Deployment of bio-CCS: case study on bioelectricity

Drax Power Station, United Kingdom

Contribution of IEA Bioenergy Task 45 to the inter-task project *Deployment of bio-CCUS value chains*

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Author: Zoe M Harris, Imperial College London & IEA Bioenergy Task 45

Editor: Olle Olsson, Stockholm Environment Institute & IEA Bioenergy Task 40

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Preface

Substantial amounts of negative emissions may be required if global climate change is to be limited to well-below 2°C above pre-industrial levels, as is the ambition of the 2015 Paris Climate Agreement. Among the different negative emissions options available, bioenergy with carbon capture and storage, also referred to as bio-CCS or BECCS, is arguably one of the most commonly discussed in climate policy debates.

Up until recently, bio-CCS was primarily discussed in terms of its potential and drawbacks over very long timeframes, e.g., 2050 and beyond, but there is now growing focus on more near-term aspects. The IEA Bioenergy inter-task project *Deployment of BECCS/U value chains* runs 2019-2021 and strives to provide insights about the opportunities and challenges pertaining to taking BECCS from pilots to full-scale projects. To this end, the project puts focus not only on technological aspects but also on how BECCS business models could be set up and the role that public policy could play in enabling sustainable deployment of BECCS. Focus in the project is on the CO_2 capture, transportation and storage phases of the supply chain. Upstream biomass feedstock supply systems are only touched upon very briefly, as these issues are analyzed to great detail in other IEA Bioenergy work.

An important characteristic of BECCS is that it can be implemented in a broad range of sectors - basically any setting where there are biogenic emissions of CO_2 available in sizeable quantities. This includes generation of heat and power in various contexts, but also industrial facilities like cement production, pulp & paper mills or ethanol plants. The specifics related to BECCS implementation can however vary quite substantially from sector to sector. This is partly because of differences in technological factors like CO_2 concentrations, but also a result of how different sectors operate under widely varying commercial and regulatory conditions.

This case study is part of a series of studies carried out under the *Deployment of BECCS/U Value Chains* project with the aim to highlight these sector-specific characteristics. The case studies provide deeper insights into the key aspects that come into play for companies that are in the process of setting up value chains for capture, transportation and sequestration or utilization of biogenic CO_2.

Summary

In the past decades, partial or full substitution of biomass for coal in power stations designed for the latter have been cost-efficient and fast strategies for utilities to reduce their use of fossil fuels, while being able to avoid stranding of assets. However, with trends towards decreased subsidy levels and a rapid reduction of costs of other renewables, bioelectricity faces challenging prospects when it comes to competing on power markets.

In this context, the emerging interest in negative emissions in the form of bio-CCS could present a new market opportunity for biomass power stations. The largest currently in operation is Drax Power Station in northern England. Here, Drax operates more than 2.5 GW of generation capacity based on biomass in the form of wood pellets. With a stated ambition to become a carbon-negative company by 2030, Drax are in the process of investigating and piloting the setup of a bio-CCS value chain based on capturing CO_2 from its four biomass-fired units.

Drax has invested into two pilot projects aimed at increased understanding of how the capture process would be implemented in practice, one using a bespoke technology developed by a firm called C-Capture and one more “off-the-shelf” solution delivered by Mitsubishi Heavy Industries. Even though the scale of implementation at Drax would be well beyond what has hitherto been done with these technologies, Drax do not see any major technological obstacles to full-scale deployment of the CO_2 capture phase of the full value chain.

There are however a set of key building blocks that need to be in place to take the next step. First, there needs to be a transportation & storage infrastructure set up. Working towards this, Drax is collaborating with other actors in the Zero Carbon Humber initiative that aims to set up a CCUS cluster in the Humber region. Secondly, there needs to be a policy framework in place that allows revenue generation for companies that produce negative emissions. While Drax see that in the long-term, negative emissions would be incentivized through some sort of international emissions trading system, complementary systems - e.g., in the form of contracts-for-difference - are needed in the short-term to initiate project deployment.

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Contents

1 Introduction

1.1 COAL-TO-BIOMASS POWER STATION CONVERSIONS AND CCS

For several decades, the use of biomass-based fuels in power stations originally designed for coal has been a cost-efficient and fast way for utilities to reduce their use of fossil fuels, while still being able to utilize existing capital assets. Implementation of this approach has tended to be done in mainly two variants: co-firing or conversion. In co-firing, the biomass fuel – typically wood pellets – is pulverized and combusted together with pulverized coal. Up to a wood pellet percentage of around 15%, this can be done with only minor additional investments in e.g., fuel handling systems. Conversion on the other hand requires more extensive investments but enables the use of 100% biomass.

The repurposing of coal power stations for use with biomass as fuel has been implemented in many places around the world, including Brazil, the US and Japan, but Europe has arguably been at the center of this development (Roni et al. 2017). Rapidly decreasing costs of other forms of renewable electricity – especially wind & solar – and changed policy frameworks, has meant that both co-firing and conversion projects have begun to be of less interest to utilities in Europe. An important question moving forward is whether the added benefit of enabling negative emissions via CCS might change this development.

Currently, there are about 20 power plant CCUS projects at various stages of development globally, with one in North America) operating commercially. However, no project in commercial operation is based on co-firing nor in coal power stations retrofitted for biomass. There is however one project that aims to do the latter. UK-based Drax operates a very large power station in northern England that over the recent decade has been converted from coal to biomass and is currently exploring opportunities to implement CCS at its facility.

1.2 BIO-CCS AT DRAX: BACKGROUND

Drax Group plc is a vertically integrated energy company. This means that in addition to its electricity generation business, Drax e.g., owns three pellet mills in the Southeastern United States as well as retail operations supplying energy to a range of commercial and industrial customers. As for its generation operations, Drax owns and operates a portfolio of flexible low carbon and renewable electricity generation assets across Britain, which include pumped storage, hydro and energy-from-waste assets in Scotland. Its main generation site - Drax Power Station in North Yorkshire in England – is the UK's largest power station supplying around 5% of the country's electricity.

Drax Power Station one of the largest power stations in Europe with a total generation capacity of almost 4 GW and was originally constructed, and for many years operated as, a coal-fired power station. However, a series of investments beginning in 2013 have enabled it to use biomass instead of coal in four of its six boilers and Drax Power Station now produces around 11%% of the UK's renewable electricity.

Given the increased focus on the role of BECCS and negative emissions in reaching a net-zero target, and the fact that Drax has a well-developed biomass supply chain and the technical expertise required to develop capture technology, Drax has decided to invest heavily in the development of BECCS.

2 About Drax and the project

2.1 PLANT INFO AND CAPTURE OPTIONS

As noted in section 1, in 2013 Drax began converting its coal-firing units into solely biomass-firing units and to date (late 2020), four of six 645MW units have been converted to biomass generation. The fuel for the four units is in the form of wood pellets primarily sourced from North America. Drax utilises a number of certification schemes to ensure sustainability for wood pellets, predominantly the Sustainable Biomass Program (SBP), which builds upon the Sustainable Forest Initiative (SFI), Forest Stewardship Council® (FSC®)1 and the Programme for the Endorsement of Forest Certification (PEFC). In addition, Drax has its own sustainable biomass sourcing policy that is overseen by an independent advisory body of scientist and forestry experts.

Since subsidies for biomass power generation in the UK are due to end in 2027 (BEIS 2020), Drax has focused on reducing the costs of its biomass by around a third to £50/MWh by 2027 to ensure it can continue to operate profitably after this date. Creating a long-term future for sustainable biomass enables the development of BECCS so Drax can meet its ambition to be carbon negative by 2030.

Drax estimates that with BECCS it could capture up to 4 Mtonne CO_2 per year per Drax unit and that, subject to the right investment framework from the UK government, work to build the first two BECCS units could get underway in 2024, Drax would then be capturing up to 8MtCO_2[1], more CO_2 than is emitted, thereby make the company carbon negative by 2030. This means Drax could deliver 40% of the CCC's 2050 BECCS power target by 2030. This can be compared to the 50-60 Mt estimated as necessary for the UK as a whole (Committee on Climate Change 2019; National Grid ESO 2020; Royal Society and Royal Academy of Engineering 2018).

To date (late 2020), Drax has invested in two BECCS pilot projects. The first pilot project used a solvent developed by C-Capture to capture 1 tonne of CO_2 per day during the pilot phase. Data obtained during this pilot is currently being analysed to understand the potential of the capture technology and how it can be scaled up at Drax (Drax 2020a). This particular solution is relatively bespoke and one of the primary challenges of this solution is working out how to scale up production of the solvent to reach the level required for a full scale BECCS unit.

The second pilot has been up and running at Drax since late September 2020, running smoothly and capturing carbon. This project uses off-the-shelf technology from Mitsubishi Heavy Industries and is testing the viability of this established technology against biomass flue gases. Two solvents are being tested, KS-1 – which has been delivered at 13 commercial plants, and a newly developed KS-21 – which is designed to achieve significant performance improvements and cost-savings (Drax 2020b). According to Drax, the technology challenges are not vast when compared to other post combustion carbon capture applications. For example, compared to coal, biomass is naturally much lower in nitrogen and sulphur-based contaminants.

2.2 POST-CAPTURE OPTIONS

Drax anticipates that a CO_2 transportation and storage (T&S) network will be used to transport CO_2 from the Drax power station to a storage site under the North Sea (Endurance). The UK government is increasingly focused on the development of CCUS clusters to decarbonise industrial regions (BEIS 2021). Drax is a

[1] Note that this differs somewhat from current annual emissions from biomass generation - 12.7 MtCO_2 in 2019 - due to slightly different operational characteristics when in a BECCS setting.

founding member of the Zero Carbon Humber initiative, which aims to deploy CCUS technology across the Humber cluster – the UK's most carbon-intensive industrial cluster. This T&S network is fundamental to enable wider decarbonisation with CCUS in the region, with power stations, hydrogen producers, and industrial CCUS users all looking at the possibility of connecting. The group anticipates that up to 44MtCO_2 could be captured per year in the Humber region, fairly evenly split between industrial CCUS, hydrogen production, and BECCS. The company believes that Drax power station could be well placed to act as an anchor project for the cluster by providing the T&S network with a stable supply of CO_2.

3 Moving to deployment?

In terms of taking the step to full commercialisation, technological challenges should not be prohibitive. Furthermore, in terms of having physical room for the capture units, this should not be an issue either. There is ample available land on site at the Drax power station, which will be available for other uses such as utilisation facilities and hydrogen production facilities, including the area where the coal is stored following the end of commercial coal generation in March 2021.

However, the Drax BECCS project would require a support mechanism to cover the cost of negative emissions and supplement the revenue that the plant could get from generating renewable electricity. Here, Drax has considered a number of different policy mechanisms to support BECCS deployment, all of which attempt to account for the fact that BECCS produces two useful products – renewable power and negative emissions. Examples of possible mechanisms could be:

1. *Power Contracts for Difference (CfD)*. Under this scheme a BECCS operator would be rewarded for both low-carbon power, and negative emissions under a single power CfD price (£/MWh). This would instil investor confidence as a well understood mechanism, and could be implemented in a timely manner with limited administrative burden.

2. *Carbon payment*. Under this scheme a BECCS operator would be rewarded per tonne of carbon sequestered on a £/tCO_2 basis as rewarded through a carbon pricing regime.

3. *Power CfD + carbon payment*. This scheme is a hybrid of the two schemes. Under this scheme BECCS operators would receive a payment (£/tCO_2) for carbon sequestered, and a contract for difference (£/MWh) payment on the low-carbon power produced.

Having said this, these suggestions are likely to be more important in the short term. Drax have assumed that over the long term, a BECCS policy mechanism would transition to an enduring subsidy-free scheme – such as the inclusion of negative emissions within an emissions trading scheme, such as an EU or UK-ETS.

As noted in section 1, an important incentive for Drax to pursue its BECCS project is the 2027 phase-out of governmental subsidies for biomass-based electricity generation. Another workstream aimed at meeting the challenge of the subsidy phase-out involves reducing biomass costs down from £75/MWh to £50/MWh. These workstreams are not mutually exclusive as the £50/MWh biomass cost target applies to BECCS as well. However, the operational regimes would be different depending on which objective is prioritized. If the aim is to maximize negative emissions, baseload operations would be the appropriate modus operandi, whereas focusing on peaking operation without BECCS would be a way to take advantage of electricity price spikes.

In addition to these policy-based means of generating revenue to cover the cost of BECCS, there is emerging interest from private investors in purchasing negative emissions to offset their carbon emissions, a market that Drax expects to develop over time.

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Further Information