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The Potential Role for Biomass as a Long-Duration Store of Energy – scoping study for the Supergen Bioenergy Hub and the UK Energy Research Centre

Executive Summary

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Headlines

- There is an increasing requirement for long-duration energy storage to accommodate seasonal and weather-related variations in wind and solar electricity generation. Government targets for the decarbonisation of the UK energy system are leading to large-scale deployment of these renewable generation technologies to displace the use of fossil fuels for electricity generation and in the heat and transport sectors.
- **Bioenergy infrastructure and supply chains**, such as seasonally harvested crops, waste wood and forestry by-products, **currently store energy at scale over relatively long periods**. There is the potential to use this characteristic to **facilitate greater flexibility** in the operation of **heat, gas and electricity** systems and markets.
- All current use of **biomass** within the UK energy system is **shaped by Government policy, incentives and regulation**. **These do not currently promote flexible operation** of bioenergy production particularly on smaller capacity sites.
- The **capital and operational costs** of bioenergy production are **well understood** and are already delivering **cost-competitive commercial operations**. This knowledge could be used to deliver a lower-cost solution to the **long-duration energy storage challenge**, complementing the other solutions currently being proposed.
- A current focus for **UK Government** bioenergy **policy** is the delivery of **negative emissions** from **large-scale bioenergy with carbon capture and storage (BECCS) operations**. There is also the potential for **smaller-scale biomass** operations to deliver both **BECCS** and other on-going system benefits, such as **providing a store of energy that can be used flexibly**. These opportunities shouldn't be ignored.

Background

This study has arisen from a collaboration between the Supergen Bioenergy Hub, the UK Energy Research Centre (UKERC) and Cultivate Innovation Ltd, exploring the potential for biomass to act as a flexible, low-carbon store of energy within the UK energy system.

The UK's National Energy System Operator (NESO) has identified that biomass "provides a renewable low carbon power source" that can be used as dispatchable generation to "help meet demand during times of low wind and solar output", contributing to the delivery of a more resilient energy supply. However, where carbon capture and storage (CCS) is installed to create a "negative emissions" BECCS system, NESO suggest that higher load factors would be desirable to "maximise carbon removal from the atmosphere". NESO also quotes the Climate Change Committee (CCC), who identified BECCS as the 'best long-term use of scarce bioenergy resources' in an energy generation context.

Whilst the study reported here does not challenge these assertions, it has drawn on knowledge from around 50 public, private and academic-sector stakeholders to explore the implications of this strategy on the biomass sector. It has sought to understand the role of biomass as a store of energy in gas and heat as well as electricity markets, and whether this role can be sustained alongside the delivery of BECCS in the medium and long term.

Approach

The study has been delivered through engagement with a range of relevant stakeholders, supplemented by reviews of both the academic and grey literatures, with the following specific aims:

- Establish existing evidence for the potential of sustainably produced biomass from a range of sources to act as long-duration stores of energy, delivering flexibility across the energy system through both 'firm' and 'dispatchable' delivery of electricity, heat and gas.
- Understand the combinations of technology, feedstock and geographical location that are most likely to facilitate the delivery of BECCS; provide a better understanding of the timescales for this transition; and explore where energy production from biomass without CCS may persist for longer while still delivering overall system benefits.
- Explore the implications (commercial, economic, environmental, social and technical), both for fuel supply chains and the energy system, of optimising the use of biomass in these contexts.

Specifically, the study has sought to address the following research questions:

- What are the technical and commercial implications of more flexible operating regimes on gas, heat and electricity production from biomass between now and 2030 and in the longer term?
- What fuel/plant types are best suited to these operational regimes, how do you ensure flexibility and availability of these plants, and what are the cost implications of doing this?
- In this context, what are the implications for bioenergy plant capacity up to 2030 and beyond?
- How, when and where is BECCS likely to become commercially viable in a wide range of operational scenarios and under what conditions would BECCS displace unabated operation?
- What are the constraints that might prevent delivery of these scenarios both in the fuel supply chain and with respect to plant investment/operation?
- What are the implications for biomass resource production in the UK, how is this likely to compete with international feedstock supply chains, and what are the relative implications from a carbon accounting perspective?

To deliver answers to these questions, the work has been structured around three equally weighted themes:

- **Plant, infrastructure and products:** current operation, future operation, best match to flexibility needs
- **Dynamics of BECCS:** timescales and feasibility of a transition to 100% BECCS
- **Supply chains:** UK and international - what are the impacts of flexible use of biomass

Findings

Potential

Bioenergy infrastructure and supply chains, such as seasonally harvested crops, waste wood and forestry by-products, currently store energy at scale over relatively long periods and have the potential to facilitate greater flexibility in the operation of heat, gas and electricity systems and markets.

The volumes of biomass currently available in the system are commensurate with the scale of need for long-duration energy storage, and there are operational assets at a range of scales that are capable of utilising these resources to support the system. Added to this, the flexibility potential of biomass operations is diverse, geographically as well as temporally distributed.

It is important to remember that bioenergy feedstocks act as a market. There are opportunities for greater commoditisation of this market and the potential for further expansion of UK feedstock supply chains for flexible bioenergy production.

Flexible operation will have an impact on supply chains. Incentivising the use of biomass for energy storage without also incentivising increases in plant capacity could reduce the amount of bioenergy in the system and have a detrimental effect on hard-won feedstock supply chains. Any decision that reduces the volumes or increases the price of biomass feedstock that is utilised in non-BECCS applications could adversely impact supply chains, and reduce the potential for future BECCS implementations.

Policy

All current use of biomass within the UK energy system is shaped by Government policy, incentives and regulation. These do not currently promote flexible operation of bioenergy production particularly on smaller capacity sites. Future policy seeking to address the need for long-duration energy storage in the UK's energy system should consider the potential for biomass to play a role in delivering these services.

Policy and regulation will play a key role in setting the future direction of bioenergy and this creates opportunities for government. However, there are also challenges, and examples exist where policy and regulation are or can be actively detrimental to the biomass sector. Without urgent action, there is a risk that operations currently supported by Renewables Obligation Certificates (ROCs) will be forced off-line as this support mechanism comes to an end. In these cases, assets may be decommissioned, operational teams disbanded, and the potential for energy storage and other flexibility benefits would be lost to the system.

There is significant pressure being placed on the UK Government to reduce the use of biomass for energy production on the basis of concerns about emissions and sustainability of supply chains. The use of UK-produced feedstocks, particularly waste streams that would otherwise go to landfill, may help to allay some of these concerns.

Current policy, incentives and regulations appear to be hampering industry's ability to use biomass flexibly. If it is accepted that it would bring additional value, governments could develop approaches that actively support such flexible operation. In common with developments in all parts of the energy system, development of policy and regulations that support flexible biomass operation will involve complex interactions between diverse actors, but research and innovation can make the problem tractable.

Costs

The capital and operational costs of bioenergy production are well understood and are already delivering cost-competitive commercial operations. This knowledge could be used to deliver a lower-cost solution to the long-duration energy storage challenge, complementing the other solutions currently being proposed.

Although feedstock flexibility brings technical challenges, new biomass plants designed to provide flexibility could do so with greater efficiency and larger turndown ratios, further increasing the potential of biomass to deliver benefits and a range of value streams to owners and operators.

There is also a range of existing, smaller-scale distributed operations that, with appropriate support, would have the potential to deliver flexibility in different ways. In particular, biomass to heat should not be overlooked, particularly in an industrial context. Biomass to heat can deliver energy system flexibility, especially when integrated with heat storage, but challenges remain, requiring incentives for innovation and new business models. With appropriate support, other smaller-scale operations could also be converted to deliver BECCS.

Smaller distributed operations could also be cost effective from a supply chain perspective. They can support local economies, make efficient use of indigenous resources, and reduce waste. This could have greater political viability than some larger-scale options for long-duration energy storage.

BECCS

A current focus for UK Government bioenergy policy is the delivery of negative emissions from large-scale BECCS operations. There is also the potential for smaller-scale biomass operations to deliver both BECCS and other on-going system benefits, such as providing a store of energy that can be used flexibly. These opportunities shouldn't be ignored.

There are many uncertainties about the timing and availability of CO_2 transport and storage solutions; however, some small-scale biogas operations are ready now to deliver BECCS and could combine this with seasonal energy storage and flexibility. In addition to negative greenhouse gas (GHG) emisions, these operations could provide both firm and dispatchable power to electricity markets whilst delivering similar services to both heat and gas markets. With appropriate support, other smaller-scale operations could also be converted to deliver BECCS.

There is a dividing line when considering whether BECCS plants would operate flexibly, based on an assumption that the negative emissions from BECCS are always the highest value use case for bioenergy in stationary applications. There's a belief that flexibility reduces this value. In many contexts this needs to be challenged. Making a BECCS plant flexible is very dependent on economics and geography, but there are specific cases/places where flexible BECCS plants could add value. This value would need to be delivered throughout the supply chain and may be dependent on the development of CO_2 transport and storage.

Conclusions and further work

This study has established that bioenergy supply chains already store energy over prolonged periods, and that there is potential to make use of this characteristic to address the seasonal variations in wind and solar renewables output that affect electricity, heat and gas markets. There are multiple options for delivering system flexibility with biomass. Additional work will be needed to establish the scale of this potential on a commercial basis and in the context of the wider economy.

Future work will also need to take account of the transition to BECCS and the relative value that both negative emissions and lower-cost energy stores deliver to the energy system. The current study has shown that the two are not mutually exclusive, but require regulatory frameworks and incentives that deliver commercial benefits from delivering both services to the overall system.

This complexity has not generally been taken into account in energy system modelling work and for a range of reasons past modelling efforts have provided inconsistent results when predicting future requirements for biomass feedstocks. Consideration of the energy storage potential of biomass within these models may help to create greater certainty in the role of biomass within the overall energy system.

When considering the role of bioenergy in delivering both negative emissions and flexible stores of energy, it is essential that a whole systems approach be taken. Whilst the cost of energy production on any particular plant will be important to its commercial viability, the true value that the operation delivers has to be considered in a whole systems context, shaped by appropriate policy and regulation.

Project Partners

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Cultivate Innovation is an energy focussed innovation research consultancy that connects people and empowers them to build high quality relationships that deliver lasting impact. It specialises in working with organisations who are delivering innovative low-carbon energy solutions.

Built upon experience of working at a senior level with both the private and public sectors, Cultivate is recognised by its clients as an organisation that can bridge the gap between academia, industry and consumers by understanding that engineers and investors speak very different languages and that these conversations take place in a context framed by policy regulations and broader societal needs.

The Supergen Bioenergy Hub is the UK's national research consortium, dedicated to developing sustainable bioenergy systems that support the UK's transition to a sustainable, affordable and resilient low-carbon energy future.

Funded jointly by the Engineering and Physical Sciences Research Council (EPSRC) and the Biotechnology and Biological Sciences Research Council (BBSRC), the Hub takes a whole-system research approach, covering the full chain of biomass and bioenergy, including research on biomass resources, pre-treatment and conversion technologies, energy vectors, bio-based chemicals and materials, and whole systems analysis.

Working with multi-sector stakeholders from industry, policy and the wider community, the Hub aims to identify pathways for delivering biomass and bioenergy solutions with wider social, economic and environmental benefits.

The Potential Role for Biomass as a Long-Duration Store of Energy – scoping study for the Supergen Bioenergy Hub and the UK Energy Research Centre - Full Report:

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