulverised coal and IGCC). No estimates are given in the study for oxyfuel power plants.

COSTS

Year of Euro	2015									
	Euro per Functional Unit	Current			2030			2050		
Investment costs	€ / kWe	1,300.00			950.00			950.00		
		1,100.00	–	2,000.00	650.00	–	1,200.00	650.00	–	1,200.00
Other costs per year	€ / kWe	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max
Fixed operational costs per year (excl. fuel costs)	€ / kWe	28.00			24.00			24.00		
		28.00	–	28.00	24.00	–	24.00	24.00	–	24.00
Variable costs per year	€ / MWh	0.48			0.48			0.48		
		0.32	–	0.64	0.32	–	0.64	0.32	–	0.64

Costs explanation

Costs are given in terms of additional costs per kW of power production capacity. The investment and operational costs of the existing plant are not included.
Data is based on (pulverised) coal-fired power plants, as there is more data on oxyfuel CCS costs available for these than for biomass or MSW plants. Costs for solid biomass and MSW are expected to be similar as a large portion of the costs are for the cryogenic air separation unit (approximately 60% of additional costs) (IEAGHG, 2014b). Besides the air separation unit, additional investments are required for a CO2 purification unit and additional costs for the power cycle and utility units (IEAGHG, 2014b). Additional fixed O&M costs include higher maintenance costs, labour costs, admin, insurance and taxes (IEAGHG 2014b). The variable O&M costs are not much higher than the reference plant because oxyfuel technology does not require additional chemicals, cooling water, etc. (ZEP, 2011).
Rubin et al. (2015a) report costs per ton CO2 captured ranging between 27-51 €/ton. Reports on costs per avoided ton CO2 range between 30-64 €/ton CO2 for new power plants (IPCC, 2005; Rubin et al. 2015a; IEA, 2013; ZEP 2011, IEAGHG, 2014b) and between 33-68 €/ton avoided CO2 for retrofits (IPCC, 2005). The cost of add-on or retrofit CCS is generally higher due to project specific costs, such as construction challenges due to limited space, integration of the existing plant with the new CO2 capture plant and lower economies of scale at smaller existing plants (Rubin et al. 2015a).

ENERGY IN- AND OUTPUTS

Energy carriers (per unit of main output)	Energy carrier	Unit	Current			2030			2050		
	Main output: Electricity	PJ	-1.00			-			-		
			-1.00	–	-1.00	Min	–	Max	Min	–	Max
	Electricity	PJ	1.33			-			-		
			1.30	–	1.43	Min	–	Max	Min	–	Max
		PJ	-			-			-		
			Min	–	Max	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 23-30% (% more input/MWh; see Rubin et al, 2015; IPCC, 2005; IEA, 2013). Here, it is indicated as additional electricity required for the cryogenic air separation unit and CO2 compression unit. Additional electricity demand is approximately 0.35 MWh/ton CO2 captured (IEAGHG, 2014b).

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		-0.92			-			-	
			-1.00	–	-0.82	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 supercritical pulverised coal (SCPC) power plant with no CCS. 90-98% CO2 reduction assumed (Rubin et al., 2015a). CO2 from flue gas before capture (including CO2 from additional fuel consumed due to CO2 capture) ranges from 0.92-1.10 ton CO2/MWh (Rubin et al., 2015a; IEAGHG, 2014b). Emissions to the atmosphere after capture are 0.02-0.30 ton CO2/MWh (Rubin et al., 2015a; JRC, 2014; IEAGHG, 2014b). Emissions for a SCPC plant without CCS are in the range of 0.75-0.9 ton/MWh (Rubin et al. 2015a; JRC, 2014; Mantripragada, 2019; IEAGHG, 2014b).										

OTHER										
Parameter	Unit	Current			2030			2050		
Capture rate	% CO2 captured		0.92			-			-	
		0.90	–	0.98	Min	–	Max	Min	–	Max
Solvent consumption			-			-			-	
		Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-	
		Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-	
		Min	–	Max	Min	–	Max	Min	–	Max
Explanation	Oxyfuel plants are, in principle, able to capture nearly all of the CO2 produced. However, the need for additional gas treatment systems to remove pollutants such as sulphur and nitrogen oxides lowers the level of CO2 captured to slightly more than 90% (IPCC, 2005).									

REFERENCES AND SOURCES

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