

Value of Biomass with Carbon Capture and Storage (BECCS) in Power

Summary Report

Drax

05 April 2021



Study Objectives and Overview

Baringa has been engaged to help Drax understand the system value of Biomass with CCS (BECCS) both within power and whole system decarbonisation, as part of meeting the UK's Net Zero targets

Questions the study addresses

Emissions

- To meet Net Zero is there significant demand for negative emissions in the energy system?
- How early do we need negative emissions?

Economics

- What is the optimal build-out and role of BECCS-Power given competing abatement options?
- How do system costs change in the absence of building BECCS-Power?

Role of Drax

- What is the role and value of the Drax-project as part of a broader need for BECCS-Power?
- How robust is the role for Drax given uncertainty around key BECCS and wider system factors?

- ▲ The focus of this engagement has been to build a primarily quantitative evidence base to understand the system value of BECCS-Power and the role of the Drax-BECCS project within this.
- ▲ Drax is considering the potential retrofit of 2 of its existing 630 MW biomass units with CCS¹, with the first unit online from 2027. Each unit has the potential to deliver 4 Mtpa of negative emissions. The project is unique as a relatively inexpensive source of negative emissions that can be deployed before 2030 and is an important first step in a wider UK BECCS programme.
- ▲ We have explored the role of BECCS-Power in driving cost-optimal energy system outcomes for the UK Net Zero targets using three scenarios: **Central**, **Downside** and **Upside**. The latter frame conditions that are less or more favourable for BECCS-Power compared to other negative emission routes, such as BECCS-Hydrogen.
- ▲ The analysis has deployed both a “**whole energy systems**” modelling lens, given the multi-sector/energy-vector nature of BECCS, as well as a “**detailed power system**” lens to explore the nuances of the specific role for BECCS-Power and the Drax BECCS-project.
- ▲ Key assumptions have been aligned to the extent possible with key UK Government and Climate Change Committee (CCC) published sources, in particular benchmarking our results with analysis seen in the recent CCC 6th Carbon Budget.

Drax already plays a major role in UK decarbonisation efforts Baringa

Conversion of the existing biomass units to BECCS is a unique opportunity to make Drax the UK's first negative emissions power station from 2027

Drax: A Vital Contribution to UK Decarbonisation

- ▲ Drax has already made a material contribution to the decarbonisation of the UK's energy system, converting four of its coal power units to biomass
 - Three of the biomass units are supported by a Renewables Obligation accreditation and the fourth by an Investment Contract
 - All four support mechanisms expire in 2027
- ▲ Drax has a unique opportunity to make another significant advance towards the UK's 2050 net-zero emissions target by adding carbon capture (CC) to its biomass units and becoming the UK's first negative emissions power station from 2027
 - Plans are progressing to add CC to two biomass units (just under 1GW). A final investment decision will be required in 2024 to achieve this
 - The capital cost of retrofitting CC at Selby is significantly lower than developing a new build Bioenergy Carbon Capture and Storage (BECCS) facility
 - As the largest CO₂ capacity project on the T&S system Drax would significantly lower the unit cost, enabling the connection of other strategically important power and industrial CC sites in the region

A unique opportunity to provide negative emissions from 2027

- ▲ Drax is looking to transition from its existing renewable biomass operations to fitting carbon capture and storage and producing negative emissions
 - Converting existing biomass units to BECCS would secure the long-term future of the site
 - A Carbon Payment + Power Contract for Difference (CfD) would underpin the necessary investment at the Selby site and enable capture of 8MTCO₂ per year – a significant contribution to the 20 to 40 MTCO₂ per year the CCC say will be required in 2050
- ▲ There is currently a window of opportunity to deliver a crucial element of the UK's decarbonisation infrastructure. Baringa has modelled the case for deploying BECCS at Drax from 2027 and shown that:
 - Achieving the net-zero target without BECCS-Power would cost the UK an additional £15bn, or £17 a year for every household
 - Not deploying Drax in 2027 would cost the UK an additional £5bn and make achieving the 5th and 6th carbon budgets significantly harder

The Drax-BECCS project is a ‘no regrets’ option



Our analysis demonstrates the Drax BECCS-Power project is a ‘no regrets’ option across a wide range of scenario conditions, enabling the UK to meet net-zero in a cost optimal manner

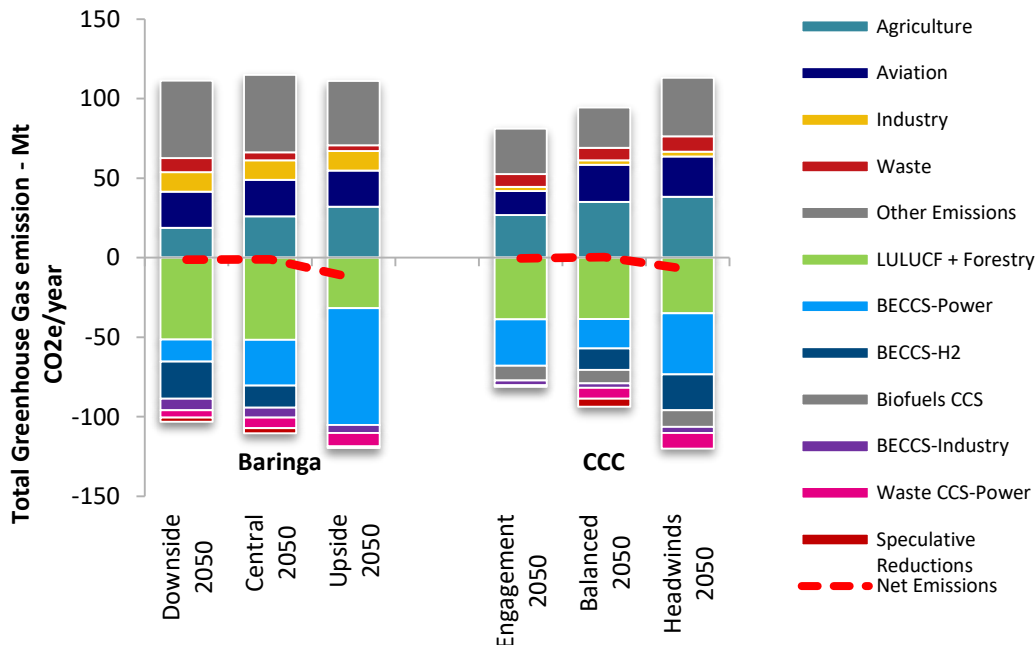
- ▲ **Negative emissions across a broad range of sectors are required at significant scale to achieve Net Zero**
 - Negative emissions are required to offset residual emissions across the economy. Engineered solutions such as BECCS-Power can make a major contribution.
- ▲ **It is cost-optimal to deploy BECCS-Power in the late 2020s**
 - Early deployment of negative emissions technologies is critical to achieving the UK’s intermediate carbon targets. Deployment of BECCS-Power before 2030 is cost-optimal in all scenarios and early deployment will enable BECCS-Power to scale up ahead of 2050.
- ▲ **BECCS-Power has a critical and significant role to play in achieving Net Zero**
 - BECCS-Power is deployed in all scenarios – with 2-10 GW of capacity in 2050 – providing 13-73 Mtpa of negative emissions. The **Downside** and **Central** cases (13-29 Mtpa) are broadly in line with the 16-39Mtpa of negative emissions from BECCS-Power suggested by the CCC, whilst the **Upside** case (73Mtpa) shows an outcome where the economics strongly favour BECCS-Power over alternative BECCS options. Running BECCS at high load factors will provide strategically important benefits, including banking negative emissions to mitigate the risk of under-performance in other sectors, while also providing a valuable source of firm, reliable negative carbon power to complement intermittent renewable technologies.
- ▲ **Achieving Net Zero will be significantly more expensive without BECCS-Power**
 - This ranges from a further £4-69bn in total discounted system costs across the pathway to 2050. In our **Central** case, without BECCS-Power, discounted system costs will be circa £15bn higher by 2050, equating to around £17 every year for each household in the UK.
- ▲ **The conversion of Drax’s existing biomass units from 2027 provides a unique opportunity to achieve low-cost negative emissions at scale**
 - Drax BECCS is deployed in all scenarios – with between 1 and 9 GW of additional new build capacity required by 2050. Without Drax BECCS, discounted system costs of achieving net zero by 2050 rise significantly, ranging from £2-6bn across the pathway.
- ▲ **While the optimum mix of negative emissions technologies in 2050 is unclear, deploying BECCS-Power in the late 2020s is “no regrets”**
 - Conversion of Drax’s existing biomass units can pave the way to a substantial programme of new build BECCS and other negative emissions technologies, such as biomass gasification to produce hydrogen with negative emissions, with the optimum pathway being refined as technologies mature and costs evolve. Drax BECCS can also provide an important “anchor project” for development of the CO2 Transmission & Storage infrastructure as part of the Humber CCS cluster. Additionally, Drax’s consistent demand for biomass can aid in the development of sustainable biomass supply chains.

Negative emissions are critical to achieving Net Zero

These are required at scale across various sectors, including engineered removals such as BECCS

Emissions

- To meet Net Zero is there significant demand for negative emissions in the energy system?
- How early do we need negative emissions?



- ▲ Negative emissions are required to offset residual emissions across the economy. Engineered solutions such as BECCS-Power can make a major contribution.
- ▲ Our analysis suggests there is very strong demand for CO₂ removals (50-90 MT CO₂e) in addition to LULUCF (Land Use, Land Use Change and Forestry) to offset residual emissions from sectors that are harder to decarbonise, e.g. agriculture, aviation and certain heavy industries.
- ▲ BECCS-Power provides a large portion of negative emissions in all cases, even in scenarios where conditions for BECCS-Power are less favourable compared to other BECCS negative emission routes.
- ▲ BECCS-H2 plays an important complementary role to BECCS-Power, and is a key biomass consumer in the Central and Downside scenarios. In both cases, BECCS-Power is added earlier in the pathway, while the need for BECCS-H2 develops later.

* "Other Emissions" consists primarily of non-agricultural land-use emission sources

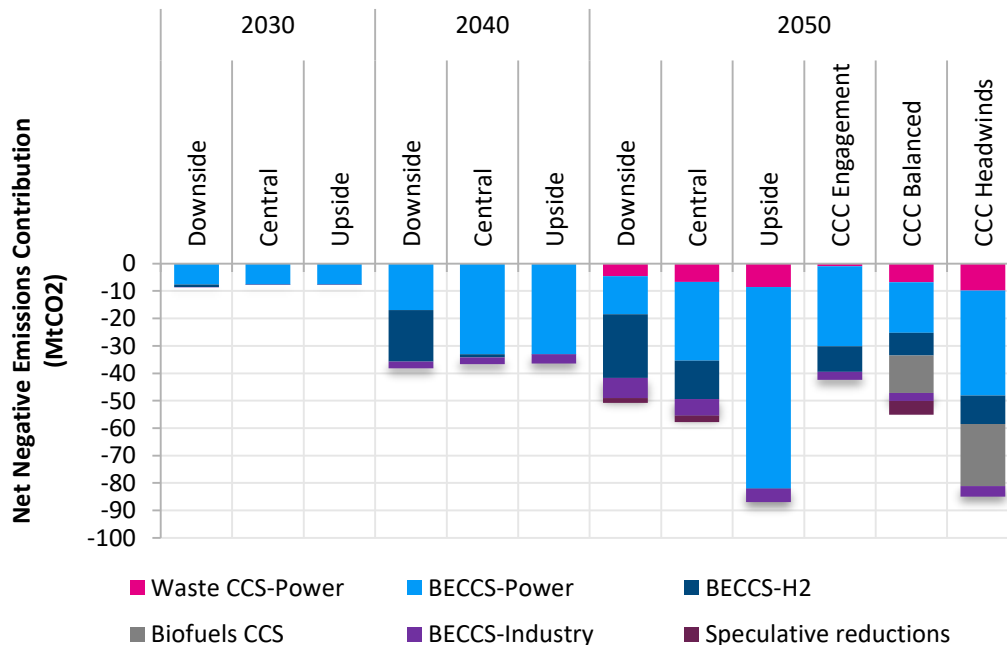
Baringa scenarios are framed by the degree to which assumptions are favourable for BECCS-Power, whereas CCC scenarios focus on different whole system pathways to Net Zero.

Deployment of BECCS is cost-effective in the late 2020s

Early deployment of negative emissions technologies is critical to achieving the UK's intermediate carbon targets across all scenarios

Emissions

- To meet Net Zero is there significant demand for negative emissions in the energy system?
- How early do we need negative emissions?



- ▲ Early deployment of negative emissions technologies is critical to achieving the UK's intermediate carbon targets. Deployment of BECCS-Power before 2030 is cost-optimal in all scenarios and early deployment will enable BECCS-Power to scale up ahead of 2050.
- ▲ This is necessary if the UK is to reach both its intermediate targets (e.g. 68% reduction in overall emissions by 2030) and Net Zero by 2050 in a cost-effective manner. To achieve this, significant investment in and support for BECCS will need to be undertaken. This is consistent with the key messages in the CCC's recent 6th Carbon Budget publication.
- ▲ Deployment of BECCS-Power in the late 2020's is integral to meeting the targets in the Fifth Carbon Budget. In all scenarios, it is cost-optimal to deploy BECCS-Power in the late 2020s. The total gross removals from BECCS-Power is 8 MTpa in 2030, growing to 16-33 MTpa in 2040, and 13-73 MTpa in 2050.

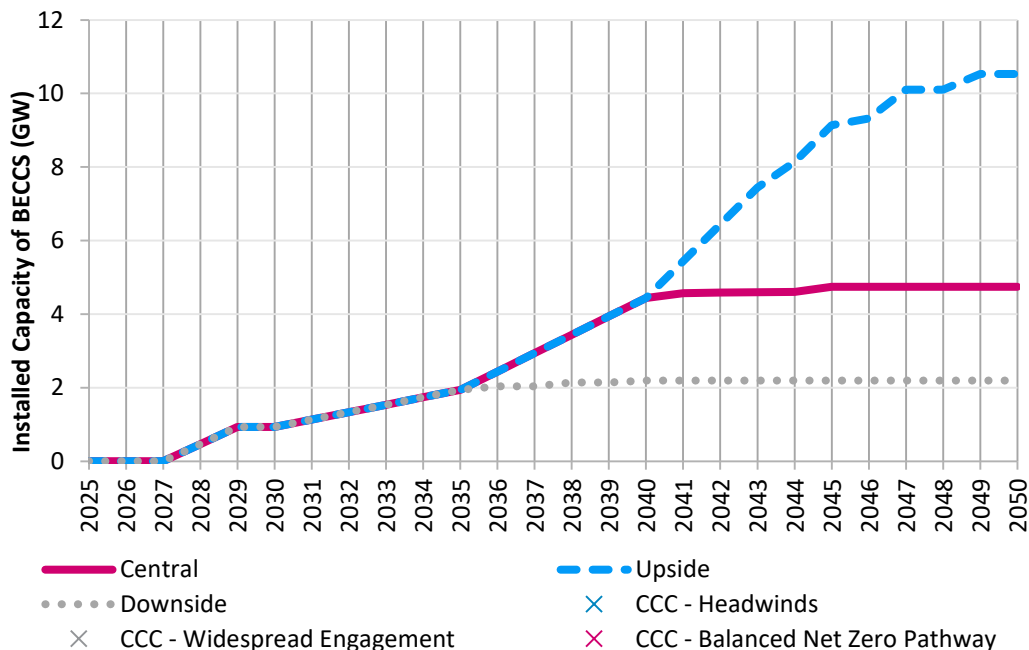
Drax-BECCS in the late 2020s is a “no regrets” option



Material capacity of BECCS-Power, including the Drax project, is chosen to be deployed across all scenarios as part of driving cost-optimal pathways to meet Net Zero

Economics

- What is the optimal build-out and role of BECCS-Power given competing abatement options?
- How do system costs change in the absence of building BECCS-Power?



- ▲ BECCS-Power is deployed in all scenarios – with 2-10 GW of capacity in 2050 – providing 13-73 Mtpa of negative emissions. The Downside to Central cases (13-29 Mtpa) are broadly in line with the 16-39Mtpa of negative emissions from BECCS-power suggested by the CCC, whilst the Upside case (73Mtpa) shows an outcome where the economics strongly favour BECCS-Power over alternative BECCS options. Running BECCS at high load factors will provide strategically important benefits, including banking negative emissions to mitigate the risk of underperformance in other sectors while also providing a valuable source of firm, reliable negative carbon power to complement intermittent renewable technologies.
- ▲ Two Drax biomass units* are converted to BECCS in 2027-29 in all three cases. An additional 1-9 GW of new build BECCS is added from 2030-2050.
- ▲ In the Downside case, where conditions are deliberately less favourable for BECCS-Power, an additional 1 GW of new build BECCS is still deployed over and above Drax by the mid-2030s.

*When converted to BECCS, Drax units are de-rated from 630 MW to 460 MW

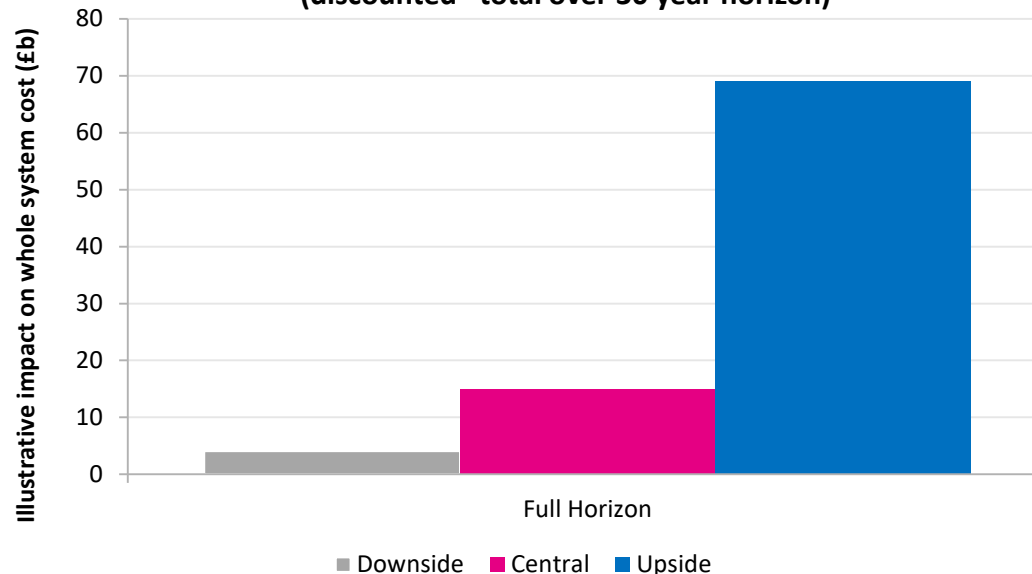
Achieving Net Zero without BECCS-Power is more expensive Baringa

In our Central case this is broadly equivalent to around £17/household/year to 2050

Economics

- What is the optimal build-out and role of BECCS-Power given competing abatement options?
- How do system costs change in the absence of building BECCS-Power?

**Opportunity cost of not having BECCS-Power as a technology
(discounted* total over 30 year horizon)**



*Assumes 3.5% social discount rate.

- ▲ The additional total system costs, in the absence of BECCS-Power, range from a further £4-69bn across the pathway to 2050. In our Central case, without BECCS-Power, system costs will be circa £15bn higher by 2050, equating to a cost of £17 every year for each household in the UK.
- ▲ This measure of the “value of BECCS” power is defined by an opportunity cost approach, i.e. if BECCS-Power as a technology was not allowed, how much more expensive would the system design be in its absence to achieve the same outcomes in terms of net zero targets, security of supply, etc.
- ▲ Even in the Downside, which is unfavourable for BECCS-Power by design, BECCS-Power delivers a £4bn net benefit to the system.

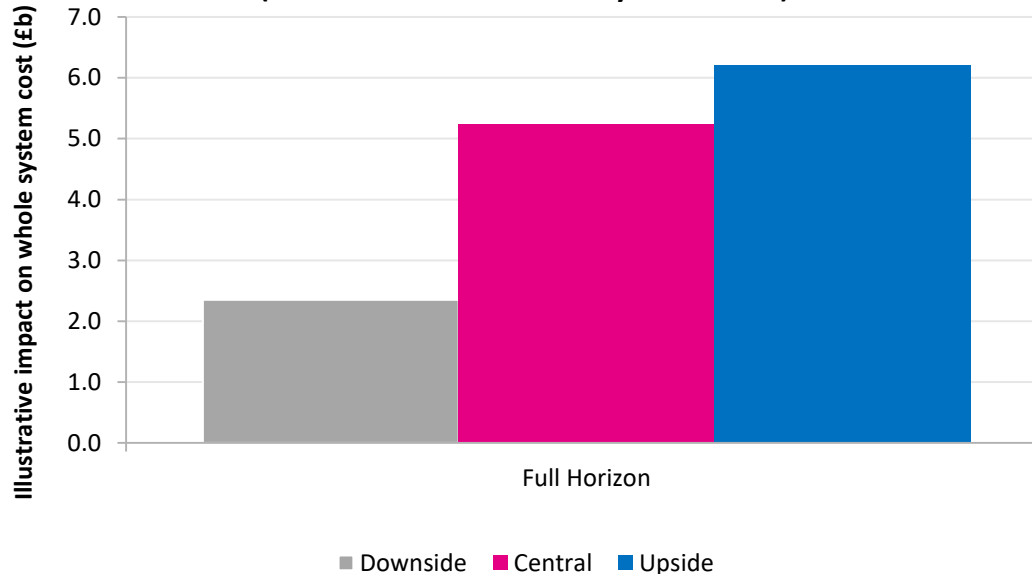
Achieving Net Zero without Drax-BECCS is more expensive

In all scenarios the decarbonisation pathway is lower cost if Drax-BECCS is deployed in 2027 compared with waiting to implement new build BECCS in the 2030s

Role of Drax

- What is the role and value for the Drax-project as part of a broader need for BECCS-Power?
- How robust is the role for Drax given uncertainty around key BECCS and wider system factors?

Opportunity cost of not having the Drax-BECCS project (discounted* total over 30 year horizon)



*Assumes 3.5% social discount rate.

- ▲ Drax-BECCS is deployed in all scenarios – with between 1 and 9GW of additional new build capacity required by 2050. Without Drax-BECCS, system costs rise significantly, ranging from £2-6bn across the pathway. By not deploying Drax-BECCS in 2027, the system is unable to deploy any BECCS-Power until the 2030s.
- ▲ The opportunity cost of not having the Drax-BECCS project is driven by both the lower cost of the Drax project compared to new build, as well as the value of facilitating power sector and broader decarbonisation efforts earlier in the pathway, particularly given the UK’s challenging target of a 68% reduction in emissions by 2030.
- ▲ There are additional associated benefits of Drax-BECCS:
 - Conversion of Drax’s existing biomass units can pave the way to a substantial programme of new build BECCS and other negative emissions technologies, such as biomass gasification to produce hydrogen with negative emissions, with the optimum pathway being refined as technologies mature and costs evolve.
 - Drax-BECCS can also provide an important “anchor project” for development of the CO2 Transmission & Storage infrastructure as part of the Humber CCS cluster as well as providing a bank of early negative emissions in case of slow progress decarbonising other sectors.

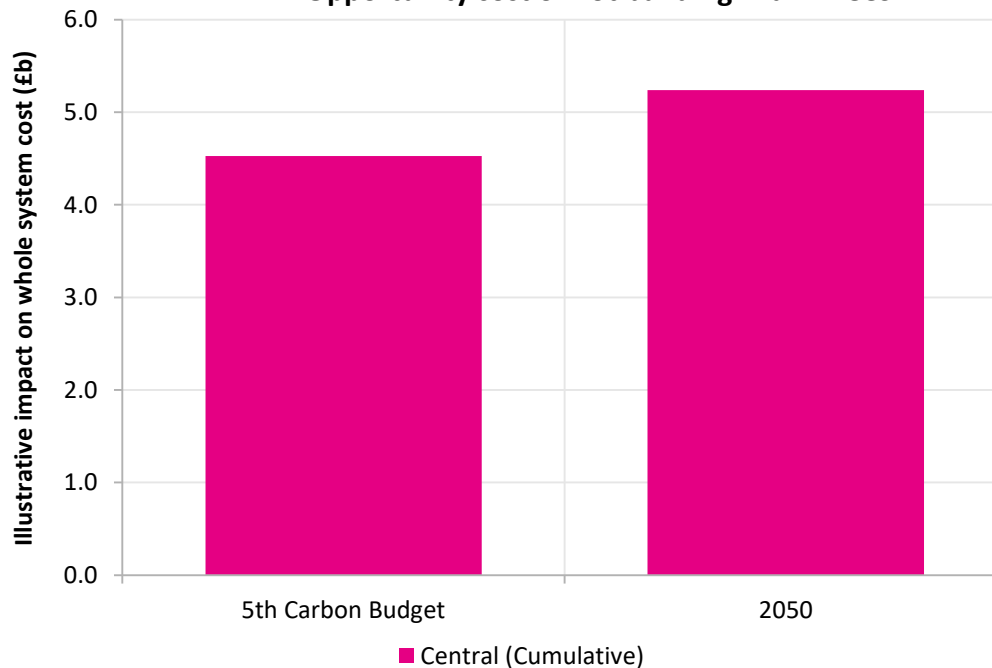
The value of Drax materialises early in the pathway

Decarbonising the UK without Drax-BECCS comes at a significant cost, of which the majority is concentrated during the period of the 5th Carbon Budget.

Role of Drax

- What is the role and value for the Drax-project as part of a broader need for BECCS-Power?
- How robust is the role for Drax given uncertainty around key BECCS and wider system factors?

Opportunity cost of not building Drax-BECCS

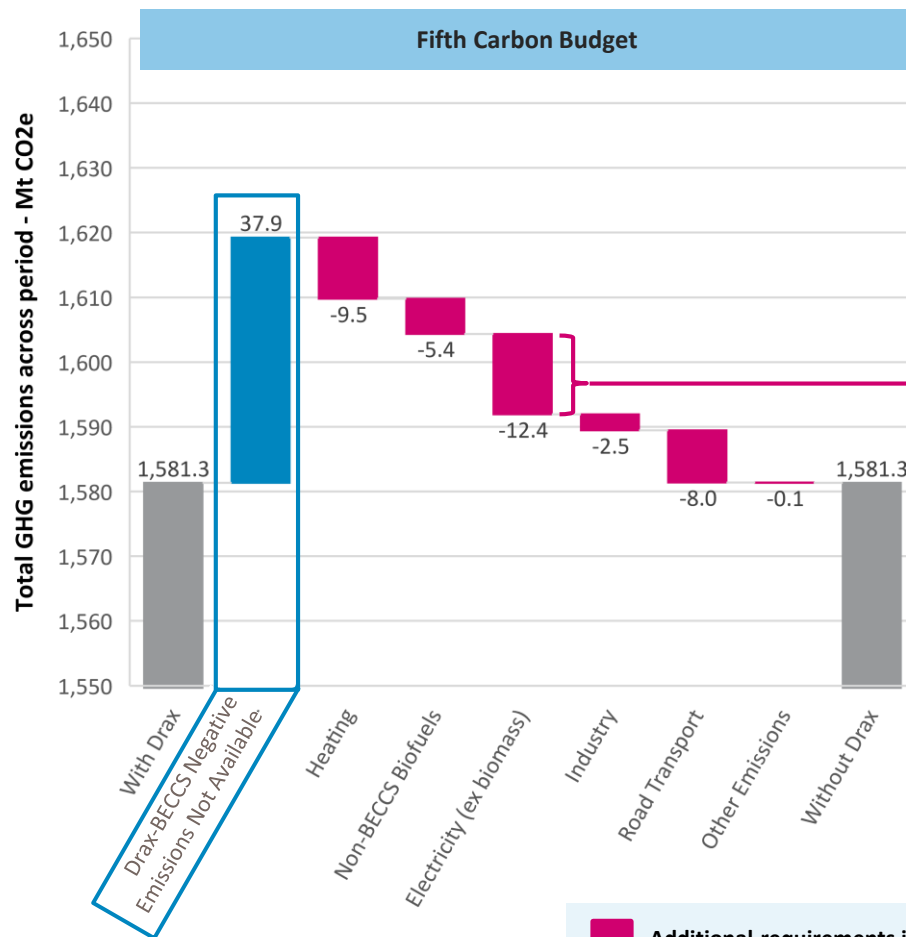


- ▲ **The additional system costs without Drax-BECCS are particularly material in the short term.** In the Central Case, over 80% of these cost increases, due to not building Drax, are incurred before the end of the Fifth Carbon Budget.
- ▲ In particular, this is driven by the reduction in emissions that would need to happen elsewhere in the energy system (power and other sectors) in the absence of Drax-BECCS, across the Fifth Carbon Budget period. This is equivalent to a cumulative total reduction of circa 38 MtCO₂.
- ▲ In power, incremental emissions abatement would need to come from a significant net increase in wind and solar build across the Fifth Carbon Budget. This amounts to more than 10 GW of new capacity, over and above the 30 GW that already needs to be built across this period, even when Drax is deployed.
- ▲ Similarly, significant additional investment in decarbonisation of domestic heating and road transport is also required in the absence of Drax-BECCS. This includes a further 2 MTPa reduction in domestic heating emissions. This is approximately equivalent to deploying an extra 0.5M heat pumps (or a city the size of Birmingham) across the Fifth Carbon Budget, on top of the circa 3M already being deployed.

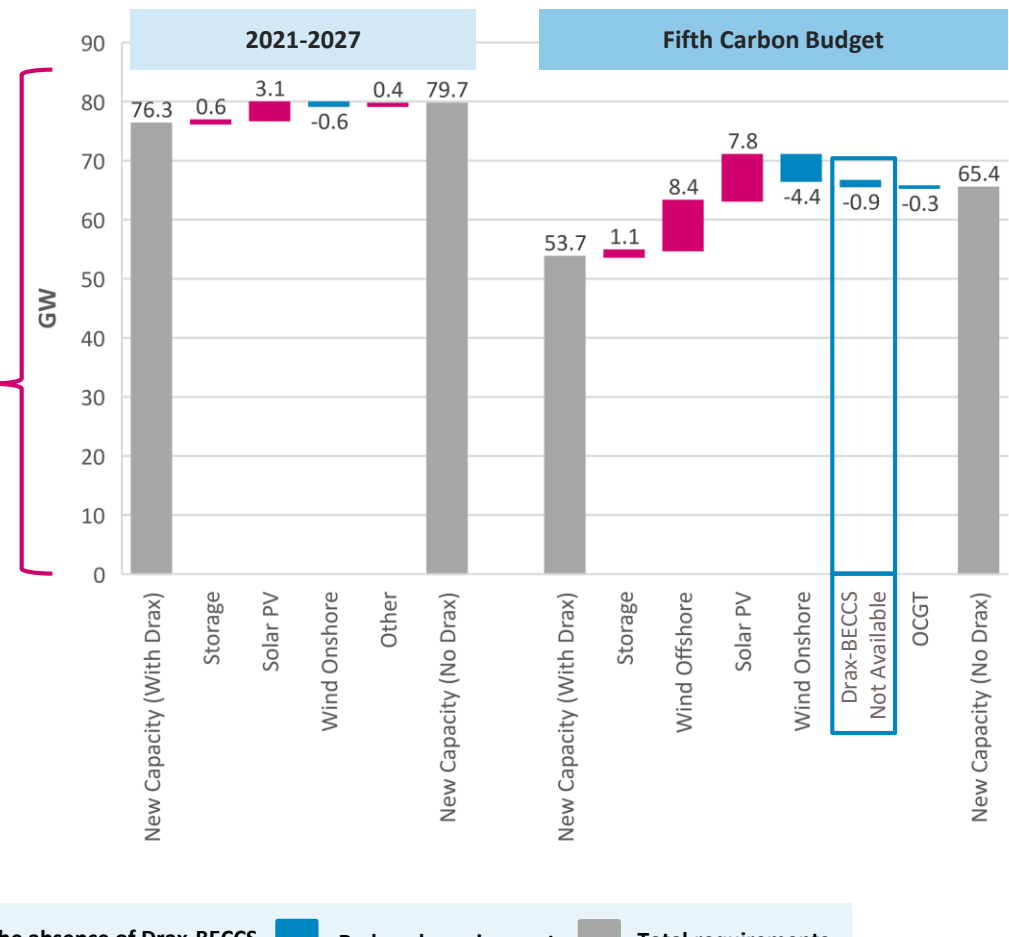
Without Drax, significant extra renewable capacity is required Baringa

In the absence of Drax-BECCS, the energy system needs to deploy more expensive decarbonisation routes in electricity generation, industry, heating and road transport – the latter two requiring increased consumer action

5th Carbon Budget Period Emissions with & without Drax-BECCS



Power Generation Capacity with & without Drax-BECCS



BECCS-Power plays a critical role in achieving Net Zero

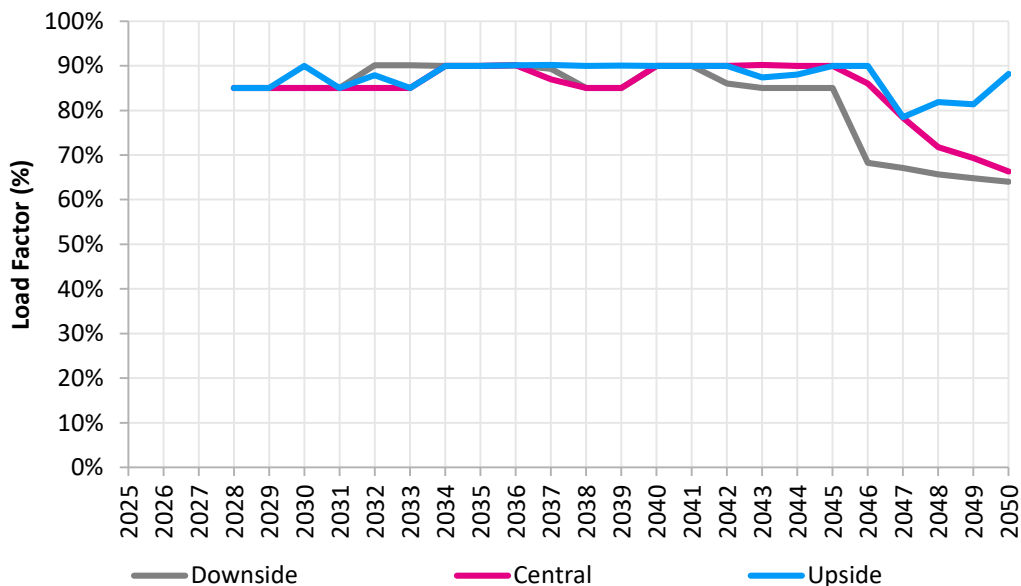


The load factor for BECCS-Power remains high through to 2050, with flexibility to balance intermittent renewables becoming increasingly important in the latter part of the timeline

Role of Drax

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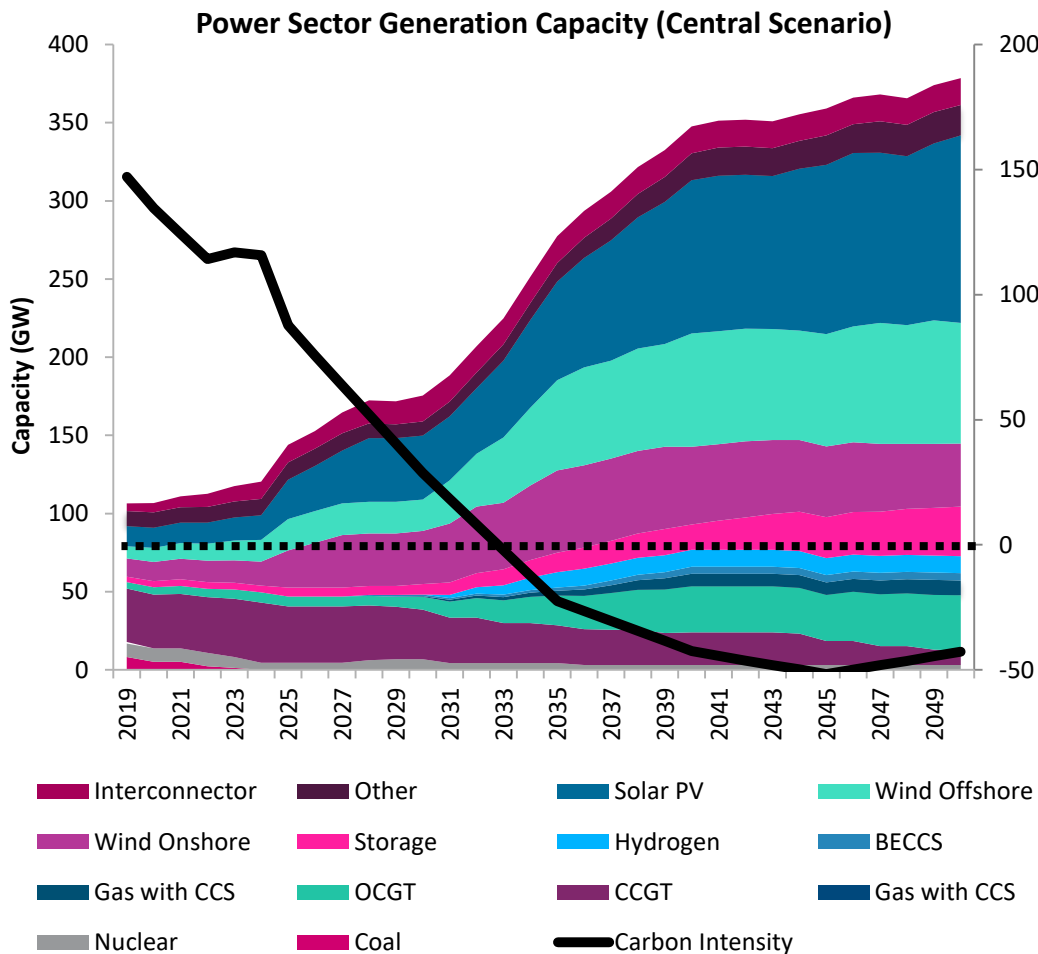
Drax-BECCS Load Factor



- ▲ Drax BECCS is deployed in all scenarios, even the Downside, which is deliberately unfavourable for BECCS-Power. In addition to being deployed, the operation of Drax is robust across the scenarios, with operation at high load factors.
- ▲ Whilst we have imposed a floor of 85% on the Drax load factor until 2045*, Drax is still chosen to be deployed in all scenarios, and in many cases operates above this floor.
- ▲ Later in the pathway, BECCS can potentially provide dispatchable negative emissions generation, supporting the base of intermittent renewables and filling in for the diminished role of flexible fossil fuel plant.
- ▲ In the Downside and Central cases, it is cost-effective to run the BECCS capacity at high load factors for a significant part of the pathway. However, in the last 10 years, some biomass is diverted to BECCS-H2 reducing load factors for flexible BECCS to around 70%. In the Upside case, high load factor operation is seen throughout.

The power sector capacity mix is transformed by 2050

Heavy electrification in many sectors of the wider energy system leads to a huge increase in decarbonised power with the system becoming carbon neutral by the early 2030s



- ▲ By 2050 the power sector sees a huge expansion in renewable electricity, with capacity increasing 7-fold from today and representing 65% of (nameplate) capacity. All coal plant is shut by 2024.
- ▲ The capacity of BECCS reaches 5 GW by 2050 (Central case). Both units of Drax-BECCS are deployed in 2027/28. Drax combined with rapid expansion of renewables helps the system become carbon neutral by the early 2030s. Continuing expansion of BECCS leads to the power sector being significantly net negative by 2050.
- ▲ There is also significant expansion of low carbon flexible plant in the form of batteries, H2 turbines and mid-merit gas with CCS, as well as a gradual expansion of interconnectors and demand side flexibility.
- ▲ Managing a grid with an increasing proportion of intermittent generation is becoming a challenge. Low and negative carbon technologies that provide inertia and other ancillary services, such as BECCS, are increasingly important.

Other includes Hydro, Marine, Waste CCS, Oil, Unabated Biomass/Waste



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