Portland energy recovery facility

Post combustion carbon capture plant pre-feasibility assessment

August 2021

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Consulting Engineers Limited

Portland ERF Post Combustion Carbon Capture Plant

Powerfuel Portland Limited

Pre-feasibility Assessment

ENGINEERING CONSULTING

Document approval

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Document revision record

Revision no	Date	Details of revisions	Prepared by	Checked by
0	03/08/2021	First issue	CAJ	SMO
1	05/08/2021	Updated following client comments	CAJ	SMO

Contents

1 Introduction

1.1 Background

Powerfuel Portland Limited (Powerfuel Portland) is developing an energy recovery facility (ERF) with the capacity to process 183,000 tonnes per year of refuse derived fuel (RDF) at the Portland Port on the Isle of Portland in Dorset. The facility will be known as the Portland ERF and will have a gross power output of 18.1 MW and will emit approximately 180,000 tonnes of carbon dioxide (tCO_2) per annum at the nominal design capacity. Given the unrecovered biogenic content of the residual waste, Government policy classifies this ERF as a partially renewable generation source.

As part of the UK's commitment to meeting its net zero target by 2050, the UK government has identified carbon capture, usage and storage (CCUS) as a key route for decarbonisation of sectors such as energy from waste (EfW)[1]. As a consequence, and consistent with its stated approach to minimise the carbon intensity of the Portland ERF, Powerfuel Portland is assessing the feasibility of integration of a post combustion carbon capture (PCCC) plant into the Portland ERF. Operation of a PCCC at the Portland ERF would provide a means of capturing approximately 95% of the CO_2 produced. The CO_2 would then be transported by ship for utilisation and/or storage offsite.

Fichtner Consulting Engineers has been engaged to carry out an initial assessment to determine the potential technical feasibility of integrating a PCCC plant with the proposed ERF.

1.2 Objectives

The primary objectives of the pre-feasibility study are as follows:

1. Identify the most suitable PCCC technology for operation at the Portland ERF;
2. evaluate the technical feasibility of integration of PCCC at the ERF; and
3. provide high level commentary on the possible capital and operating costs for the PCCC plant and the potential government support to facilitate delivery of overall commercial viability of operation of the capacity of PCCC plant identified.

1.3 Abbreviations

Abbreviation	Meaning
BEIS	Department for Business, Environment and Industrial Strategy
CCC	Climate Change Committee
CCS	carbon capture and storage
CCUS	carbon capture usage and storage
EfW	energy from waste
ERF	energy recovery facility
ICC	Industrial Carbon Capture
PCCC	post combustion carbon capture
RDF	refuse derived fuel

[1] Department for Business, Energy and Industrial Strategy, 2021: Carbon Capture, Usage and Storage - An update on the business model for Industrial Carbon Capture

2 Conclusions

2.1 Post combustion carbon capture

1. Post combustion capture of CO_2 using amine solvents has been used in the oil and gas sector for decades and is an established mature technology for the capture of CO_2 from flue gases.
2. Although PCCC technologies have a long track record in the oil and gas sector, commercial operation of these technologies on ERFs has only been demonstrated on three plants globally and none in the UK. Of these demonstration systems, the largest has a nominal capture capacity of 10 tonnes of CO_2 per day.
3. Extensive testing and development of amine solvents and the associated abatement systems for commercial deployment of amine based technologies in EfWs is ongoing by all of the major technology developers.
4. Given the significant capital and operating costs for implementation of PCCC, the Department for Business, Energy and Industrial Strategy (BEIS) is developing business models to incentivise investment in these technologies. In the absence of government support or alternative financing mechanisms, the EfW industry in the UK considers initial investment in these technologies to be prohibitive.
5. Currently, it is not a requirement of UK law or policy or planning law or policy to apply PCCC at ERFs or similar plants. Also, although the Environment Agency has issued BAT guidance on CCUS for power plants, it is not a requirement for environmental permitting.

2.2 Integration of PCCC at the Portland ERF

1. Integration of PCCC using amine solvents at the Portland ERF is technically feasible and would contribute to an increase in the R1 energy efficiency of the plant.
2. A PCCC plant with the capacity to capture 181,000 tCO_2 would occupy an area of approximately 4,000 m^2. We understand that sufficient land area is available close to the Portland ERF and Powerfuel Portland has reported that the Port landlord is supportive of providing access to the land subject to contract, to allow implementation of a PCCC plant in the future.
3. Relative to inland sites without access to a CO_2 transport pipeline, the Portland ERF has significant locational advantages given its port location as it avoids the need to transport the CO_2 by land with the associated cost, carbon impacts, and impacts on the highway network.

3 Carbon Capture and Storage

3.1 Process and technology description

In the carbon capture process, CO_2 is extracted from a mixture of gases to create a high purity CO_2 stream. The CO_2 captured can then be injected into underground formations (storage), used in the manufacture of a wide range of products including carbonated beverages, foaming plastics, and refrigerants or used as a plant growth enhancer in algae production and in commercial greenhouses. Overall, the process is referred to as carbon capture and storage (CCS).

Where the CO_2 can be used as a resource in another process the process is referred to as carbon capture, usage and storage (CCUS).

In the UK and in Europe, MSW and RDF are two of the main feedstocks used for power generation. These feedstocks contain a mixture of plant and fossil fuel derived materials which are of biogenic and non-biogenic origin respectively. Consequently, coupling of EfW plants with CCS allows for the capture of CO_2 produced from the combustion and gasification of both the biogenic and non-biogenic fractions of the waste. This means that EfW plants can become net-negative emission plants. Furthermore, for EfWs in the UK, CCS is considered by the UK government as essential to meeting the UK's 2050 net zero target[2].

To date, only three demonstration scale CCS systems have been operated on flue gas from EfW plants[3]. Of these plants, the largest has a nominal capture capacity of 10 t/day CO_2.

The major processes in CCS are:

1. separation and compression of CO_2 from a mixture of gases, which is collectively known as CO_2 capture;
2. transport of the compressed CO_2 to a storage/utilisation site; and
3. injection, measurement, monitoring and verification, which together are known as storage.

The technologies developed for carbon capture can be divided into four main categories:

1. pre-combustion;
2. post-combustion;
3. oxyfuel combustion; and
4. direct air capture (DAC).

Pre, post and oxyfuel combustion technologies all require a point source of CO_2, such as combustion of fossil fuels or biomass. A point source of combustion is not required for direct air capture systems.

Post-combustion capture is considered to be the most viable process for capture of CO_2 from power generation processes, as it provides a means for near-term capture from existing power generation and other industrial sources. It is currently the technology most widely developed and is the process which is discussed in this report for the capture of CO_2 from the Portland ERF.

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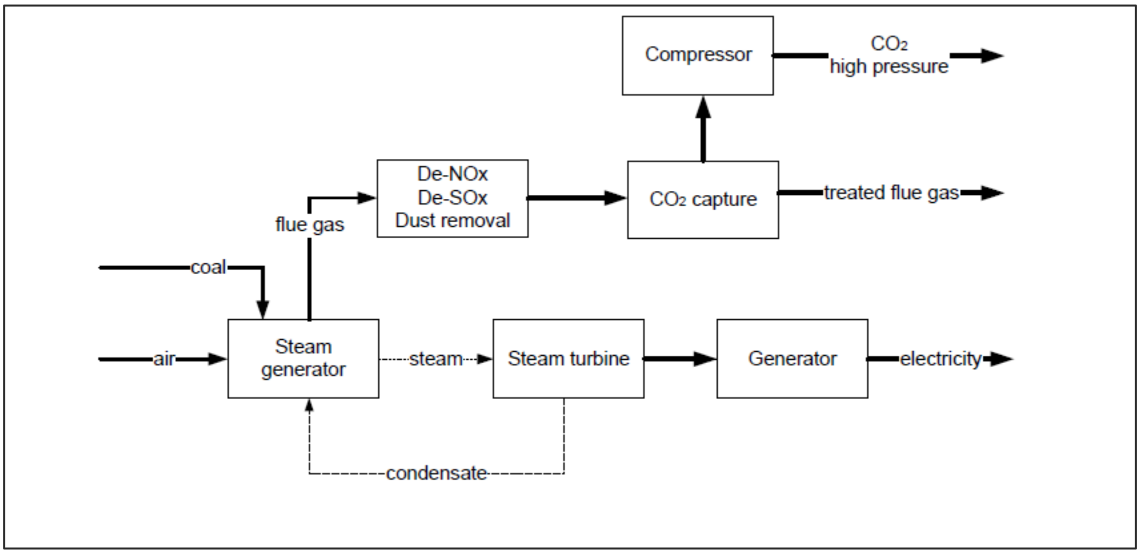
2 Department for Business Industry and Environmental Strategy 2021: Carbon Capture Usage and Storage: Amendments to Contracts for Difference Regulations page 7.

3 Larger plants have been installed on other (e.g. coal) power plants (the largest plant built to date is 3,250 t/day CO_2). The configuration of CCS plants is largely independent of the fuel used in the power plant, although there are differences in contaminants which need to be taken into account. An EfW plant in Norway, requiring a capture capacity of around 1,200 tCO_2/day has applied for European Innovation funding for construction of a full scale PCCC system. If funding is received, the plant is scheduled for completion in 2026.

3.2 Post combustion capture

Post-combustion capture refers to the capture of CO_2 from the flue gas produced from combustion of fuels. A process flow outline of the key component processes of post-combustion capture technology is illustrated below (this diagram is for a coal-fired steam generator, but the principles also apply to a waste-fired steam generator as in an EfW plant).

Figure 1: Process flow diagram of post-combustion CO_2 capture.



The main types of post-combustion capture technologies currently proposed and under investigation are as follows:

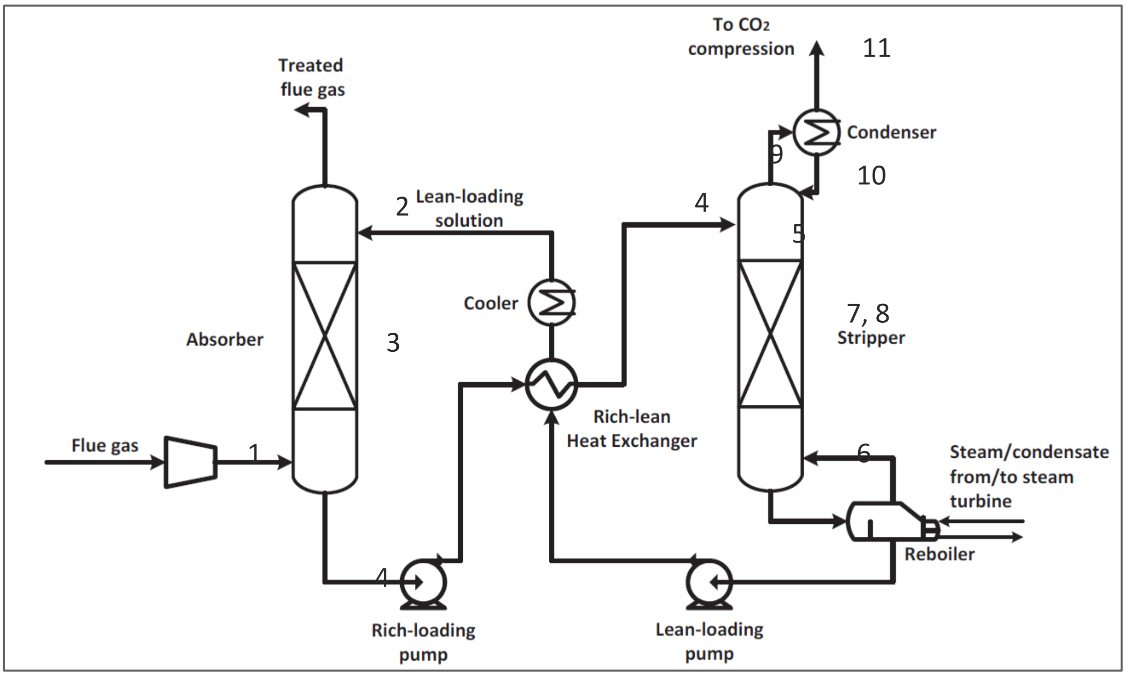
1. chemical absorption;
2. adsorption;
3. membrane separation;
4. chemical-looping combustion;
5. calcium-looping; and
6. cryogenic separation

Of these technologies, the most mature technology is chemical absorption using amine solvents, which has been used for decades in the removal of CO_2 from raw natural gas. Consequently, it is the technology which has been selected by EfW developers and operators across the globe for decarbonisation of this sector.

3.2.1 Post combustion capture using chemical absorption

In chemical absorption, a liquid sorbent is used to separate the CO_2 from the flue gas. The sorbent is then regenerated through a stripping or regeneration process by heating and/or depressurisation. The energy for regeneration is supplied by steam. Generally, 20-30% monoethanolamine (MEA, a class of alkanolamine) has been used as the primary reference solvent for chemical absorption. MEA has a high absorption efficiency for CO_2 of over 90%. A schematic outlining the process and key component systems in operation in a post-combustion capture process is shown in *Figure 2*.

Figure 2: Schematic of a basic chemical absorption process for CO_2 capture



Source: (Wang, Zhao, Otto, Robinius, & Stolten, 2017)

The process steps are numbered sequentially and occur as follows.

1. The flue gas from the EfW enters the bottom of the absorber and flows upwards.
2. The lean-loading solvent solution enters at the top of the absorber and flows downwards.
3. The counter-current flow between the flue gas and lean-loading solvent solution within the absorber results in absorption of some of the CO_2 in the flue gas into the solvent solution.
4. The solvent solution with absorbed CO_2 is called the rich-loading solution, which is pumped up to the top of the other column (known as the stripper).
5. In the stripper, the rich-loading solution flows down the column.
6. The stripping steam, generated in the reboiler, flows upwards in the stripper column.
7. This results in a counter current flow between the rich-loading solution and stripping steam.
8. The heat from the stripping steam breaks the chemical bonds between CO_2 and the solvent.
9. The CO_2 is carried up by the ascending steam towards the overhead condenser.
10. The condensed steam is directed back to the stripper as a reflux.
11. The product stream with high CO_2 purity is obtained.

4 Integration of a PCCC at the Portland ERF

4.1 Technical feasibility

Our review of the nominal design data for the Portland ERF shows that integration of PCCC at the proposed plant is technically feasible.

As there are no full scale PCCC plants in operation at EfWs, there are several key aspects of operation of PCCC systems which will need to be evaluated to ensure that the operation of the ERF is optimised. We are aware that developmental work is ongoing by all of the major carbon capture technology providers to ensure commercially viable optimised operations of integrated ERF and PCCC systems.

4.2 Portland locational advantages

The Portland ERF's location at the Portland Port offers a significant locational advantage in comparison to inland ERF sites which do not have access to pipeline transport for CO_2.

The International Energy Agency (IEA) recommends that where a PCCC plant is located close to a port, the CO_2 can be discharged directly to a liquefaction plant where it would be compressed and cooled by refrigeration before delivery to the ship[4].

Ships dedicated to the transport of CO_2 (CO_2 tankers) have been in operation since 1988, currently these tankers have carrying capacities of 1,000 m^3 (1,060 tCO_2) and are rated for medium pressure transport at 16 – 21 barg and -30°C. Tankers for the transport of liquified natural gas (LNG) have capacities ranging from 120,000 – 140,000 m^3 and it is envisaged that CO_2 tankers with similar capacities will be constructed to manage the projected global increase in transport of CO_2 due to large scale decarbonisation of the power and industrial sectors.

[4] International Energy Agency 2004; Greenhouse Gas R&D Programme Ship Transport of CO_2 – Report Number PH4/30, July 2004

5 Commercial Considerations

The capital and operating cost estimates outlined here include the capital costs for construction of a PCCC plant and compression of the CO_2 to the site boundary. It does not include any costs for the transportation and shipment of the CO_2.

Based on the projected capital and operating costs, integration of PCCC can significantly increase the development and operating costs for ERFs. Like several ERF developers, Powerfuel Portland believes that without Government support or other form of economic incentive, installation of CCS cannot be supported by existing revenues and would not be commercially viable. The estimated capital and operating costs for the CCS plant are outlined in the table below.

5.1 Cost estimates

Table 1: Estimated capital and operating costs for a PCCC plant at the Portland ERF

Parameters	Units	With 100% CCS
Estimated CCS plant capital cost	£m	70
Estimated CCS plant operating cost	£m/year	2

5.2 Eligibility criteria – BEIS Industrial Carbon Capture Model

As part of the UK government's plan to incentivise deployment of CCS in the EfW sector, BEIS is currently developing the ICC business model which outlines the commercial framework within which the contract will be managed. ICC contract holders will be paid for each tonne of CO_2 captured and transferred to a transport and storage company (T&SCo).

One of the key technical criteria proposed by BEIS for eligibility for award of an ICC contract is that the ERF will need to demonstrate that it is energy efficient through achievement of the R1 (or similar) energy recovery status. Based on the nominal design data for the Portland ERF, the facility could achieve an R1 of 0.69 which is higher than the threshold value of 0.65.

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