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Gas cleaning challenges for coal-fired oxy-fuel technology with carbon capture and storage

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ABSTRACT

As one of the three major carbon capture technologies associated with carbon capture and storage (CCS), oxy-fuel technology is currently undergoing rapid development with a number of international demonstration projects commencing in the progression towards commercialisation. The CO_2 gas quality from oxy-fuel differs from pre- and post-combustion technologies, having higher levels of inert gases, oxygen, sulphur and nitrogen gases and other impurities such as mercury in the flue gas. Operations are available for adjusting gas quality, in the furnace, and by cleaning and treating flue gas with further removal of impurities during compression. Thus, knowledge of the impact of gas quality on power plant and materials, on transport systems and also gas quality regulations for storage is required, as the cost of gas cleaning is likely to be more significant for oxy-fuel than for other carbon capture technologies. The gas cleaning challenges are identified, with examples of two issues, one being the impact of sulphur impurities, and the other being gas quality impacts and control influencing CO_2 compression.

1. Introduction

Reduction of greenhouse gas emission from coal-fired power generation can be achieved by efficiency improvement, switching to lower carbon fuels and CO_2 capture and storage (CCS). There are several options for capture and storage of CO_2 from coal combustion and gasification [1], including:

- Post-combustion capture: CO_2 capture from conventional pulverised coal-firing plant with scrubbing of the flue gas by chemical solvents, solid minerals, etc.
- Pre-combustion capture: Integrated gasification combined cycle (IGCC) with a shift reactor to convert steam and CO to make H_2 (a fuel) and CO_2 (that can be stored).
- Oxy-fuel combustion: Combustion in oxygen rather than air, with recycled flue gas.

Conventional pf coal-fired boilers, i.e., currently being used in power industry, use air for combustion in which the nitrogen from the air (approximately 79% by volume) dilutes the CO_2 concentration in the flue gas. During oxy-fuel combustion, a combination of oxygen (typically of greater than 95% purity) and recycled flue gas is used for combustion of the fuel. A gas consisting mainly of CO_2 and water vapour is generated with a concentration of CO_2 that can be purified if required for sequestration. The recycled flue gas is used to control flame temperature and make up the volume of the missing N_2 to ensure there is enough gas to carry the heat through the boiler. Fig. 1 details the unit operations associated with the technology.

The projected development of oxy-fuel technology for first-generation plant [2] is projected to 2025 in Fig. 2, this using an ASU for oxygen supply, standard furnace designs with externally recirculated flue gas, and limited thermal integration of the ASU and compression plant with the power plant. This includes the currently announced pilot-scale and industrial scale plant and demonstrations with and without CCS.

In Fig. 2, gas quality is listed as an early research and regulation issue. The CO_2 gas quality from oxy-fuel differs from pre- and post-combustion technologies, having higher levels of inert gases, oxygen, sulphur and nitrogen gases and other impurities in the flue gas, as given in Table 1. Thus, knowledge of the impact of gas quality on power plant and materials, on transport systems and also gas quality regulations for storage is required, as the cost of gas cleaning is likely to be more significant for oxy-fuel than for other carbon capture technologies. The high priority for gas quality R&D is due to its impact on the cost and energy penalty of CCS associated with oxy-fuel technology, which is of greater relevance to its application in Australia than in most other countries, for there is no installation for sulphur removal system at Australian power plants.

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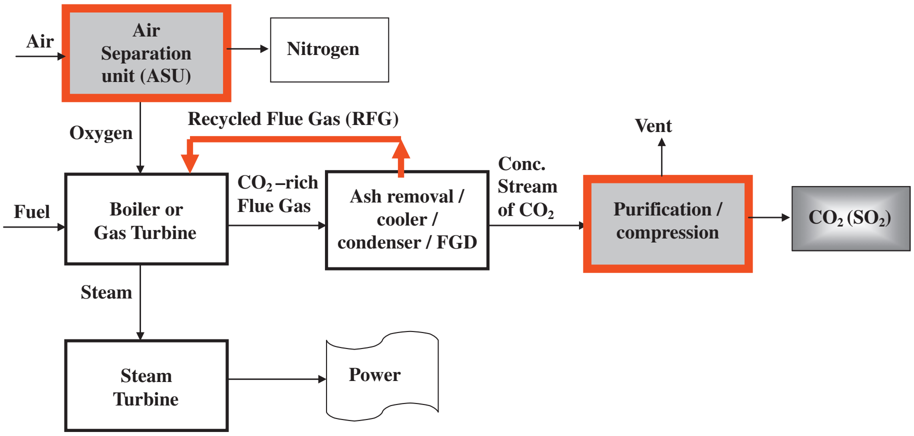

Fig. 1. Simplified flow sheet for oxy-fuel technology, showing in bold the additional operations added to a standard pf plant [1].

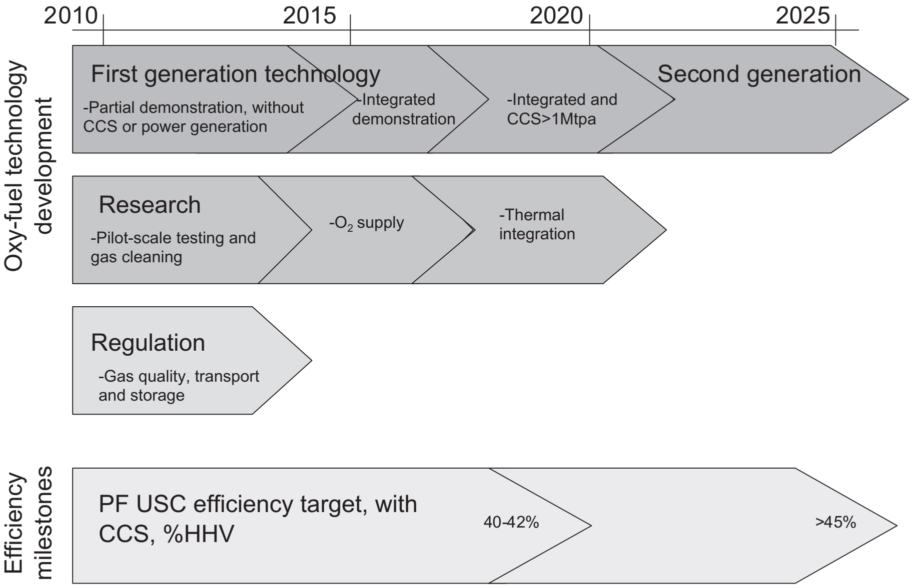

Fig. 2. Simplified roadmap for oxy-fuel technology deployment. Noted HHV% net basis efficiency in black coal-firing Ultra Super Critical (USC) plant can be higher in colder country [2].

Table 1
Illustrative CO_2 stream compositions, vol% or as stated, for coal-fired CCS technologies [3].

	Oxy-fuel combustion		Post-combustion capture		Pre-combustion capture
Gas stream	Raw flue gas prior to the CO_2 purification plant	CO_2 product	Raw flue gas prior to gas absorption by solvent [4]	CO_2 product	CO_2 product
CO_2 (%)	67	>99		>99	95–99
H_2O (%)	10			<1	<1000 ppm
Total sulphur (SO_2, H_2S, COS)	600–1800 ppm for black coal 300–900 ppm for brown coal	<200 ppm	200–600 ppm for black coal 100–300 ppm for brown coal	2 ppm	3 ppm as SO_2, H_2S, COS
Total nitrogen (NO, NO_2, NH_3, HCN, etc.)	300–700 ppm for black coal 100–200 ppm for brown coal	<200 ppm	300–700 ppm for black coal 100–200 ppm for brown coal	5 ppm	50–100 ppm as NH_3 and HCN
Hg (ug/Nm^3)	0.3–1.0	<0.1	1–10	Uncertain	Uncertain, but Hg removal common
Trace element emissions	Ppm–ppb level	Uncertain	Ppm–ppb level	Uncertain	Uncertain
Combustibles (%) (H_2, CH_4, CO, etc.)	0	Trace			0.05–0.02
Inerts (%) (N_2, Ar, etc.)	18.4		70–80	Trace	Trace
O_2 (%)	4.5		5–10	Trace	Trace