The CBB Pathway: the role of biomass in successfully decarbonising power in the UK

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The scale of the climate challenge mandates far-reaching action across virtually every sector, but none more important than the power industry. As the world's largest source of emissions, power generation must transform itself totally, but it will also have to become even more central to the global energy system. Electrification of transport and heat in particular, as well as hydrogen production and other technologies will create massive new demand for electricity. That electricity will need to be low-carbon and draw on increasing levels of intermittent power sources, which creates new challenges for balancing the grid from second to second and from season to season.

Almost every energy system around the world will face these dual problems:

1. How do we move to more low-carbon renewables at lowest cost and lowest economic impact?
2. How can we manage a low-carbon grid cost-effectively to ensure security of supply to all citizens?

For both questions and at each stage of the decarbonisation process, biomass has provided a key supporting service. The UK, a pioneer in the use of biomass power at scale, is currently demonstrating how the use of biomass can support wholesale and systematic change in the emissions profile of power generation. This change is not merely a stepping stone, but instead part of a pathway to long-term, scalable decarbonisation that will ultimately lead us to Net Zero and even negative emissions. We call this the Coal-Biomass-BECCS (CBB) Pathway.

System profile	Decarbonisation priorities	Biomass services
Pre-transition or Early stage transition: Little decarbonisation, high dependence on coal power	• Shutdown of coal. • Minimise costs of new infrastructure and plants. • Protect jobs/workers in power sector. • Maintain security of supply. • Avoid stranded assets.	• Economic: Conversions of coal stations to biomass preserves jobs, infrastructure and asset values. • Systemic: Biomass preserves reliable functionality of coal but with significantly lower emissions.
Medium stage transition: Progress made in adoption of renewables to a strategically significant degree for grid operation	• Flexibility of power grid to respond to weather fluctuations affecting power supply. • Reliability of interseasonal supply and variable load factors.	• Systemic: Biomass offers distribution or transmission-level flexibility services, including inertia and grid balancing. • Biomass provides interseasonal optionality due to fuel storage.
Advanced transition: Significant reduction in power sector emissions, high deployment of renewables	• Power grid flexibility and interseasonal supply • Negative emissions needed to compensate for hard-to-decarbonise economic activity in 'net zero' scenarios.	• Sustainable Biomass provides one half of BECCS equation – providing potential for negative emissions.

Table 1: Stages of the CBB Pathway.

The lessons of the journey from coal to biomass to BECCS are universally applicable.

The UK's successful power decarbonisation strategy provides a model for other countries, having reduced electricity emissions by 71.7% since 1990.[1] While not every country will need (or have the ability) to follow the CBB Pathway all the way to largescale BECCS, the lessons of the journey from coal to biomass to BECCS, with its emphasis on stability, flexibility, and sustainability, are universally applicable.

The CBB Pathway is a stable, cost-effective route map for lasting and meaningful decarbonisation.
It does not provide all the answers to the widespread challenges posed by climate change, but it does support deep decarbonisation of power systems as part of a range of energy options. The flexibility and stability that biomass brings as part of the transition away from coal allows for greater expansion of intermittent renewables such as wind and solar power. The use of biomass

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in a renewable energy mix not only supports decarbonisation now, but also opens the door for negative emissions which will prove crucial if we are to have a chance of avoiding catastrophic global warming.

Moving away from coal

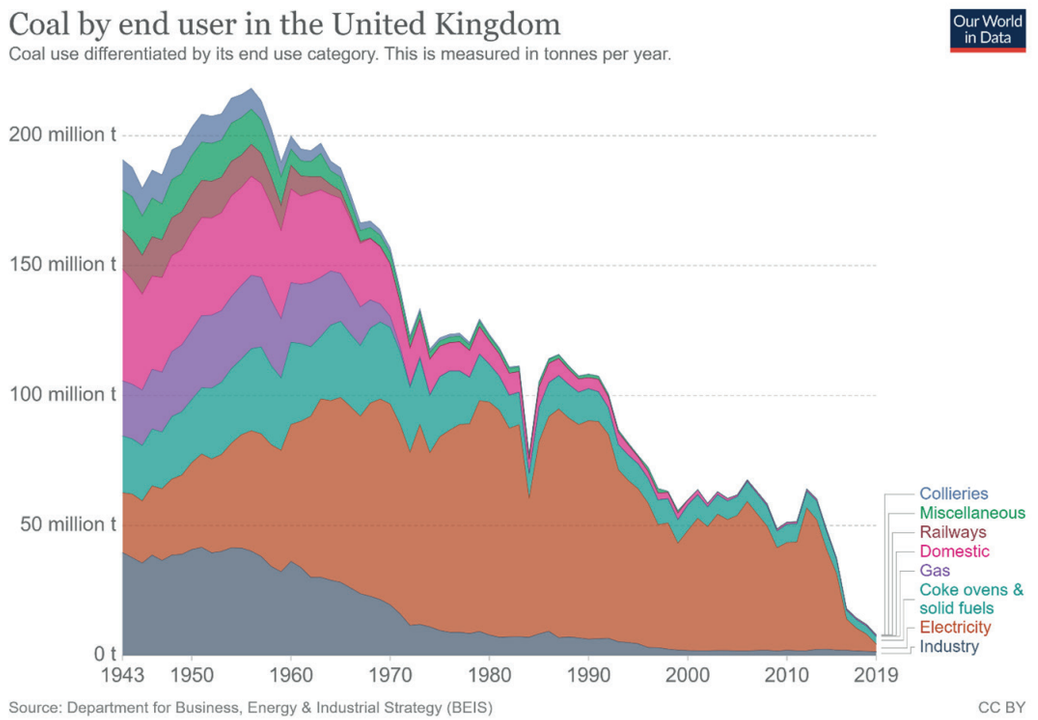
The UK's pre-eminence in the Industrial Revolution fostered an historic dependence on coal as its primary energy source. This dependence began to decline steeply from the 1960s with the growing importance of gas and other energy sources, but even by 1990 coal still made up 30% of primary energy consumption in the UK.[2] The last few decades has seen huge progress in shifting away from fossil fuels, and the COVID-19 pandemic has perhaps struck the final blow to coal use in the UK. In order to understand where we go next, however, we need to examine the traditional workings of the UK's energy system.

The large use of coal in the UK worked well (in operational terms) as part of a traditional, centralised, highly manageable energy system. Leaving aside its negative environmental impact, coal is useful because of its functionality. Coal is easily storable and transportable, allowing it to provide great flexibility for heat and power solutions, whether at a micro or a macro level. Like other thermal plants, coal-burning power stations also generate inertia which allows the power grid to respond smoothly to changes in supply and demand, increasing the efficiency and lowering the cost of the energy system.

Coal is, however, exceptionally high in greenhouse gas emissions and must be removed from the energy system. How can we replace that functionality without using coal itself?

Redesigning the power system

Over the last fifteen years, the UK has been undertaking a fundamental redesign of its power system. The use of CfDs (Contracts for Difference) and other subsidies has allowed high investment and cost reductions in renewable technologies by shielding developers (and consumers) from volatile wholesale prices.[3] In June 2019, the UK became the first major world economy to commit to reaching net zero emissions in legislation, setting 2050 as the target date to achieve this.[4] The target looks credible because of progress in the power sector, with renewables' share of electricity generation reaching a record high in 2019 of 37.1%.[5]



The UK's phase-out of coal over the past twenty years has caused a dramatic decrease in emissions but has had knock-on effects for the reliability and functionality of the grid. The welcome development of renewable power sources has increased the need for interseasonal storage and flexibility in the UK energy grid and led to greater pressure on the system.[8] During the UK's COVID-19 lockdown, low demand and high renewable generation emphasised the challenge, with the costs of extra balancing services estimated at an extra £500 million over the summer.[9] Some suggested that this was a glimpse at the future grid – high in variable renewables, relatively low on the traditional stabilising services of thermal plants. The UK expects to grow offshore wind capacity alone from around 10GW now to 40GW in 2030, suggesting a growing need for stability and flexibility.[10]

Biomass has played a central role in this success story. Biomass is the largest source of renewable energy in the UK, and the second-largest source of renewable electricity (behind wind power).[6] The 62.8% reduction in emissions from UK energy supply since 1990 would simply not have been possible without the reliable supply and use of sustainable, well-managed biomass feedstocks.[7]

The story is far from complete, but the foundations for net zero have been laid. New technologies and renewable energy sources have come onto the market, benefitting from subsidies, carbon pricing and regulatory pressures. This has created new questions for energy system operation and a growing understanding of the importance of **whole system costs**. Biomass has had, and will continue to have, an important role to play in the redesign, because it is able to provide key services to the grid that other renewables cannot. This is the second stage of the CBB Pathway.

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THE ENERGY MIX

Services which can be provided by different power technologies

Technology	Nuclear	Inter-connector	Wind	Thermal (Biomass, gas & coal)	Solar	Batteries	Pumped Storage
Frequency Management	Potential[1]	Yes	Partial[2]	Yes	Partial[2]	Yes	Yes
Voltage Management	Yes	Yes	Partial[2]	Yes	No	Yes	Yes
Inertia	Yes	No	No	Yes	No	No	Yes
Reserve	No	Yes	Partial[2]	Yes	No	Yes	Yes
Restoration	No	Potential	Future[3]	Yes	Future[3]	Future[3]	Yes

1. Currently pressurised water reactor at Sizewell can provide Frequency Response; next generation nuclear reactors will be flexible
2. Service can be provided but is variable in quantity and intermittent in availability; some wind farms were successful in a recent Scotland Reactive Tender
3. National Grid ESO is exploring the potential for wider provision of black start services

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Bioenergy provides firm and dispatchable power which allows for exactly such greater integration of variable sources of electricity. As the system evolves, more effort is being invested into market mechanisms to reward such reliability. The UK's Capacity Market, which provides contracts for capacity guarantees up to four years ahead, and newer markets for flexibility services, are creating an ecosystem that increasingly values reliability and flexibility. Further reforms are expected that may well embed this trend further.

Biomass power supports system flexibility, allowing for higher renewables deployment. The UK's experience shows that this flexibility will be increasingly valued by systems around the world following a similar path.

Sustainability

Following in the UK's footsteps down the CBB Pathway would be meaningless if the biomass used does not meet stringent sustainability criteria. Fortunately, the UK is also leading the way when it comes to sourcing and using sustainable biomass. The UK's sustainability governance system has been developed by government and industry and, in many cases, goes well beyond the sustainability criteria set out in the EU's Renewable Energy Directive.[11] All government support schemes for bioenergy in the UK are conditional on sustainability criteria designed to ensure positive environmental outcomes. These schemes cover an array of bioenergy technologies across the sectors of heat, power and transport.[12]

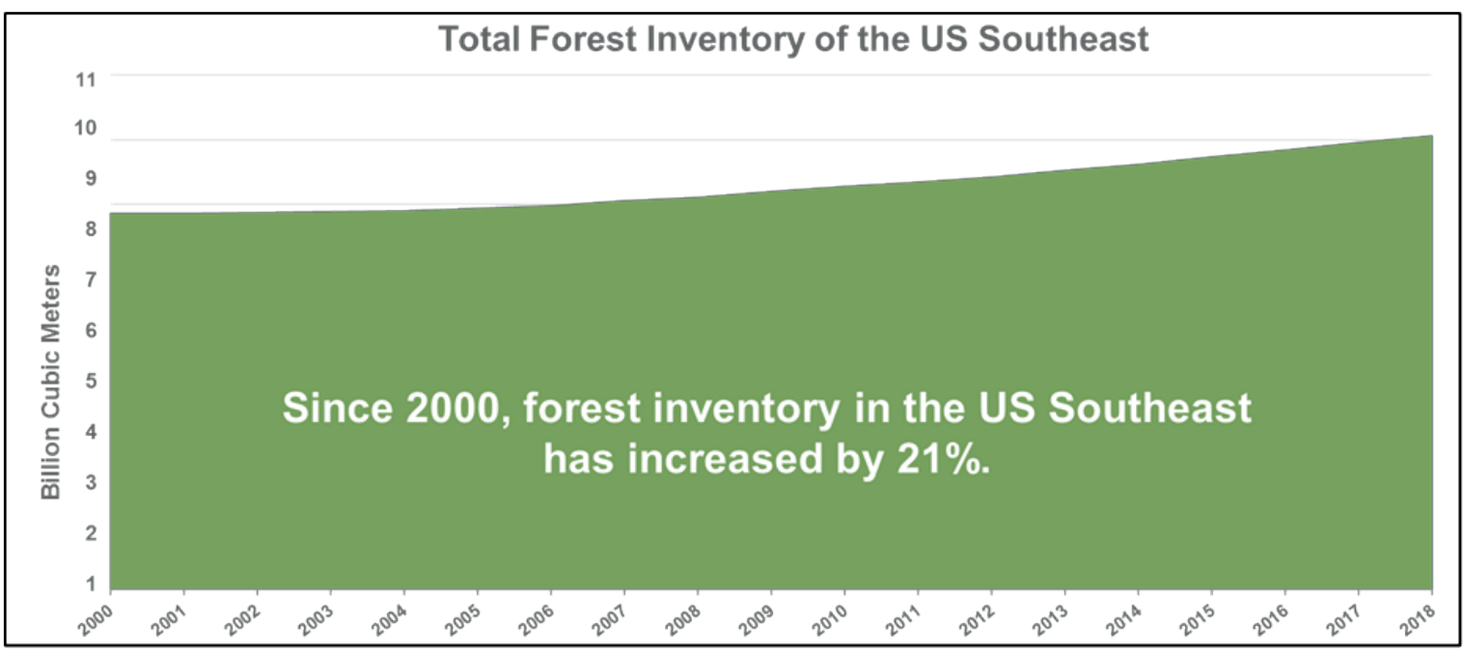
These positive sustainability outcomes are not just theoretical, they are evidenced by the data on the ground. A large part of the UK's current biomass supply comes from the US Southeast, where the increase in imports to the UK has supported the continued growth of these forests (see graph).[13]

It is important to understand that the growing forests, such as those in the US Southeast, are expanding because of markets for forest products, not in spite of increased demand. The use of biomass in power generation provides a market for forest owners to sell their cuttings, branches and other low-value wood which is often underutilized or simply has no other buyer. The new revenue streams that bioenergy provides incentivise reforestation and improved forest management, leading to an increase in carbon stock and protecting against the climate dangers posed by land-use change.

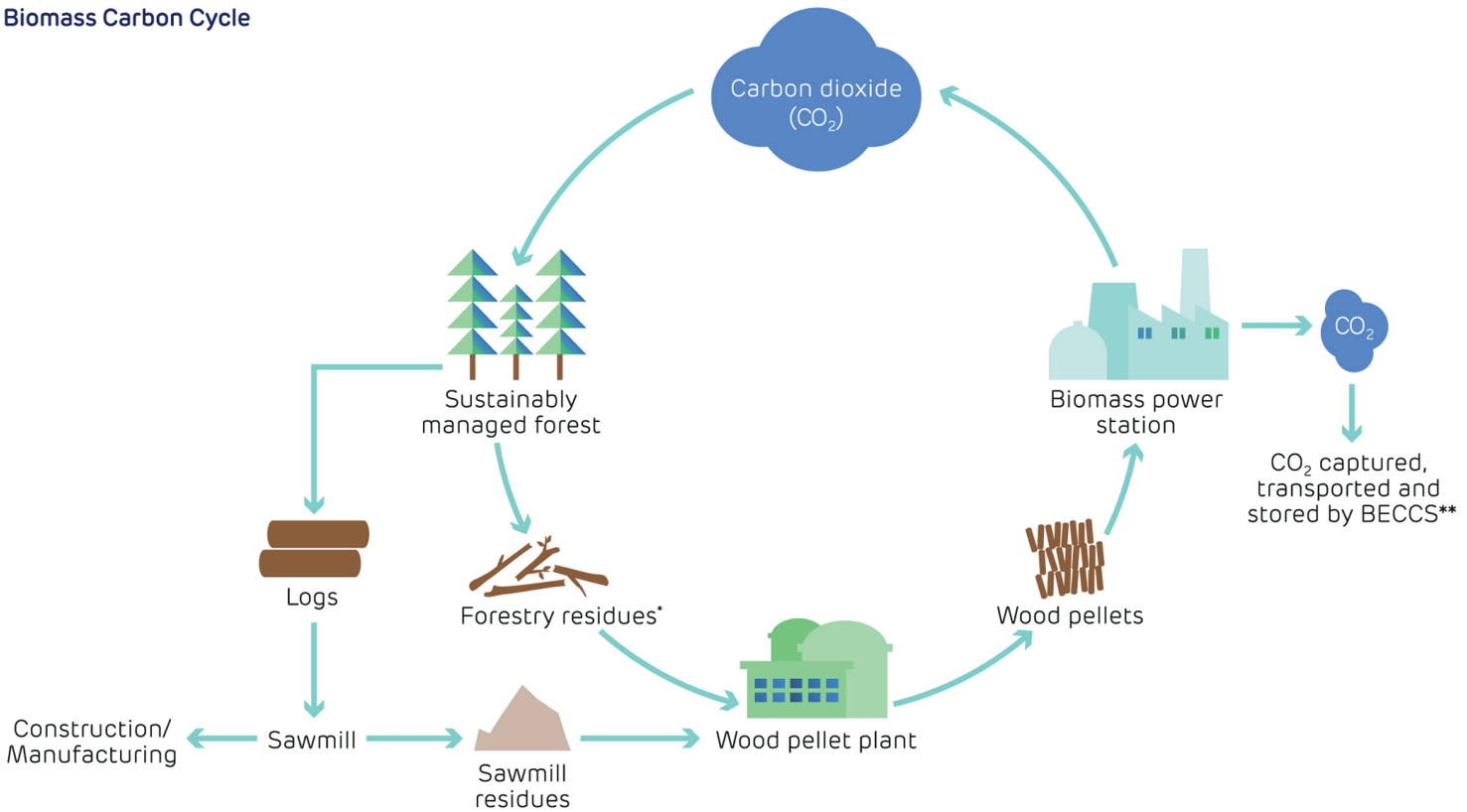
Beyond zero

The UK has been moving successfully along the CBB Pathway and can point to genuinely world-leading action on reducing emissions.

Biomass continues to hold remarkable potential for supporting further decarbonisation. Research by the Renewable Energy Association shows that the role of bioenergy



Biomass Carbon Cycle



* Forestry residues includes branch tops and bark, thinnings and low-grade roundwood

** BECCS is a bioenergy, carbon capture and storage system, with CO_2 resulting from power generation captured and stored in an aquifer under the North Sea

There is widespread agreement on the need for BECCS and other carbon capture technologies amongst the most influential climate voices.

in the UK could sustainably be increased by a factor of 2.5 by 2032.[14]

Looking ahead, the CBB Pathway continues towards sustainable and long-term positive climate outcomes. Central to this is Bioenergy, with Carbon Capture and Storage, or BECCS, where sustainable biomass is used to generate energy and the resulting CO_2 produced is captured and buried underground. This process results in net negative emissions because trees (or crops) absorb CO_2 as they grow, which is then removed from the atmospheric carbon cycle. When these organic materials are used as fuel, carbon capture technologies prevent the CO_2 being re-released into the atmosphere, instead using or storing it underground.

There is widespread agreement on the need for BECCS and other carbon capture technologies amongst the most influential climate voices. The UN Intergovernmental Panel on Climate Change (IPCC) set out four illustrative model pathways for limiting global warming to a rise of 1.5ºC above pre-industrial levels. Three of these four pathways involve BECCS to varying degrees, whilst the first pathway is dependent upon a massive reduction in global demand for energy predicated on energy-efficient technologies and changes in behaviour. In the UK, the CCC has said that BECCS could sequester between 20 and 65 $MtCO_2e$/yr. by 2050.[15]

Large-scale use of BECCS is only desirable if the biomass required is sourced sustainably and in line with positive climate outcomes. Based on the UK's experience, this can only be done with the help of strong regulatory regimes which act as a backstop for the normal operations of sustainable forestry markets.

Our analysis suggests that, when using clear sustainability filters on environmental, economic and socio-political grounds, there is enough available biomass feedstock globally to deliver 1-4Gt of CO_2 abatement without impacting healthy forests, food supplies or causing harmful political, social and economic effects.

Bioenergy supply chains have great potential to support forests and sustainable principles, and the bioenergy industry must take

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the lead in guaranteeing that the energy transition does not come at the expense of local communities or knock-on emissions elsewhere.

Conclusion

The CBB Pathway is a route map to deep decarbonisation which provides a way for countries, no matter their environmental progress so far, to advance their climate contributions. The UK is a case study for the value that can be delivered by transitioning from coal to biomass, building biomass plants and eventually generating BECCS. The CBB Pathway does not provide all the answers, but it is proving a very important tool.

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