TECHNOLOGY FACTSHEET

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OXYFUEL COMBUSTION CO2 CAPTURE FOR POWER PLANTS - GASEOUS FUELS

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Author	Sam Lamboo
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 gaseous carbon-rich fuels such as natural gas or biogas mixed with high purity oxygen in power plants is considered. Low-carbon gases such as hydrogen are not 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 gaseous carbon-rich fuels to group them together in one factsheet. The focus of this factsheet is solely on oxyfuel combustion CCS at power plants operating on gaseous fuels. The reference power plant is a combined cycle gas turbine (CCGT) without CCS and all reported data is relative to it (e.g. investment costs are additional costs for equipment suitable for high combustion temperatures, oxygen production and carbon capture, which means that 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 is part of the CO2 capture process. CO2 pressure after capture is around 11 MPa (IEAGHG, 2015). At this pressure 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) 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 5 Oxyfuel CCGT plants are less developed than oxyfuel plants for solid fuels such as coal (IEAGHG, 2014). Cryogenic air separation units are a mature technology. (Kotowicz et al., 2019; IEAGHG, 2014).

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	Mton CO2/year		2.20								
			2.20			-			2.20		
			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

Capacity utlization factor	-
Full-load running hours per year	7,500-8,000
Unit of Activity	Mton/year
Technical lifetime (years)	25 (IEAGHG, 2015)
Progress ratio	0.98-0.93 (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 given here is compatible with a typical oxyfuel CCGT plant (~750 MW). Smaller (bio)gas CCGT plants will have lower capacity. Capture potential is dependent on the 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) learning rate projections for natural gas CCGT with post-combustion CCS (2-7%). No estimates are given for oxyfuel plants. As oxyfuel plants are less developed than post-combustion CCS (TRL 9) it can be expected that oxyfuel CCGT plants can have higher learning rates, despite the technological maturity of air separation units which represent the largest cost factor.

COSTS

Year of Euro	2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	€ / kWe	1,050.00			-			-		
		860.00	–	1,150.00	Min	–	Max	Min	–	Max
Other costs per year	€ / kWe	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max
Fixed operational costs per year (excl. fuel costs)	€ / kWe	36.75			-			-		
		30.10	–	40.25	Min	–	Max	Min	–	Max
Variable costs per year	€ / MWh	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max

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. Additional investments compared to an air-blown CCGT include an air separation unit, a CO2 purification unit and additional costs for the power cycle and utility units (IEAGHG, 2015). Additional fixed O&M costs include higher maintenance costs, labour costs, admin, insurance and taxes (IEAGHG 2015). Data is based on oxyfuel CCGT plants, as there is more data on oxyfuel CCS costs available for these than for biogas plants. Costs for biogas are expected to be similar as a large portion of the costs lie in the cryogenic air separation unit (approximately 60-65% of additional investment costs compared to a air blown CCGT (IEAGHG, 2015)). Fixed O&M costs are estimated at 3.5% of additional investment costs, based on IEAGHG (2015). The corresponding cost of avoided CO2 is 60-95 €/ton (IEAGHG, 2015).

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	1.30			-			-		
			1.25	–	1.33	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 20-25% (IEAGHG, 2015). Here, it is indicated as additional electric power required for the cryogenic air separation unit and CO2 purification and compression unit. Additional electricity required for CO2 capture is an estimate of 0.73-0.84 MWh/ton CO2 captured (IEAGHG, 2015).

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		-0.35			-			-	
			-0.38	–	-0.33	*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 power plant with no CCS. A 90-98% CO2 reduction is assumed (IEAGHG 2015). CO2 emissions from flue gas before capture (including CO2 from additional fuel consumed due to CO2 capture) ranges from 0.37-0.42 ton CO2/MWh (IEAGHG, 2015). Emissions to the atmosphere after capture are about 0.04 ton CO2/MWh (IEAGHG, 2015). Emissions for a CCGT plant without CCS are in the range of 0.34-0.37 ton/MWh (Rubin et al., 2015a; JRC, 2014; IEAGHG, 2015).										
OTHER											
Parameter	Unit		Current			2030			2050		
Capture rate	% CO2 captured			0.90			-			-	
			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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