Developing an alternative framework for sustainable biomass policy design to support the UK's transition to net zero.

DANIEL JAMES TAYLOR

Doctor of Philosophy

ASTON UNIVERSITY

December 2024

Thesis Abstract

Developing an alternative framework for sustainable biomass policy design to support the UK's transition to net zero.

Daniel James Taylor, Doctor of Philosophy, 2024

Beyond the technical challenge of defossilising energy systems to address the climate emergency, the transition to renewable energy is a process of political, economic, and social change. Biomass is unique as the only renewable source of carbon, yet its sustainable deployment faces significant barriers within policy. This research explores the political economy of biomass use within the context of the United Kingdom's (UK) net-zero targets, addressing a critical gap in understanding the non-technical factors shaping biomass policy.

A political economy approach enabled the analysis of how socio-political and economic systems influence biomass policy design and implementation. A systematic literature review provides the theoretical foundation, while qualitative data from twenty-six semi-structured interviews with stakeholders, including policymakers, industry representatives, and non-governmental organisations, provide valuable insights into policy drivers, impacts, and trade-offs associated with biomass use.

Results show that UK biomass policy is influenced by a desire to focus on economic growth opportunities while achieving carbon emission reductions. However, the benefits of biomass use are centralised, leading to many of the benefits being disconnected from local communities. This fuels public perception that biomass is being exploited for profits rather than to support people and the planet. Bringing biomass out from behind the scenes and redistributing benefits to a wider set of stakeholders has the potential to mobilise greater political support for its continued use to achieve net zero.

Considering this, an alternative policy framework emphasising decentralisation, cross-sectoral integration, and equitable benefit distribution is proposed. The framework aims to maximise the potential for biomass to contribute to the transition to a net zero energy system while enhancing environmental and social capacity. By highlighting the deficiencies in the political economy of biomass use in the UK, this research addresses the gap in understanding of the non-technical factors shaping biomass policy design.

Dedication

I would like to dedicate this thesis to my partner, Beth. She has been through every step of this PhD project with me. I am extremely grateful for her, and for the faith she had in me when I doubted myself along the way.

Personal Acknowledgements

I would like to thank my supervisors Mirjam Röder and Katie Chong for their unwavering support over the past three years, helping me overcome imposter syndrome on multiple occasions, and providing me with a strong foundation to tackle this research.

I would also like to thank Patricia Thornley for joining my supervisory team in the final stages of my PhD, and for convincing me that a PhD would be a good step in my career when I was working at the Supergen Bioenergy Hub in 2021.

Thank you also to the 26 individuals who gave up their time and provided me with such rich and honest insights during the interview process.

List of Abbreviations

Abbreviation	Definition
ARBRE	Arable Biomass Renewable Energy
BECCS	Bioenergy with Carbon Capture and Storage
BEIS	Department for Business, Energy, and Industrial Strategy
CBDR	Common but differentiated responsibility
CCC	Climate Change Committee
CCS	Carbon Capture and Storage
CfD	Contracts for Difference
CHP	Combined Heat and Power
Defra	Department for Environment, Food, and Rural Affairs
DESNZ	Department for Energy Security and Net Zero
DfT	Department for Transport
EIA	Environmental Impact Assessment
ESC	Energy Crops Scheme
FIDeR	Final Investment Decision for enabling Renewables
GDPR	General Data Protection Regulations
GHG	Greenhouse gas
GIS	Geographic Information System
HANPP	Human Appropriation of Net Primary Production
IPCC	Intergovernmental Panel on Climate Change
LAEPs	Local Area Energy Plans
LAT	Literature Analysis Tool
LCA	Life-cycle Assessment
MLP	Multi-Level Perspective
MRV	Monitoring Reporting and Verification
NAO	National Audit Office
NbS	Nature-based Solutions
NGO	Non-governmental organisation
PIS	Participant Information Sheet
RED	Renewable Energy Directive
RHI	Renewable Heat Incentive
RO	Renewables Obligation
RTFO	Renewable Transport Fuel Obligation
SAF	Sustainable Aviation Fuel
SDGs	Sustainable Development Goals
STS	Science and Technology Studies
TEA	Technoeconomic Analysis
UK	United Kingdom
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

List of Tables, Figures

Figures

Tables

Contents

1. Introduction

1.1. The United Kingdom's political economy, biomass, and net zero.

The climate, ecological, and energy crises require change in our political, economic, and societal systems to ensure we decouple humanity from a reliance on fossil fuels, prevent rising carbon dioxide emissions, and develop sustainable solutions for people and the planet. Renewable energy transitions present an opportunity to harness non-fossilised sources of energy. However, this transition threatens the interests of powerful oil and gas companies, who have benefitted from the fossil-fuelled status quo for decades. Furthermore, the emergence of political targets, such as new laws for achieving net zero emissions, has further politicised the energy transition in a way that motivates actors to ensure they win, mitigating any impact that new policy may have on their financial assets, profits, and growth. Renewable energy technologies exist, but non-technical political, economic, and societal barriers also exist, preventing their sustainable deployment to end our reliance on fossil fuels.

One renewable energy source is arguably more complex and controversial than the rest. Biomass is unique as the only renewable source of carbon; however, it is subject to intense scrutiny and criticism. Despite this, organisations such as the Intergovernmental Panel on Climate Change (IPCC) and the United Kingdom's (UK) Climate Change Committee (CCC) highlight the role of biomass in achieving net zero carbon emissions. Bioenergy can potentially deliver net zero solutions, displacing fossil resources flexibly across multiple sectors. However, its links to our environment mean bioenergy spans multiple policy arenas, which are made more complex by the challenges of a politicised energy transition. This complexity is fuelled by polarised public debate around bioenergy that is exploited by various actors (such as energy producers or non-governmental organisations), who present themselves to the public as experts, exert power over the debate, and influence future policy decisions.

The emergence of net zero targets has legitimised the potential for bioenergy to deliver negative emissions, linking its use to carbon capture and storage. However, reducing the focus of bioenergy to carbon balances within net zero energy systems detracts from the potential for bioenergy systems to deliver the environmental, social, and economic changes needed to address the climate, ecological, and energy crises. Whilst not a "silver bullet" solution to decarbonisation, the flexibility of bioenergy and its potential to displace fossil fuel use across multiple sectors makes it a viable part of the UK's plans to achieve net zero. However, the UK's political-economic situation determines how biomass is extracted from our natural environment, where and how it is used, and thus who benefits from its extraction.

The transition to net zero is more than the technological challenge of decarbonising our energy systems; it is a process of non-technical factors, such as environmental, social, and economic change,

which could impact the distribution of wealth, benefits, and inequality within our society. This challenges elected policymakers and civil servants in the UK seeking to maintain their social contract with the public. That social contract ensures the public can 'keep the lights on' as energy is delivered to them nationally in a reliable and affordable manner. Whilst there is broad literature on the technological challenges of utilising biomass feedstocks to achieve different aims and displace fossil fuel usage, there is little research into the non-technical factors influencing the design of biomass policy to contribute towards our transition to net zero. This research aims to address the gap in the literature identified by understanding how the political economy of renewable energy transitions impacts their success in displacing fossil fuel use, considers the implications for policy that seeks to use biomass to achieve net zero, and puts forward an alternative policy framework for biomass that maximises sustainability in line with net zero targets.

1.2. Research aims and thesis overview.

To address the gap identified in the literature, three primary research questions spanning the political economy of the UK, net zero, and the benefits of utilising biomass were formulated:

1. **How does the political economy of energy transitions impact their success in replacing fossil fuels and reducing carbon emissions?**
2. **How has policy impacted the sustainable use of bioenergy to achieve carbon emission reductions in the UK since 2000?**
3. **How does the UK's political economic situation determine who benefits from, and who pays for, the deployment of sustainable bioenergy systems, to achieve net zero by 2050?**

A literature review aimed at addressing the first primary research question is presented in Chapter 2, which examines the political economy of renewable energy, and provides observations on the trade-offs challenging the utilisation of bioenergy to reach net zero. Following this, the political economy of bioenergy, the influence of net zero goals, and their intersection with the broader UK bioenergy policy landscape is discussed. The results of the literature review, demonstrating how the success of using biomass sustainably to contribute towards achieving net zero will depend on the impact of the UK's political economy, informed the design of the research activity aimed at addressing the second and third primary research questions. The methodology presented in Chapter 3 outlines how the researcher designed and developed a semi-structured interview process, identified, and sourced experts from across industry, policy, and non-governmental organisations involved in the UK biomass and bioenergy sector, and how the researcher conducted the interviews to gather insights. This concludes with a reflection on the research design, considering the impact of bias, the value of reflexivity in this research activity, and the limitations of the study. Chapter 4 presents the results of

the coded thematic analysis conducted on the insights gathered during interviews, spanning the drivers for policy, policies themselves, and impacts of policy in relation to the deployment of bioenergy in the UK. It also covers the observations made by the researcher at the time of interviewing and ends with a reflection on the research process and product. The discussion presented in Chapter 5 pulls out the key themes that emerged from the data, framing them in the context of the UK's political economy and the findings of the literature review presented in Chapter 2, discussing in depth the consequences for future policy frameworks on biomass use. This discussion informs the design of an alternative framework for biomass policy which is presented in Chapter 6, considering the deficiencies and challenges identified in the discussion, and putting forward an alternative which seeks to maximise benefits for people and the planet in pursuit of net zero. The thesis concludes with two chapters: a closing, Chapter 7, which summarises the research process and product, and a final Chapter 8, which presents considerations for future work not covered within the scope of this research.

2. Literature review

NB: For the avoidance of doubt, the following chapter was published as part of the researcher's first review paper titled "Designing biomass policy: The political economy of renewable energy transitions for net zero" found at: https://doi.org/10.1002/wene.512

2.1. Literature review methodology.

A systematic literature review was undertaken to identify the research gap, situate the research within existing literature and understand the strength of existing knowledge around the use of biomass and political economy studies. Taking a systematic approach ensures clarity about how the literature review is carried out, minimises the risk of error influencing results and enables reproduction of the results by others (Booth, Papaioannou *et al.* 2012). A systematic approach also lent itself to the use of a Literature Analysis Tool (LAT) created in Microsoft Excel, enabling the comparison of papers via the keyword, title, and abstract fields to provide a "Relevance Score" based on the user's research interests and focus (which are outlined in Figure 1 below). A high "Relevance" score in the LAT indicates that the abstract contains many user-identified terms or phrases based on research interests, goals, methods, and focus. This was done to find all applicable pieces of research whilst minimising the potential for missing relevant research. Leveraging the LAT has maximised the benefits of taking a systematic approach, minimised the risk of error in a literature search and reduced the time required to analyse the relevance of selected papers (Taylor 2023).

This systematic literature review aims to position the use of biomass to produce energy and products within the context of the United Kingdom's net zero ambitions, legislated for by the UK government. To do this, the politics of renewable energy and the clean energy transition are explored to understand broader non-technical barriers to renewable energy deployment. This is followed by an analysis of biomass use covering bioenergy, bioproducts and the wider bioeconomy to explore how policy decisions influence sustainable biomass use. Given the recent emergence of 'net zero' within public discourse and policymaking, biomass use for achieving net zero emissions will be explored in the context of the politicised energy transition. An overview of the literature review methodology, a detailed description of how a literature analysis tool was leveraged to achieve a systematic approach and an outline of current UK policy impacting biomass are also provided.

The climate, ecological, and energy crises require societal, political, and economic system changes to achieve sufficient positive benefits for people and the planet. This review demonstrates that renewable energy transitions have the potential to deliver those changes at multiple levels; however, this has politicised the energy transition. The unique position of biomass as a renewable source of energy and carbon means it has the potential to deliver sustainable impacts on social, economic, and environmental factors. However, political and social barriers exist to its sustainable deployment to

achieve net zero targets in the UK. Given the interconnections between biomass use, climate change, and renewable energy, the use of a broad and interdisciplinary approach, such as political ecology, is justified. Political ecology will enable the interrogation of non-technical barriers to sustainable bioenergy deployment in the UK, seeking to maximise benefits for people and the planet whilst being sensitive to existing political and economic factors.

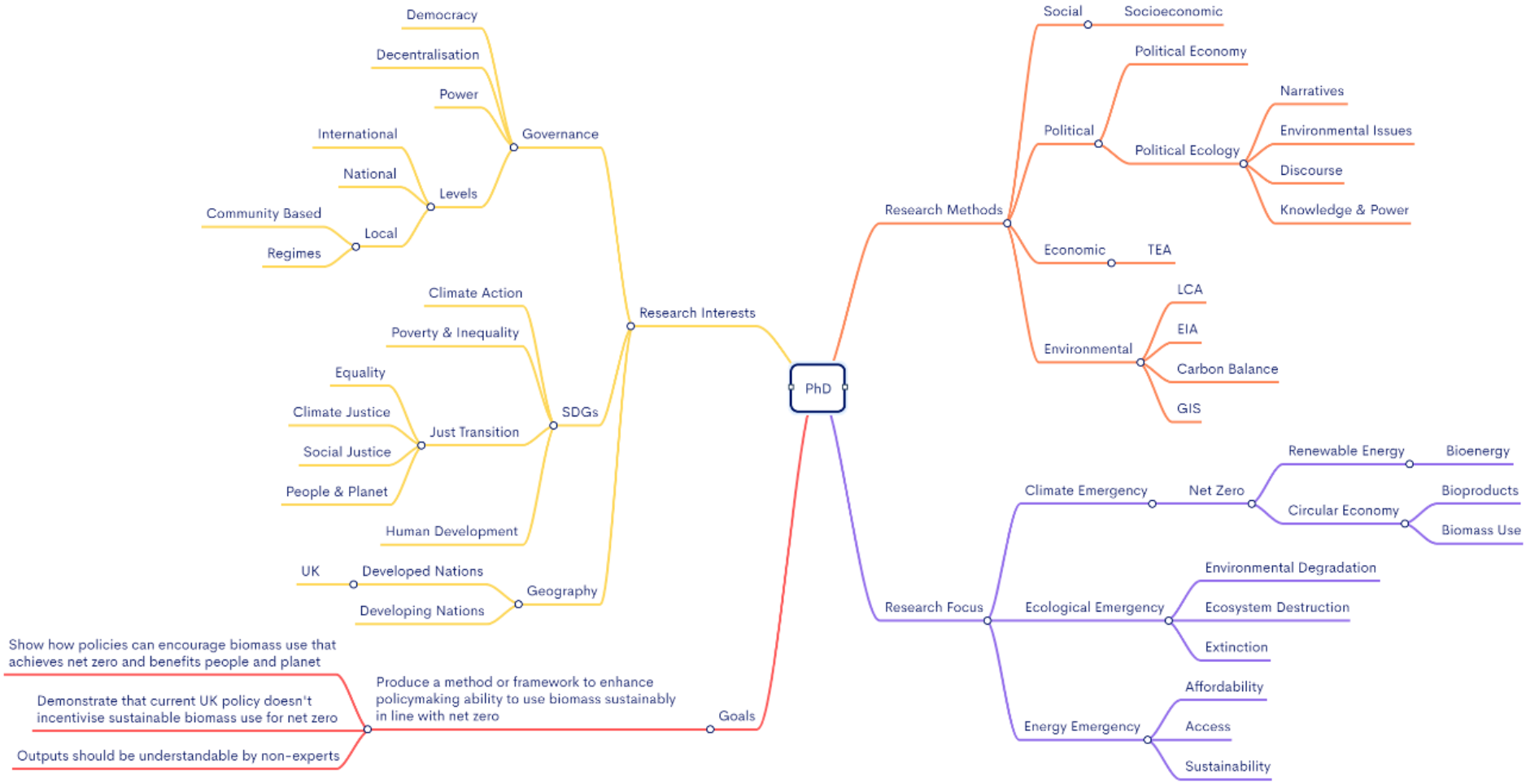

Figure 1 - A mind map of research focus, interests, methods, and goals to summarise and triangulate the aim of the research, and guide the words searched for in the literature to determine relevancy to the research.

The systematic approach included ten steps, as shown in Figure 4 below; Planning, Scoping Searches, Literature Search, Screening, Collating, Paper Selection, Data Extraction, Quality Assessment, Analysis and Synthesis, and Write Up. Planning began with identifying key interests, research questions and theoretical approaches, which informed which terms would be used to perform the Scoping Searches. For example, searching for research using online bibliographic databases covering “biomass” and “political economy” showed that little work was completed in this area. Therefore, the initial search was expanded to investigate “renewable energy” and “political economy”, then triangulating to ensure all relevant research was captured. Consultation with an information specialist at Aston University revealed that in addition to Web of Science, it was worth checking an additional database, SCOPUS, to ensure social science angles to political economy were being covered. This was key to ensuring relevant literature was captured from an interdisciplinary perspective, as both databases have a different research focus.

Initial searches returned thousands of results; therefore, the search protocol was modified to increase the specificity of results, using Boolean operators such as “AND” and “OR” to capture papers via their abstract, title and keywords. The search protocol was refined through several iterations before the final literature search, which involved using the same protocol across both Web of Science and SCOPUS to ensure consistency of results. Merging the results from two sources posed an additional challenge due to duplication of results. However, by utilising the LAT to examine the extracted search results in Microsoft Excel, quick removal of duplicate results by comparing the digital object identifiers was achieved.

As seen in Figure 2 below, the level of research into renewable energy and political economy grew from 2015 onwards, however this trend has not been seen in research that focuses on the UK. This broader literature search for existing research that references renewable energy and political economy only returned 218 results, of which only 10 focused on the UK. Of those 10 UK focused results, just 1 result referenced biomass or bioenergy. This is backed up by the results of the more specific literature search into biomass and political economy, as seen in Figure 3 below. This specific literature search returned 188 results, of which only 7 focused on the UK. Of those 7 UK focused results, just 1 result referenced biomass or bioenergy, the same single UK focused piece of biomass research from the previous broad search (a duplicate). Overall, there were 34 duplicated results across the two searches, indicating the broad nature of biomass research which goes beyond a focus on energy uses, but also highlighting a defined gap in existing research on both the political and economic aspects of biomass use in a UK context.

Analysis of the collated searches revealed a significant increase in papers published focusing on political economy, renewable energy, biomass, and bioenergy from 2010 onwards. This coincides with the beginning of the co-firing of biomass (in this case, compressed wood pellets) and coal on a large scale in the UK, in addition to major European Union (of which the UK was part until 2020) legislation such as the Renewable Energy Directive, which prompted research into the interface between biomass and policy. Due to these points, the literature between 2010 and 2022 was considered, covering 12 years, and the focus on the UK is justified.

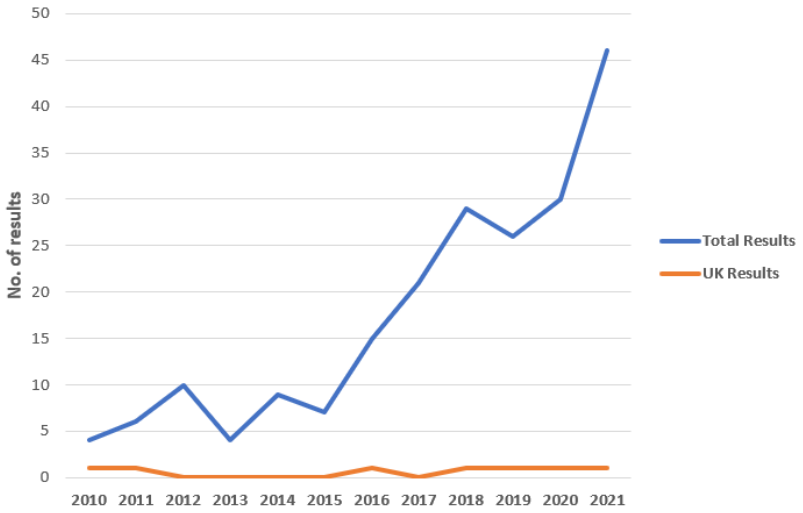

Figure 2 - A graph showing the number of literature search results per year which reference renewable energy and political economy, highlighting the number of results which focus on the United Kingdom.

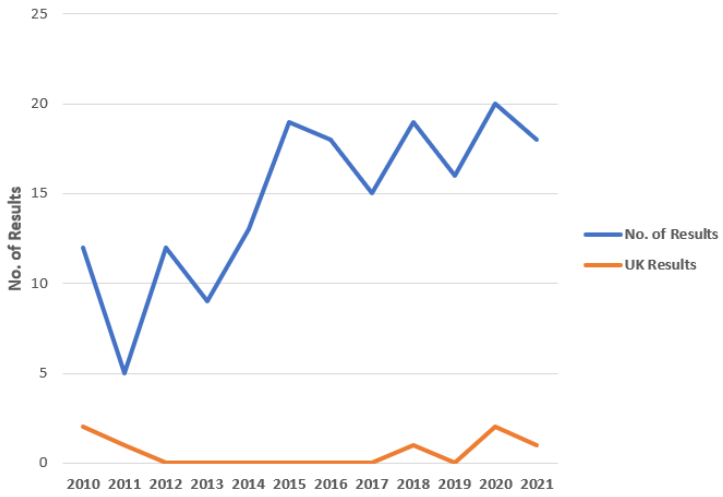

Figure 3 – A graph showing the number of literature search results per year which reference biomass and political economy, highlighting the number of results which focus on the United Kingdom.

1. Planning

- Setting out timescales and identifying initial search terms
- Identifying keywords and topics via research focus mind map

2. Scoping Searches

- Testing and iterating search protocol, "biomass AND political economy", "renewable energy AND political economy"
- Reviewing and refining strategy with information specialists

3. Literature Search

- Final searches using "renewable energy AND political economy OR political ecology" (returning 346 results) triangulating to "bio* AND political economy OR political ecology" (returning 286 results) in SCOPUS and Web of Science
- Identifying a time period to focus on, and refining search protocol further

4. Screening

- Using the Literature Analysis Tool (LAT) to screen papers based on identified research interests and keywords appearing in the abstract

5. Collating

- Collating data on each paper from both databases in the LAT to identify duplicates (removed 34 total duplicates).
- Aligning data in the LAT with reference software EndNote to build bibliography

6. Paper Selection

- Prioritising papers with higher relevance to the research focus using the LAT
- After relevancy check, 68 papers identified within the "renewable energy AND political economy OR political ecology" search for review, and 25 papers identified within the "bio* AND political economy OR political ecology" search for review

7. Data Extraction

- Systematic review of selected papers and note taking
- Analysis of paper data in the LAT to understand the development of research over time in relation to the research focus

8. Quality Assessment

- Analysing abstracts and notes taken of most relevant papers to verify applicability to the research

9. Analysis and Synthesis

- Comparing and contrasting papers, developing arguments and critically analysing arguments made

10. Write Up

- Structuring chapters in the literature review to reflect the searches completed
- Situating the literature within current political contexts and identifying the research gap

Figure 4 - Systematic Literature Review Steps, adapted from Booth et al. (2012)

Screening of papers continued with an analysis of "Relevance", determined by the number of key research interests and keywords which appear in the paper's abstract. Those papers with the highest "Relevance" score were selected for full-text analysis as they were the most likely to focus on research topics relevant to political economy, renewable energy, biomass, and bioenergy. The "Relevance" scores also justified the search protocol, confirming that the papers returned were of interest and related to the research focus and objectives. Collating references in EndNote and processing abstract data in the LAT enabled quick analysis to understand which papers to extract data from, beginning with the papers which scored most highly for "Relevance". Figure 1 outlines the general topics of interest and guides which phrases were searched in each abstract to determine "Relevance". Data extraction, quality assessment, and synthesis were made simpler by leveraging the LAT to prioritise time and focus on the most relevant papers, enabling quick identification of the research gap and achieving the aims of this systematic literature review.

2.2. The politics of renewable energy transitions.

2.2.1. Politicising energy transitions.

Described as "the defining issue of our time" by the United Nations (UN) Secretary-General in 2018 (Guterres 2018), climate change is an inherently "wicked problem" (FitzGibbon and Mensah 2012) that impacts every aspect of life on Earth. The Intergovernmental Panel on Climate Change (IPCC) demonstrates this in its Sixth Assessment Report, which "recognises the interdependence of climate, ecosystems, biodiversity and human societies" (IPCC 2022) and therefore incorporates interdisciplinary science in its review of factors contributing to rising emissions. The time when increasing emissions could have been stopped by technological fixes alone has passed. No single solution exists to halt the climate and ecological crises. Instead, addressing the crises will require societal, political, and economic system changes if we are to limit the impacts of further global temperature rise.

The primary change required within our societal, political, and economic systems is to end the reliance on fossil fuels extracted and utilised for energy and products, emitting carbon dioxide into our atmosphere. Not only has the use of coal, oil, and gas fuelled a rise in global temperatures, but it has also fuelled a rise in global inequality. Many countries worldwide owe their recent historical economic development to the exploitation of fossil fuels, such as the UK's Industrial Revolution, in which coal played a major role (Turner 2021). However, less economically developed countries which did not have the same chance are now restricted in their access to and use of fossil fuels due to the global push towards de-fossilisation. This is made more complex by the state of the fossil fuel market, which has been capitalised on by a handful of multinational corporations, centralising power and profits from the extraction of fossil fuels in the hands of a private corporate elite (Carrington 2022).

The clean energy transition intends to address this by replacing fossil fuels with renewable energy sources like wind, solar, biomass, hydroelectric or geothermal. However, as the impacts of climate change permeate every part of human life (often unequally), the transition to renewable energy is also profoundly interconnected to our wider societal, political, and economic systems. This has severe implications for the decarbonisation of our energy systems, as the move toward renewable energy use threatens the success of successful energy producers, which politicians may seek to protect in exchange for political support (Schwerhoff and Sy 2019). Changes to these energy systems will create sustainability benefits, trade-offs, winners, and losers. This has led to the increased politicisation of the energy transition, as actors are motivated to protect their interests, ensure they benefit from changes and avoid costs which will impact their profitability.

2.2.2. The political economy of renewable energy.

Leading policymakers and government actors leverage green modernisation narratives to further their goal of protecting the triple bottom line of people, profit, and the planet. The prioritisation of technological fixes (technofixes) to address global challenges, such as poverty and climate change, is permissible under the United Nation's sustainable development agenda (Bergius and Buseth 2019). Within the wider sustainable development movement, this encourages actors to seek perceived "win-win" scenarios via technofixes which deliver socio-economic benefits (people), financial growth (profit), and environmental protection (planet).

The same "win-win" scenarios are sought within the energy transition, with grassroots-level storylines based upon imagined futures of energy self-reliance and security, ecological sustainability, decentralisation and community-level governance (Morris 2013). However, Morris (2013) argues that successful renewable energy projects integrate into existing social, technological, and economic structures to maintain the status quo, utilising eco-modernisation strategies to ensure they deliver environmental and social benefits. Since eco-modernisation is built upon the premise that environmentalist policies will benefit the economy and lead to growth, renewable energy projects must develop within the confines of an existing market-based system, primarily focusing on economic development. Similarly, Jasanoff and Simmet (2021) highlight how a top-down approach, such as a technofix presented to the public as a solution to the energy transition, will maintain the status quo if energy consumers do not consider more power or distributed ownership a priority. Unless they are presented with or involved in an outline for a 'better future', consumers' needs may be met by an unsustainable technology that ensures they can still heat their homes or put the lights on, rather than linking the energy transition to societal change.

This contrasts with the principles of a 'just' transition for energy, propagated by many grassroots actors seeking to link social justice movements to environmentalist movements, delivering a "win-win" for people and the planet. The empowerment of communities brings social justice in the form of energy justice through the ownership of domestic policy reform, where a range of actors have input in renewable energy projects. However, this is more difficult to achieve where policies favour market-based solutions (Muller, Claar *et al.* 2020). This is more complex when policies are enacted nationally at a central level without consideration for local contexts. In contrast, localised interventions promote opportunities for co-designed socio-economic programmes alongside energy technology transfer (Muller and Claar 2021). Despite this, supporters of energy justice seek to address the energy trilemma of secure supply, affordability, and sustainability by diversifying the energy sources and actors involved, protecting consumers from global price fluctuation, and moving away from fossil-based sources.

Whether developed via market-based solutions or not, the success of small-scale renewable energy projects relies on political, economic, and technological alignment. This is more easily achieved through programmes that promote community participation and empower local people to own the new system when supported by a robust marketing plan, demonstration project, and promotion to and within the identified community of beneficiaries (Sovacool 2018). Sergi, Babcock *et al.* (2018) support this, adding that the success of niche renewable energy projects relies on an environment that promotes innovation, where the decentralisation of power occurs through loosened regulatory frameworks and clear frameworks for tariffs are provided to small-scale operators. However, it is important to note that due to the complexity of the energy transition, it is not an either/or scenario; there is potential for centralisation and decentralisation of power to take place at many different levels within public or private models of ownership (Ferrall, Heinemann *et al.* 2021).

Whilst decentralisation is touted as the key to the success of innovative renewable energy projects, Spivey (2020) identifies that it comes with risk to the state who are charged with the sustained provision of energy at a national scale; therefore, all interventions will be subject to public scrutiny as they hold the power to shape profitability in the private energy market. Spivey (2020) continues by pinpointing market-based approaches as the cause for this risk, as state intervention must ensure low power rates for consumers while balancing the interests of incumbent energy producers who hope the intervention does not impact the value of their investments and assets. This limits capitalism's ability to achieve the socioecological changes needed to address climate change through renewable energy. The state is driven to balance the conflicting interests of energy stakeholders to ensure the delivery of energy security on a national scale. Even though it is the responsibility of the state to ensure

the provision of energy on a national scale, the marketisation of energy means it is a commodity to be traded rather than a public service (Ferrall, Heinemann *et al.* 2021); this determines the relationship between the state, the people and energy producers.

Despite asserting that market-based approaches put renewable energy deployment at the mercy of powerful actors, Cetkovic and Buzogany (2016) highlight that different market-based economies have differing successes with their energy transitions. In contrast to the centralised decision-making system of the government in the United Kingdom, more liberal and entrepreneurial types of environmentalism have developed in countries such as Germany, where political decentralisation has occurred. This has led to freedom in the renewable energy market as the impact of state interventions such as taxes and subsidies is reduced (Wang, Moreno-Casas *et al.* 2021). Conversely, centralised decision-making at a national government level in the UK has stifled technological and policy experiments that could potentially lead to renewable energy success (Cetkovic and Buzogany 2016).

Temper, Avila *et al.* (2020) further develop this perspective to highlight that decarbonisation within any economy is not a standalone process but interwoven with social issues that market-based approaches cannot deal with alone. Localised community-based approaches seek to mobilise people, reshape, and challenge the existing energy system to redistribute power, address social issues, increase democratic participation, shorten energy chains, and seek climate justice (Temper *et al.*, 2020). They outline how policymakers involved in climate and energy should consider these points, building on Spivey's (2020) perspective that the state must balance the conflicting interests of various actors within the energy system by adding social and ecological pressures to the mix. This demonstrates the politicisation of the energy transition, where stakeholders compete to maximise the benefits of the energy transition for their own gain, meaning policymakers are left to decide who 'wins' and who 'loses'.

Fathoni, Boer *et al.* (2021) also pinpoint existing power asymmetries within energy systems that favour incumbent energy producers, highlighting that decentralising these systems will challenge the incumbents' power and dependency on fossil fuel fuel-based systems that maintain the status quo. Fathoni, Boer *et al.* (2021) argue that focusing on a variety of small-scale actors will bring in diverse perspectives, challenging the marginalisation of community voices by dominant actors in the energy system, such as incumbent energy producers. However, this relies on engaged civic participation (Morris 2013), which Bhamidipati and Hansen (2021) argue is the state's responsibility to foster by building capacity and knowledge within local communities. This is not without risk, though, as decentralised energy approaches such as community development trusts can be vulnerable to

corporate capture when community projects are co-opted by commercial interests that engage in a top-down hierarchy under the guise of knowledge transfer (Harnmeijer, Toke *et al.* 2018).

Whilst civic participation in renewable energy deployment is key to project success, mobilising political support in the immediate term differs depending on local people's specific needs. For example, Lakhanpal (2019) identifies that contentions around the deployment of renewable energy technologies differ depending on a country's developmental state, as do the expectations of national and local actors involved in transition projects. In developed states, there is more likely to be public resistance to a renewable energy project on the grounds of aesthetics or location. In contrast, in developing states, conflicts are more likely to arise over access to land or impact on livelihoods (Lakhanpal 2019). Despite this, Garrido, Sequeira *et al.* (2020) find that developed nations with higher income are in a position to be more concerned with environmental and climate issues than developing nations, with greater emphasis on environmental sustainability within research. This implies that although developed states can deploy and harness renewable energy sources, local communities are likely to be more concerned about the potential for change to their local environment and landscapes than decarbonising energy systems, thus creating contestation.

Whether in developed or developing nations, land use and the environment are important factors in deploying renewable energy, playing a pivotal role in the politics and processes that determine political support for renewable energy projects over time. This is due to how local communities perceive landscapes, which are often challenged by deploying renewable energy technologies, such as wind turbines being installed on hillsides (Calvert, Greer *et al.* 2019). This is supported by McCarthy and Thatcher (2019), who identify how different renewable energy sources have different geographies and differ on issues of land use, criticising top-down approaches which view land as available for renewable energy deployment regardless of its value to local people. Much like the way market-based approaches value energy as a commodity rather than public good (Ferrall, Heinemann *et al.* 2021), renewable energy deployment also raises questions about how land is valued and what services it offers from a local, national, and international perspective.

Land use is a prime example of how the tension between national and local priorities can also detract from the success of renewable energy deployment. Baker and Sovacool (2017) outline how national government priorities will be driven by state responsibility to provide reliable and increasingly sustainable energy supplies; their priority will be least-cost technologies that deliver maximum carbon reductions, such as solar parks or wind turbines. This may contrast with local demands where communities resist large infrastructure development, seeking greater compensation for political support, such as improved livelihoods and increased productivity (Osiolo, Pueyo *et al.* 2017). Adding

international dimensions further complicates this, as whilst globalisation has opened opportunities for international energy markets via the mobility of production, renewable energy developments are at the mercy of global risks and geopolitical tensions (Baker and Sovacool 2017).

2.2.3. Implications for renewable energy transitions.

Several key themes stand out within the literature on the political economy of renewable energy transitions, summarised below in Figure 5. The complexity of the transition is apparent when observing the many levels over which it must occur, as it transcends borders at a global level, down to differing between communities at a local level. This raises the question of who should make the decisions and at which level. In a capitalist economy such as the UK, this is complicated by the role of private interests and the implications for the elected government's social contract with the public, to whom they are responsible for providing reliable and affordable energy. The politicisation of the energy transition has occurred, as policymakers must now decide how to implement policy that achieves the UK's net zero ambitions, whilst determining who wins and loses in the transition to renewable energy.

This will mean trade-offs for people, profits, and the planet, all of which are threatened by today's climate and ecological crises. These trade-offs will motivate different actors to protect their long-term interests and influence the political economy of renewable energy transitions, determining the distribution of potential wealth and growth arising from de-fossilising our economy. The conflict between public and private interests arises at local, national, and global levels, which fuels debate over who should own our energy systems. This demonstrates that privatisation and centralisation can occur at many different levels. Renewable energy transitions offer an opportunity to challenge existing political and economic institutions as a vehicle with which local or marginalised communities can argue for social and environmental benefits, calling for change from the economic status quo.

	 **Social Contract** (Why?)	 **Energy Decarbonisation** (What?)	 **Approach** (How?)
Main Points	*Policymakers are responsible for ensuring a secure, affordable national energy supply.* *In return, policymakers receive political support from the public.* *Competes with the powerful vested interests of energy incumbents in capitalist economies.*	*A variety of renewable energy options are available, each with different benefits and trade-offs.* *The challenge for policymakers is to implement decarbonisation without impacting the terms of their social contract with the people.* *Energy incumbents lobby for technology lock-in and path dependency, which protect their financial assets.*	*Local approaches are more likely to mobilise political support, whereas top-down approaches are more likely to maintain a status quo.* *Decentralised, co-designed approaches build buy-in, involve more diverse actors.* *Renewable energy transitions can provide a vehicle to practice alternative economic approaches.*
Questions	*Does the social contract include an environmental element too?* *How are public and private interests represented and reconciled in policy?*	*Which technologies should be supported, and how does policy support them to replace fossil fuels?* *Which technologies offer an opportunity to maintain the social contract and appease private interests?*	*Who should intervene, and at what level?* *Decentralisation vs centralisation of political, economic, and social power?*

Figure 5 - A table demonstrating the key themes and questions which arise from the existing literature on renewable energy transitions and political economy.

2.3. Using bioenergy to achieve net zero.

2.3.1. The political economy of bioenergy systems.

Biomass is unique in its position as a renewable energy source, as the only source of non-fossilised carbon; however, its use for energy is controversial and the focus of negative media attention (Crowley 2022). Other renewable energy sources, such as solar and wind, are often idealised as the perfect solution to society's climate, ecological, and energy crises. The use of biomass for energy is subject to greater scrutiny due to the way it is interconnected with nature, ecological systems, and our land. Whilst public resistance to the development of wind and solar farms has opposed change in landscapes, the image of bioenergy focuses on the extraction of biomass from our natural world. It is sometimes disconnected from our immediate landscapes (such as the import of biomass from other countries). In the UK, this image works against developing, cultivating, and using biomass feedstocks like energy crops (van der Horst and Evans 2010). Despite all renewable energy sources being extractive in nature (e.g., precious metals to produce photovoltaic cells for solar panels, embodied carbon in the construction of huge wind farms), the image problem associated with biomass use is due to the extraction of it from our natural world, such as fields and forests. The process of extraction can be measured using models such as the Human Appropriation of Net Primary Production (HANPP), which demonstrates human impact on the biosphere, primarily driven by the increase in the productive capacity of natural ecosystems by their conversion to managed lands (Krausmann, Erb *et al.* 2013).

The framing of bioenergy as either “good” or “bad” in public discourse makes the implementation of policy even more difficult, as often the trade-offs associated with bioenergy projects are context-specific, warranting multidisciplinary analysis into the sustainability of bioenergy deployment (Hess, Sumberg *et al.* 2016). For example, in developing nations where fuel poverty can be more prevalent, the inefficient combustion of low-quality biomass in residential settings produces negative social and environmental outcomes. Still, these are only likely to be overcome by policy that addresses social, political and cultural barriers (Sovacool 2012), going beyond technical measures focusing on efficiency or process optimisation. Both Hess, Sumberg *et al.* (2016) and Sovacool (2012) demonstrate the complexity of achieving success in bioenergy deployment and emphasise the need for context-specific, multidisciplinary analysis (such as political economy) to highlight non-technical barriers to using biomass sustainably. Biomass technology can offer viable opportunities to empower local communities to manage their own energy needs, however aside from the economic and technological factors involved, the most successful projects often focus on capacity building and developing alternative livelihoods for local people to ensure the longevity of the system implemented (Palit, Sovacool *et al.* 2013, Röder, Jamieson *et al.* 2020, Röder, Mohr *et al.* 2020, Röder, Chong *et al.* 2022).

Singh and Singh (2019) build on this, asserting that bioenergy projects delivered as top-down technofixes ignore historical, political, and cultural contexts, leaving societies at the mercy of private industrial interests which dominate discussions at the cost of long-term sustainability objectives. Similarly to the literature on other renewable energy transitions, Singh and Singh (2019) highlight the need to mobilise popular support for bioenergy projects via engagement and discussion with the public if they are to be politically viable and sustainable. However, this can prove difficult to implement in practice as this opens up the opportunity for bioenergy projects to practice alternative economic approaches which challenge the status quo, therefore structural power resists changes to locked-in path-dependent fossil fuelled energy systems (Hielscher, Seyfang *et al.* 2011). Given that existing economic approaches to energy provision in the UK have delivered massive profits and political influence to fossil fuel companies, it is justifiable to suggest that sustainable bioenergy deployment could challenge this status quo via alternative economic approaches, such as the one suggested by Purkus (2016).

Purkus (2016) demonstrates that bioenergy policy could benefit from a new institutional economics approach that goes beyond a focus on efficiency measures, opening opportunities for policy design that seeks to change at an institutional level (Purkus, Röder *et al.* 2015). However, as outlined by Hielscher, Seyfang *et al.* (2011), the threat of change motivates existing power structures, such as incumbent energy producers, to seek to minimise the impact of potential change on their finances. One way they can achieve this is through engagement with the bioeconomy via green technofixes. Backhouse and Lorenzen (2021) highlight where existing agro-industrial companies have monopolised technological advancements to dominate knowledge generation and force future technical path dependencies on society for their own benefit. In a nation with access to an abundance of biomass resources, the risk of this taking place is increased, as biomass resource availability can encourage industrial interests to diversify their portfolios, extracting and utilising what they can to maintain financial power. Whilst it might seem that biomass availability leads to an easier transition away from fossil fuels, a different approach is required to minimise any negative impacts and ensure a just transition that achieves social and environmental objectives (La Rovere 2020).

2.3.2. The impact of net zero on bioenergy.

One key driver of changes to reduce greenhouse gas (GHG) emissions has been the emergence of 'net zero' goals and targets. The term encompasses efforts to ensure that any GHGs emitted into the atmosphere are counteracted by GHGs removed from the atmosphere so that the net emissions balance is zero. This means additional GHGs like carbon dioxide and methane are no longer being added to the atmosphere, contributing to rising global temperature change. Critics of bioenergy draw on similarities between biomass and fossilised carbon sources to argue that it maintains the existing

economic order, adds to atmospheric carbon, and acts as a simple drop-in for coal-fired power plants by engaging in a "biomass is the new coal" narrative (Harrison 2021). Conversely, supporters of bioenergy argue that the atmospheric carbon removed from the atmosphere when the biomass is grown balances with the carbon emitted when it is converted to energy; therefore, bioenergy can be net zero.

Whilst the arguments for and against bioenergy are often over-simplified and lack place-specific context, reducing those arguments to carbon balances within net zero systems commoditises carbon as something that can just be accounted for. This commodification of carbon can drive actors to focus on carbon reductions and economics, detracting from the potential of bioenergy to deliver environmental, social, and political benefits (van Rooijen 2014, Backhouse and Lorenzen 2021, Röder, Chong *et al.* 2022). However, going beyond the focus on carbon exposes the complexity of bioenergy systems, contributing to the differing perspectives in the public debate on biomass. This dissonance in the debate between private and public interests can lead to an inequality in benefits between the actors involved in bioenergy deployment, access to biomass resources, and the political structures that exist thereafter (Duvenage, Taplin *et al.* 2012).

Public perspectives are something which environmental non-governmental organisations (NGOs) have been able to leverage in their critique of biomass use by generating uncertainty around bioenergy sustainability, undermining the viability of biomass as an energy source (van der Horst and Evans 2010). Pilgrim and Harvey (2010) assert that political intervention by the state to achieve environmentalist objectives, such as carbon reductions, opens bioenergy sources to environmentalist scrutiny, often driven by political opportunity as opposed to scientific evidence. This has created an environment in the public discourse on biomass use that allows NGOs and private industrial actors to put forward their policy positions on bioenergy mostly unopposed, as the public capacity to challenge claims is reduced due to a lack of awareness and knowledge of the complexity of bioenergy systems. In the UK, this is demonstrated by public polling, which shows that the public knows the least about biomass compared to other renewable energy sources (Survation 2022).

2.3.3. The UK bioenergy policy situation.

In 2019, the UK government became the first government in the world to pass a law to achieve net zero emissions by 2050 (GOV.UK, 2019). Progress against this target is monitored by the UK's Climate Change Committee (CCC). They are an independent advisory board that advises the UK government on carbon budgets, climate change adaptation, and mitigation measures. In their latest progress report, the CCC made recommendations to the government, covering every aspect of decarbonising the UK, including the role of biomass in achieving the UK's net zero target. As well as highlighting the

need for specific policy and action on utilising biomass for energy, the CCC also demonstrate how comprehensive policy development across areas such as land, waste management, and industrial decarbonisation need to include coordinated biomass elements (CCC 2022). However, this was not fully established in the UK's revised 'Biomass Strategy' (DESNZ 2023), published in 2023. Beyond the UK CCC's advice, a wide range of policies at national and international levels impact the deployment of bioenergy in the UK, summarised below in Figure 7.

Unlike other renewables, biomass is uniquely placed to offer the potential for negative emissions, resulting in the overall removal of carbon from the atmosphere, and the development of net zero ambitions has legitimised and enabled this. Carbon removals from engineered solutions, such as bioenergy with carbon capture and storage (BECCS), or natural solutions, such as afforestation, will support negative emissions and enable emission offsets for other difficult-to-decarbonise sectors. Bodies like the IPCC and the CCC acknowledge that carbon removals will be required to meet net zero targets and reduce global temperature rise to 1.5 °C (CCC 2022, IPCC 2022). The government's ambitions in the UK rely heavily on engineered carbon removals to meet their net zero obligations. However, this creates a risk of path dependency on a technology not yet proven at scale. Bioenergy has therefore afforded the government some policy relief in accounting for the UK's carbon emissions, as they anticipate technological advancements in carbon capture that will enable a continued focus on economic priorities without drastic policy change to achieve the environmental priority of net zero (Levidow and Raman 2020).

The UK government's position has been to maintain the economic status quo and the social contract they have with the public, delivering energy on a national scale at an affordable rate, with minimal disruption to people's lives. Government focus has turned to anticipating technofixes and top-down initiatives to avoid radical societal, political, and economic system changes that the UN call for (Guterres 2018). These top-down initiatives are based on individual consumer action, such as incentivising recycling schemes, active travel options such as bus and train travel, and changing diets. Energy market interventions such as the Renewable Transport Fuel Obligation (RTFO), Renewable Heat Incentive (RHI) and the Contracts for Difference (CfD) scheme place emphasis on financial incentives to generate market competition and push innovation as the solution. This is significant for biomass use in the UK, which represented 11.6% of total electricity generation in the first quarter of 2022 (BEIS 2022) and continues to play a primary role in the UK's energy mix (see Figure 6 below).

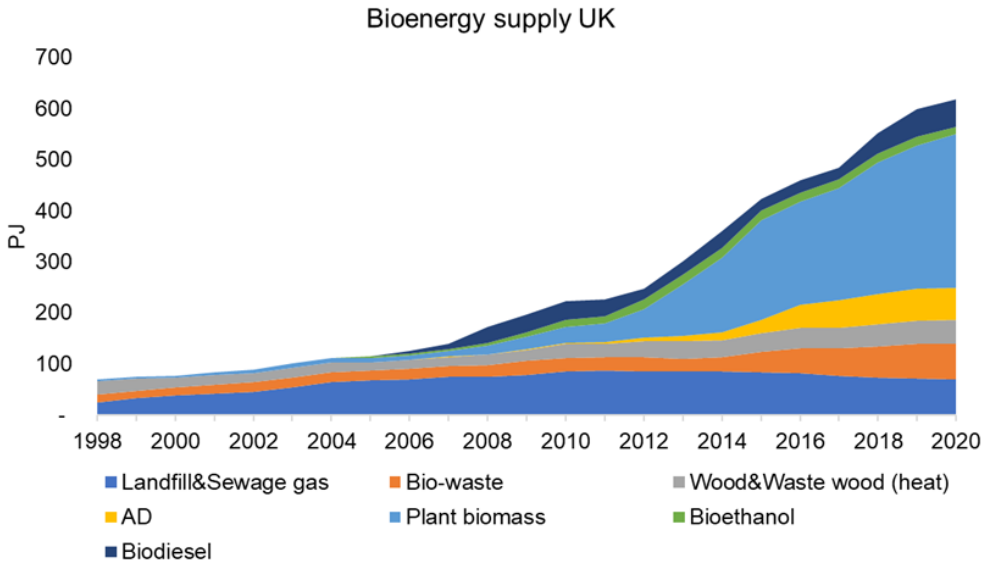

Figure 6 - A graph detailing the mix of bioenergy supply in the UK, adapted from the Digest of UK Energy Statistics (DUKES) (BEIS, 2022)

The largest contributor to the generation of electricity from biomass in the UK is the Drax power plant, located in North Yorkshire. Previously a coal-fired power facility, Drax has been converting the units of its power plant to use biomass instead of coal over the past ten years, with two out of six units awaiting conversion. With a total capacity of almost 4 gigawatts, Drax power station is the largest power station in the UK; however, its business model relies on two inputs subject to intense media scrutiny (Crowley 2022). The first is importing biomass from overseas, sourced in North America, where the biomass is harvested and processed into wood pellets before being transported to Drax's facility in the UK. The second is relying on government subsidies to guarantee their financial operations in exchange for converting their facilities from coal to biomass (Treasury 2013). Despite this, Drax seeks further financial support from the UK government to support the development of their BECCS facilities, which they hope will enable them to deliver on the government's ambitions for engineered carbon removals. This reflects the UK government's continued reliance on technology development to achieve net zero targets without disrupting the current economic order, which industrial-scale biomass operations like Drax can fulfil.

Year	Policy Event	Source Level	Description	Relevancy	Context
1990 - 1992	Non-Fossil Fuel Obligation	UK	Introduced to encourage electricity generation from non-fossil sources.	Initial market mechanism supporting bioenergy.	Driven by the need to diversify energy supply and support emerging renewables.
	Rio Earth Summit	Global	UN conference establishing principles for sustainable development	Set the global environmental agenda including forests and energy.	Occurred amid growing international environmental awareness.
1997 - 2002	Kyoto Protocol Adoption	Global	International treaty to reduce greenhouse gas emissions.	Includes biomass as a potential mitigation tool.	Response to mounting evidence of fossil fuelled climate change.
	EU Directive on Biofuels for Transport	EU	Directive promoting the use of biofuels in transport.	Direct incentive for bioenergy in transport.	Part of early EU climate and renewable energy commitments.
	Renewable Obligation Certificates	UK	Mandated electricity suppliers to source a proportion from renewables.	Key policy promoting electricity production from biomass.	Created to replace earlier support schemes like the Non-Fossil Fuel Obligation.
2005 - 2008	EU Emission Trading Scheme	EU	Cap-and-trade system for carbon emissions within the EU.	Indirect relevance via biomass carbon dioxide neutrality.	Established as a market-based tool for emissions reductions.
	Kyoto Protocol Action	Global	Actions and deliverables against the previously published Kyoto Protocol.	Included bioenergy as part of carbon reduction measures.	Followed UK's ratification of Kyoto and legislative action on emissions.
	EU Biomass Action Plan	EU	Outlined actions to promote biomass energy use across the EU.	Key strategy for bioenergy promotion.	Resulted from recognition of biomass potential in EU energy mix.
	Clean Development Mechanisms	EU	Kyoto mechanism allowing investment in emission reduction projects in developing countries.	Many projects included bioenergy.	Created to support cost-effective global emission reductions.
	EU Biofuels Strategy	EU	Outlined approach to increase biofuel use and sustainability.	Aimed at scaling bioenergy sustainably.	Driven by increasing oil prices and emission reduction targets.
2008	Climate Change Act	UK	Legally binding framework to reduce UK emissions 80% by 2050.	Includes bioenergy as a low-carbon option.	First law of its kind globally; driven by science and public pressure.

2009	Renewable Transport Fuel Obligation	UK	Requires fuel suppliers to use renewable fuels.	Promotes biofuels in UK transport sector.	Followed EU Biofuels Directive and aligned with UK emission goals.
	EU Quality Standards for Fuels & Biofuels	EU	Set standards for environmental sustainability of fuels.	Ensured biofuels met GHG and land use criteria.	Developed alongside RED to prevent adverse impacts of biofuels.
	EU Renewable Energy Directive Update	EU	Updated RED to increase targets and sustainability criteria.	Continued the commitment to sustainable bioenergy.	Strengthened EU climate policy in light of 2020 targets.
2010	Feed-in-tariffs	UK	Payments for small-scale renewable electricity producers.	Supported small-scale biomass installations.	Introduced to diversify renewable electricity generation.
2011	Renewable Heat Incentive	UK	Incentive for heat from renewable sources including biomass.	Key policy for biomass heating uptake.	Addressed need for decarbonising heat sector.
2012	UK Biomass Strategy	UK	Guidance on biomass production and energy use.	Foundational strategy for UK bioenergy sector.	Part of broader push to develop UK renewable strategy.
2013	Contracts for Difference	UK	Support mechanism for low-carbon electricity generation.	Includes biomass within contracts.	Part of UK Electricity Market Reform to secure investment.
	IPCC Fifth Assessment Report	Global	Major IPCC report summarising climate science and mitigation options.	Highlighted the role of bioenergy in scenarios.	Served as scientific foundation for future global agreements.
-					
2015	Paris Agreement	Global	Legally binding international treaty on climate change.	Reaffirmed biomass as part of mitigation portfolio.	Result of global consensus to limit warming to 1.5–2°C.
2016	EU 2030 Climate & Energy Framework	EU	Set new targets for 2030 on emissions, renewables, and efficiency.	Committed to bioenergy role in EU energy mix.	Developed after progress under 2020 framework.
-					
2018	UK Declaration of Climate and Ecological Emergency	UK	Formal UK Parliament declaration of climate and ecological emergency.	Symbolic but pressured government action on climate including bioenergy.	Sparked by public activism and scientific urgency.
	UK legislation for net zero by 2050	UK	Legal commitment to net-zero emissions by 2050.	Bioenergy given essential role in the pathway.	UK was first major economy to enshrine net zero in law.
	EU Renewable Energy Directive II	EU	Revised Renewable Energy Directive for post-2020 targets.	Introduced new criteria for bioenergy sustainability.	Update to align with 2030 climate and energy goals.
2019	Renewable Energy Guarantee of Origin	UK	Certification scheme for renewable electricity origin.	Supports transparency for biomass sourcing.	Helps consumers and businesses support green energy.
	Climate Change Act Amendment	UK	Updated Climate Change Act to reflect net zero by 2050.	Strengthened legal basis for bioenergy supporting net zero.	Driven by increasing climate urgency and public support.
2020	Brexit	UK	UK leaves the EU.	UK had to realign EU-linked bioenergy frameworks and policies.	Impacted environmental regulation continuity post-EU.

2021	Green Gas Support Scheme	UK	Subsidy scheme to support green gas including biomethane.	Targeted support for biogas supply.	Introduced to decarbonise heating and support gas grid injection.
-					
2023	Revised UK Biomass Strategy	UK	Updated biomass strategy addressing sustainability and use.	Current revised guiding strategy for UK bioenergy.	Reflects lessons from past and includes net zero ambition.

Figure 7 - A table showing policy developments relevant to bioenergy on global, European Union and United Kingdom levels since 1990.

2.4. Conclusion

The transition from fossil fuels to renewable energy requires significant change within our political, social, and economic systems; the politicisation of our energy systems further complicates that. Existing research into the non-technical aspects of renewable energy transitions highlights the challenges facing decision-makers in trying to further this transition. Firstly, the existence of a social contract between elected governments and local communities challenges policymakers to provide secure and affordable energy on a national scale, which can conflict with the interests of powerful private actors, e.g., incumbent fossil-fuelled energy producers. Secondly, the choice of which technologies to support to achieve energy decarbonisation, whilst navigating the competing priorities of the electorate and private interests and how these technologies impact the centralisation or decentralisation of power (in both a socio-political and energy production sense). Finally, the approach policymakers use to incentivise support for technologies or projects, determining beneficiaries and garnering political support, as energy transitions are also vehicles to challenge the status quo, redistribute wealth, and practice alternative forms of economics. It is clear from existing research that the political economy of renewable energy transitions is just as important to the success of the innovation in displacing fossil fuels, as the technological challenge of the innovation itself. Without a supportive and enabling environment for renewable energy technologies to scale and deploy, they will not decouple existing systems from fossilised sources of energy.

Reducing our reliance on fossil fuels and transitioning to net zero energy systems goes beyond the challenge of decarbonising our technology and includes non-technical, economic, social, and environmental factors. The politicisation of the energy debate, whereby stakeholders are motivated to engage in debates and policy to ensure they are likely to benefit from the transition, means political factors must also be considered. Research into the non-technical factors that impact the success of renewable energy technologies in replacing fossil fuel use demonstrates that the transition to renewable energy sources can change how benefits are distributed, where wealth is created, and where inequalities lie within the energy system. This means the transition to net zero poses risks to some stakeholders and rewards to others; however, these risks and rewards will be primarily determined by policy. This is particularly complex and controversial for biomass. Like fossil fuels, biomass is extracted from our planet for various applications, including energy. Furthermore, biomass extraction from our natural world involves many complex interactions with wider systems, making it difficult to engage with. Suppose this is done under the same extractive economic principles and practices as the fossil fuel industry, which has amassed vast power in the hands of a few multinational corporations. In that case, this has implications for the distribution of wealth, benefits, and inequality within our energy systems that must be considered.

Biomass is expected to play a role in the transition to net zero energy systems. However, there is little research on the non-technical factors impacting policy design for its use in the net zero transition or the subsequent sustainability implications of that policy. Uncertainty of public opinion on biomass sustainability allows actors to exploit the policy debate and make authoritative claims over knowledge of biomass supply chains, asserting themselves as experts, sometimes to further their interests or protect their assets. This presents a challenge for policymakers as they seek to maximise the benefits of using biomass to achieve their policy agendas, like net zero. However, they cannot do so without the support of both the public and private stakeholders. The current political economy determines how biomass is extracted from our natural world, by who, and how they benefit from its extraction. This raises questions the questions and themes posed in Figure 8 below. Therefore, the success of using biomass sustainably to contribute towards solving the climate, ecological, and energy crises will depend on the impact of our political economy on this finite natural resource, warranting further study.

	 **Public Perspectives**	 **Biomass Flexibility**	 **Net Zero and Carbon Balances**
Main Points	*Public debates are being exploited by self-interested actors who assert their authority to influence knowledge of and decisions about biomass use.* *Differing perspectives and framing can undermine public trust in biomass use.* *Extractive image of biomass can work against its deployment in energy contexts (van der Horst and Evans 2010).*	*Place-based contexts are vital for biomass use.* *Broad number of feedstocks, broad number vectors with a variety of applications, broad number of challenges that biomass can potentially contribute towards overcoming.* *Complex interactions with our environmental and atmospheric systems make it difficult to engage with.*	*Net zero legitimises negative emission technology approaches that use biomass, setting it apart from other sources of renewable energy.* *Can open opportunity for government to prioritise technofixes which promise carbon removals, which allows for policy relief.* *Threatens over-simplifying biomass projects by focusing on carbon, which could lead to unintended externalities.*
Questions	*How to support public decision-making on using biomass?* *How is biomass policy distributing the benefits of using biomass to achieve net zero?* *How is the policy impacted by public perspectives on biomass?*	*Which biomass feedstock is most suited to which use(s)?* *Where (both geographically and energy system-wise) can biomass use contribute to net zero?*	*How will biomass use contribute to net zero under the current political economy?* *What benefits and trade-offs exist in using biomass to achieve net zero?* *How has policy shaped who benefits from biomass to date, and will that change to achieve net zero?*

Figure 8 - A table demonstrating the key themes and questions which arise from the political economy of using biomass to achieve net zero in the UK.

3. Methodology

3.1. Selection of the theoretical approach

The purpose of this research is to examine the interactions between environmental, economic, political, and social factors influencing the use of biomass in achieving net zero goals. Given the inherently cross-cutting nature of the topic, several multidisciplinary theoretical approaches were considered during the initial stages of the research design. One possible framework was environmental sociology, which offers a valuable lens through which to understand the relationship between society and the environment, particularly by focusing on the social construction of environmental issues and the ways in which societies adapt to and shape ecological change (Lockie 2015). While this perspective aligns closely with the social and cultural dimensions of biomass use, it falls short in accounting for the power dynamics and institutional frameworks that play a critical role in shaping environmental decision-making. As such, while environmental sociology is relevant, it does not fully address the political structures and economic incentives that are crucial to understanding biomass deployment within the UK's national net zero strategy.

Another possible theoretical framework considered was Science and Technology Studies (STS), which is particularly strong in unpacking the co-production of technology and society (Sismondo 2004). STS could have offered unique insights into how biomass technologies are developed, accepted, or contested within different sociotechnical systems. It also considers the roles of expertise, knowledge production, and technological narratives in shaping the success of innovation. However, similarly to environmental sociology, STS does not focus on the political and economic power relations that structure policymaking. STS tends to focus more on the dynamics of knowledge and practice at a micro-level, whereas this research seeks to interrogate macro-level systems such as, economic incentives, policies, regulations, and institutional influence. Therefore, while STS could have provided useful tools for examining the sociotechnical framing of biomass, it would not have captured the broader political and economic forces influencing its deployment in the UK.

Alternatively, this research could have drawn from the field of institutional theory, particularly ecological or historical institutionalism, which explores how rules, norms, and structures influence stakeholder behaviour within political and economic systems. Institutional theory offers a valuable perspective for analysing how the legacy of certain policies and institutional arrangements impact the governance of biomass and the persistence of certain policy pathways. For example, it could help to explain how existing regulatory frameworks enable or constrain low-carbon biomass deployment. However, institutional theory can lean toward structural determinism, offering limited insight into the role of agency, conflict, and political strategy in shaping institutional change. Political economy, by

contrast, treats institutions not just as constraints, but also as outcomes of political struggles, allowing for a richer understanding of how institutions evolve in response to competing interests, economic pressures, and public discourse.

Finally, the Multi-Level Perspective (MLP) on socio-technical transitions, which examines system change across niche innovations, regime stability, and landscape pressures (Geels 2002) could have provided a valuable lens to approach the research. This approach is particularly relevant in the context of energy transitions and offers a structured framework for analysing how emerging technologies like those involving biomass compete with, or complement, existing systems. However, MLP is limited in its focus on power, governance, and political agency. It tends to focus more on the structural and evolutionary dynamics of transitions, rather than the contested nature of policymaking and resource allocation, which would be particularly relevant to biomass policy decision-making. In contrast, political economy explicitly prioritises questions of power, distribution, and institutional design, which is vital when considering the equity and legitimacy of biomass strategies within the broader move to achieve net zero.

In summary, whilst each of these theoretical approaches offer valuable insights into specific dimensions of using biomass to achieve net zero, political economy provides the most comprehensive and critical lens. It lends itself to the analysis of discourse, institutions, and power, allowing for the examination of the distributional impacts associated with biomass use, the role of public perception, and interrogation of the environment surrounding policy design. The broad nature of political economy provides a comprehensive approach to understanding the complex contexts and factors influencing biomass policies and practices, in line with the purpose of this research, as outlined in the following section.

3.2. Political economy and biomass

Given the complexity of climate change and the transition to clean energy, which transcends borders and impacts interconnected systems at international, national, and local levels, a broad research approach considering these contexts is justified. Political economy is a transdisciplinary field focusing on the links between the societal, political, and economic systems, which impact policy that determines aspects of an economy such as wealth distribution, growth, and inequality. A political economy approach supports inquiry larger than local situations and into generalised patterns of power structures. Since climate change mitigation and energy transitions must occur at local to international levels, it is an appropriate approach to research renewable energy transitions (Perkins 2019). A political economy approach will enable a comprehensive analysis of the forces that impact the sustainable deployment of a particular renewable energy source (in this case, biomass) in the UK. As

biomass is derived from nature, and our physical environment cannot be decoupled from political and economic forces, a political economy approach will also enable the exploration of how processes of capitalism drive environmental change (van der Horst and Evans 2010).

The field of political economy also lends itself to research on sustainable policies for energy transitions. Johnstone and Stirling (2020) assert that the capacity for mobilising political support for energy policy change is as important as the reasoning behind the policy itself. Therefore, understanding the political institutions and motivations behind energy transitions is crucial to understanding their success. Similarly, Edmondson, Kern *et al.* (2019) identify that sustainable policy for energy transitions will focus on creating incentives that generate political support, providing positive feedback and further mobilising additional supporters through time. It is not enough to deploy a sustainable energy solution; mobilising support will ensure the longevity of any benefits accrued from the transition. Despite this, Garrido, Sequeira *et al.* (2020) find that whilst research in developed nations has shifted towards the environmental sustainability of renewable energy options, little analysis has been done on the transition to renewable energy technology concerning social, economic, or political factors. A political economy approach will consider these factors when investigating the societal, political, and economic systems that impact policy in relation to renewable energy deployment.

3.3. Practical implementation.

3.3.1 Selection of practical research method.

A combination of factors influenced the selection of 1-to-1, semi-structured interviews, conducted online, as the primary method for gathering data on the complex contexts and factors influencing biomass policies and practices:

1. **Confidentiality and fairness of opportunity** – Due to the nature of the research questions, it was important that participants felt comfortable sharing their thoughts on the research topic in a confidential setting without being overheard. Therefore the 1-to-1 interview format was selected, over a focus group style format. Although a focus group setting would have enabled the observation of interactions between participants and revealed any existing power dynamics relevant to the research, questions 3a and 3b were specifically on who the participants thought would benefit from biomass use. In a focus group, this question may have proven tricky for those participants who thought others in their group were benefitting, and therefore they may not have shared their insights. A 1-to-1 interview enabled the researcher to create a secure online setting for the participants to engage in the research comfortably and enabled those participants who would otherwise stay quiet in a group setting to share

their thoughts. The researcher could then follow up with pre-determined questions or request additional context or clarification where necessary, without the participant feeling under pressure to respond a certain way, depending on who was listening. This is enabled by the researcher's positioning in the study as an independent evidence gatherer. Alternatively, a survey could have been sent out, designed to elicit the same type of insights as an interview, however this would have denied the researcher the opportunity to engage with participants to observe body language and tone of voice. Only collecting responses in word form would have lessened the quality of insights gathered, due to the nature of the topics being discussed, and not allowed the crucial interaction needed to determine both context of what was being said, and sentiment of how it was being said. Furthermore, the likelihood of a participant taking their own time, on their own, to complete a survey and deliver the same level of depth and context in their response compared to a live interview, was deemed to be too low to warrant using this method.

2. **Type of insights** – The intention of the research is to highlight the underlying themes influencing the design of biomass policy in the United Kingdom. This is reliant upon the collection of rich and deep qualitative insights from participants with expertise and experience of biomass policy design, implementation, and impact. A semi-structured approach to interviewing was selected to gather those insights, allowing for a fair comparison of responses across all participants due to the pre-determined questions posed, but enabling the researcher to engage with the participant to obtain additional context if required. A structured interview would have restricted the researcher from exploring key contexts and insights shared by the participant, whereas an unstructured interview would have increased the reliance of the research on the quality of a participant's expertise. Due to the lack of opportunity to build rapport with participants caused by interviewing online only, the semi-structured approach enabled the researcher to put the participant at ease through a more conversational approach, with the intention of garnering more open and honest responses.
3. **Access to expertise** – The researcher's prior experience as Stakeholder Engagement Manager at the Supergen Bioenergy Hub demonstrated that one impact of the Covid-19 pandemic was increased access to civil servants (a stakeholder group identified as crucial to this research activity). During the period where lockdown restrictions took place, working from home enabled increased academic access to civil servants as many were able to join one-hour video calls more conveniently, as opposed to both parties being geographically located in one place, such as an office, a meeting room, or a conference. This has continued since restrictions ended, with many stakeholders now more comfortable engaging online via video call.

Conducting interviews online enabled the researcher to provide increased flexibility for interview timeslots and reduced the impact of time and location on the availability of expertise within the civil service. This maximised the pool of potential participants by removing what could be a major barrier to their participation in the study.

3.3.2 Identifying research participants.

3.3.2.1. Categorising interviewees.

For the purposes of this study the participants were grouped into three 'Stakeholder Groups', 'Industry', 'Non-governmental organisation', and 'Policy', based on their professionally held position at the time of interview. Within the biomass and bioenergy field in the UK, there are clearly defined positions which fit under the umbrella of these three groupings:

Industry – the private sector organisations involved in the production, trade, conversion, or consumption of energy and/or products derived from biomass feedstocks, who may or may not be engaged in attempting to change the rules and regulations which govern this. This includes stakeholders such as biomass feedstock producers, energy companies, and trade associations.

Policy – the governmental or non-departmental government-associated organisations engaged in developing the rules and regulations which impact the production, trade, conversion, or consumption of energy and/or products derived from biomass feedstocks. This includes government departments and non-departmental public bodies set up by the government.

Non-governmental organisations – the non-governmental organisations engaged in attempting to change the rules and regulations which impact the production, trade, conversion, or consumption of energy and/or products derived from biomass feedstocks. This includes charities, environmental activist groups, and think tanks.

Each group has a different relationship to biomass policy design, a different role in the UK's biomass sector, and views the sector from a distinct perspective. This makes the groupings relevant to the study, enabling the cross-comparison of participant responses both individually and aggregated into groups. Participants were assigned their 'Stakeholder Group' based on their positions at the time of the interview, but given the nature of the interview questions, it was possible for participants to speak of experiences from previously held positions (which might have fallen into a different stakeholder group).

Participants were also assigned 'Focus' groupings based on their self-stated areas of expertise. The aim was to interview individuals that represented the three 'Stakeholder Groups', as well as drawing

together a range of expertise in the energy, environment, and transport policy remits that covered the bioenergy sector in the UK. This included biomass feedstock producers and farmers, bioenergy producers, trade associations, local and national policymakers, and a variety of NGOs involved in transport, environment, energy, and policy. This included the 'Focus' groupings for 'Environment', 'Energy', 'Transport', and 'General'. The inclusion of the 'General' focus was to capture those participants for whom biomass formed a part of their work but was not the primary focus of their expertise. For example, participants who had been involved in work on topics such as climate change, net zero, or environmental politics, and did not have a background in biomass and bioenergy but did have relevant knowledge to share in relation to the questions, were categorised with a general focus. Given the nature of the sector and the interview questions, many participants could focus on different niches of biomass expertise during the period they were being questioned on.

3.3.2.2. Interviewee criteria and profiles.

To mitigate the risk of participants lacking the knowledge and expertise required to respond to the interview questions, participant profiles were constructed to identify the types of individuals across the biomass and bioenergy sector who could provide insight. This also ensured that participants were sourced based on their ability to fulfil the roles identified, as opposed to participants being sourced because of a pre-conceived opinion on behalf of the researcher as to how the participant would respond to the questions, thus influencing the study. The profiles identified to provide the insight required to complete the study were as below.

Policy—Different government departments are responsible for policies that impact the development and use of biomass resources in the UK. Therefore, participants from each of the below government departments were sourced for interviews. There are also non-departmental government organisations that inform the government on broader topics such as climate change and the energy transition that will impact biomass use.

- The **Department for Environment, Food, and Rural Affairs (Defra)** has a policy remit that includes agriculture, land management, and environmental protection. Therefore, it plays a key role in policies that impact the potential growth and use of different biomass resources.

- Formerly the Department for Business, Energy, and Industrial Strategy (BEIS), the newly formed **Department for Energy Security and Net Zero (DESNZ)** owns the energy policy portfolio and the redevelopment of the UK's Biomass Strategy.

- The **Department for Transport (DfT)** is responsible for renewable transport fuels, such as biofuels, covering uses in areas from domestic transport to the marine and aviation sectors.

DfT has a key role in determining how biomass is utilised to transition away from the use of fossil fuels in transport.

- The **UK Climate Change Committee** is a public, non-departmental body responsible for providing independent advice and guidance to the government on climate change.

Industry - Private industrial interests within the UK biomass sector span the entire biomass supply-chain, from development, production, and growth of biomass feedstocks by landowners, to energy producers and consumers. They are motivated to influence policy in a way which maximises the benefits of the biomass supply-chain for them. It was intended that participants from across this supply-chain would be interviewed.

- **Feedstock producers** are landowners and growers who cultivate biomass feedstocks, such as energy crops, agricultural wastes, or forest residues. They are the stakeholders who extract biomass from the natural environment and commodify it.

- **Energy producers** are organisations that convert biomass into heat or power. They can sometimes be the same stakeholders who cultivate and grow the biomass. They are the stakeholders who use biomass to create additional value and provide services or products to consumers.

- **Trade associations** are associations set up by a collective set of organisations or individuals with common interests in a particular industry or sector. They seek to represent the views of their members, amplify their positions, and lobby the government to ensure biomass policy supports their supply chains and protects their interests.

Non-governmental organisations - Non-governmental organisations are actors within the biomass sector who seek to influence policy in separate ways to further their own agendas, such as policy think tanks and non-profit organisations such as community groups and charities. Although these stakeholders might not be focused on biomass, biomass spans multiple policy arenas, and therefore, most NGOs are motivated in some way to have a position on biomass development in the UK, even if it is not their area of expertise.

- **Think tanks** are groups that research and advocate for specific topics, usually on a political or economic agenda. Whilst most think tanks which specialise in the environment, climate change, or net zero will most likely not focus solely on biomass, it will be part of their research and analysis in determining their overall policy positions.

- **Non-profit organisations** are groups such as charities or community schemes that advocate for specific policy positions. These include environmental charities that seek to protect nature or community schemes that seek to implement local grassroots change. This includes groups that take policy positions against the development of biomass supply chains in the UK.

3.3.3 Conducting interviews.

3.3.3.1. Ethics approval.

The methods outlined in this chapter were given a favourable ethical opinion by Aston University's College of Engineering and Physical Sciences Research Ethics Committee (EPS21024 V2). This was due to the careful consideration of participant and researcher welfare, including a detailed data protection strategy in line with General Data Protection Practices (GDPR), processes to ensure the anonymity of those taking part, and the measures to identify and mitigate risks involved with the research activity.

3.3.3.2. Recruiting interviewees.

Participants were sourced through a range of methods, leveraging the established network of contacts linked to the Supergen Bioenergy Hub using direct approaches via email and LinkedIn (see Appendix 1 – Approved invitation email and Appendix 2 – Approved social media post), as well as indirect approaches such as callouts for participants on social media platforms and mailing lists. Callout requests on social media were shared by primary, secondary, and tertiary contacts, ensuring coverage of a large potential pool of participants. In addition, the snowball method, by which each participant was asked to suggest future interviewees was employed. The researcher maintained an 'Interview Dashboard' which contained the names of individuals directly invited and those who had responded, to track the number and type of participants engaged in the study and ensure the interviewee profiles identified previously were being fulfilled. Where initial attempts to secure primary targets for interview were not successful, the majority of those who declined put forward an alternative individual from their department or organisation whom they felt best placed to answer the questions posed.

3.3.3.3. Preparing and scheduling interviews.

Once potential participants had been identified and approached, either directly, because of a recommendation, or because participants had come forward to offer an interview, they were provided with a Participant Information Sheet (PIS) (Appendix 3). The PIS outlined the research aims, primary research questions, and prompted potential participants to take the opportunity to ask questions prior to commitment to an interview. This was followed by a Consent Form (Appendix 4), which confirmed the participant's rights and consent to record, capture, and store data resulting from the interview and outlined the researcher's responsibilities. It was decided not to send the interview questions ahead of time to the participants before the interview, in order to encourage participants to give

honest and open insights at the time of interview, as opposed to pre-planned responses sourced from within their organisations. Given that the researcher had set aside time over a three-month period to conduct interviews, this enabled flexibility to offer potential participants a range of dates and times most convenient for them, within working office hours, to spare an hour of their time engaging in the study. Once a date and time were agreed upon, the researcher ensured the participant had received and read the PIS and confirmed this by completing and signing the Consent Form.

3.3.3.4. Interview structure and question form.

A total of twenty-six, one-hour long, semi-structured interviews were conducted online over a three-month period from August 2023 through to November 2023. During the interview process, each participant was asked the same open-ended and follow-up questions as detailed in the Interview Question Form (Appendix 5). Each participant was given as much time to answer the question as they needed, with the researcher following up with the prepared follow-up questions. The only variance in the interview process was questions by the researcher asking for clarification or context around a given answer, ensuring comparability between responses given to each question. Each participant was asked the following (with question numbers relating to coded responses):

Q1a: What policies drove the most significant deployment of bioenergy that led to carbon emission reductions in the UK over the last 20-year period?

Q1b: What were the drivers for those policies at the time?

Q1c: What was the impact of those policies, and when was the impact felt?

Q2a: What impact has the introduction of net zero had on the deployment of bioenergy in the UK?

Q2b: How has the UK's net zero legislation impacted bioenergy deployment?

Q3a: What is using biomass to achieve net zero going to cost the UK leading up to 2050, and how will it benefit the UK?

Q3b: Who currently benefits the most from biomass use in the UK, and who will benefit from using biomass to achieve net zero by 2050?

Q3c: How do the public benefit from the UK using biomass to achieve net zero?

The questions were designed to chronologically elicit responses on specific topics related to biomass deployment in the UK. Firstly, a look back over influential policy decisions of the past 20 years, what drove them, and their impacts. Secondly, the impact that the revised net zero target had since its

introduction in 2019. And finally, consideration for how the UK achieves that target, associated costs and benefits, and the implications for stakeholders and the public. Specifically open-ended and broad in nature, the questions were designed to enable responses from a variety of stakeholder groups and areas of expertise, in recognition of the broad perspectives and positions within the UK biomass sector. Participant expertise varied, with some participants answering from their perspective of a career spanning decades, and others spanning the last five years; the questions allowed those with insight and expertise to share what they could. Designated follow-up questions minimised the impact of researcher bias on the questioning.

Interviews took between 45-60 minutes to complete. At the end of the interview, the participants were given the opportunity to add anything else they think might be relevant to one of the questions posed, in case something was worth mentioning. These responses were coded depending on their relation to the questions above. Each participant's interview recording was then saved to be processed for full transcription. Interview observations were captured in note form during the interview taking place, but the transcriptions were completed in full after the interview had ended.

3.3.4. Data analysis.

3.3.4.1. Selection of data analysis method and software.

Due to the qualitative nature of the data gathered, both NVivo and Atlas.ti were considered as tools for analysis. However, NVivo was selected as the primary software tool for analysis due to several factors:

1. **Researcher familiarity** – The researcher has previously used NVivo to conduct a discourse analysis of policy documents, and therefore had experience in leveraging its capabilities to analyse qualitative data. In contrast, the researcher has limited knowledge of Atlas.ti.

2. **Coding** – NVivo enables the coding of multiple files to single themes, which easily categorises and aggregates the data. This was helpful due to the sheer amount of data gathered and made it easier to code the data, which is the most time-consuming element of the study. The user-interface is more intuitive in NVivo for this than Atlas.ti.

3. **Queries** – The Matrix Coding Query function in NVivo allows for the cross-comparison of files and codes, enabling the identification of patterns and themes within the data. The results are exportable into Microsoft Excel, which allows for further flexibility in analysis and visualisation.

Utilising NVivo as the tool for analysis presented a few options for analytical methods, such as discourse analysis, thematic analysis, and grounded theory. Since the research questions aimed to highlight the drivers, policies, and impacts associated with utilising biomass to achieve net zero, thematic analysis seemed most appropriate to reveal and enable the interpretation of patterns in the interview data. In contrast, the primary concern of discourse analysis is to reveal the use of language and how language constructs power and might have been more suited to analysis of policy documentation as opposed to interview responses. Similarly, taking a grounded theory approach to analysis would have focused the research on the development of a theory or exploration of a phenomenon within the data from the outset, as opposed to the inductive approach that thematic analysis allows for. The intention of the analysis was to reveal and highlight themes within the data, including the cross-comparison of stakeholder perspectives which NVivo queries enable. Overall, the combination of leveraging NVivo to conduct a thematic analysis of the data was the most appropriate method to achieve the research aims.

3.3.4.2. Interview analysis.

Once interviews were complete, they were transcribed verbatim, anonymised (as per Participant Consent Forms), and imported into NVivo. Transcriptions were processed to remove the words spoken by the researcher, to enable quick comparative analysis of words and phrases used by participants in NVivo, as the researcher's words would have influenced results. For example, utilising a Word Frequency query in NVivo would repeatedly return the words which the researcher used in the questioning for each interview. The 26 interview files were then assigned attributes based on the participant's self-stated expertise (the 'Stakeholder' and 'Focus' groupings). As the interview questions were designed to elicit responses on specific topics (such as the focus of Q1a being the policies implemented), the coding framework was built around the questions, and responses were coded inductively within each question as a child-code (see Appendix 6 for the full coding framework).

The choice to code inductively was to allow for the themes to emerge from the data without the data being coded to a pre-existing set of themes, as identified by the researcher, and has the benefit of promoting data-driven thematic analysis (Braun and Clarke 2006). A thematic analysis suited this research as it enables the cross-comparison of stakeholder perspectives to highlight areas of consensus among participants, and simplifies the process of summarising key findings from large datasets (King 2004). The thematic analysis was completed by the researcher and then cross-checked by his supervisors to minimise the impact potential of bias. As the coding process progressed, similar responses were grouped under one code, and the number of new codes needing to be created was reduced. This was because participant responses from earlier interviews had necessitated the initial need to create codes, which were then applicable to responses in later interviews.

The result is a set of responses to each interview question, aggregated into codes linked to the file attributes mentioned above, enabling cross-comparison of responses from different stakeholders and focus groupings. The codes were then analysed to finalise the aggregation of similar responses and to verify that coding had been completed correctly. For analysis, the primary function used in NVivo was the Matrix Coding Query, which allowed for flexibility in analysis, enabled the comparison of themes that emerged, and the comparison of responses categorised by 'Stakeholder' (Policy, Industry, NGO) and 'Focus' (Energy, Transport, Environment, General) groups. The coded data in NVivo was used to verify and support the anecdotal evidence in the interview observation data collected by the researcher during the interview process, which supports the contextualisation of responses given.

3.4. Reflections on the research design.

3.4.1. Limiting the impact of bias.

When conducting qualitative research, it is important that the researcher is aware of the impact of bias, and from the beginning of this research activity, this research was designed to minimise the impact of bias introduced within the process. This was done through several steps, such as:

1. **Designated lines of questioning**: The researcher asked the same questions and follow up questions to each participant, only deviating from the Interview Question Form (Appendix 5) when additional context or clarification was needed for a topic or term which the participant had used, which was unfamiliar to the researcher. This reduced the impact of potential bias in the questioning during semi-structured interviews, which can become conversational if the designated questions are not adhered to.

2. **Development of the questions**: Whilst the questions are designed to elicit responses relevant to the research objectives, they are purposely broad and open-ended. This minimises the impact of researcher bias in directing responses towards a particular thematic direction and enables the participant to respond freely using their expertise and knowledge where appropriate. The questions were iterated among the researcher and his supervisors, reducing the risk of individual bias.

3. **Participant sourcing**: The researcher identified several profiles of the types of individuals suitable for interview from within the UK biomass field, then sought to fill those profiles with individuals from within a large network online, as opposed to individuals only already known to the researcher. This was done to prevent researcher bias in appointing or selecting participants based on a pre-conceived notion of how they would respond to the questions, therefore potentially shaping the interview responses in a certain direction. Those

participants who were directly approached were done so because of their known depth of expertise in a particular area, based on the recommendation of others following peer examination of suggestions by the researcher's supervisors. The rest of the participants were sourced from an open call on social media for respondents, which was shared widely across various social networks, not only from the researcher's profile, to ensure participants from beyond the researcher's direct network of connections.

3.4.2. Limitations of the study.

From the outset, there were limitations in the design of the research for which impacts could be mitigated but not entirely overcome, such as:

1. **Sample size**: Limitations on researcher time and capacity meant that any more than 30 research interviews would have become unfeasible to manage in the timeframe given. Due to the breadth of expertise and positions within the UK biomass space, this meant that some positions within the biomass sector were only represented by two participants, and this is unlikely to be an entirely representative sample of that type of stakeholder. Furthermore, obtaining interviews with policy participants from different government departments was a key objective of the research. However, turnover between roles in the civil service is high. Individuals would often move every couple of years and work in different areas of policy development; therefore, when being asked to consider policy related to biomass over longer periods, such as in Q1, they may not have had personal experience to reflect on. More interviews with civil servants would have been required to overcome this completely.

2. **Semi-structured qualitative interviewing**: The nature of semi-structured, qualitative interviews means that participants have greater control over how the interview goes and the focus on which topics are discussed. This meant that, at times, interviews had the potential to digress from the focus of the question, and at the risk of imposing bias on the responses, the researcher would not always be able to direct the participant's conversation back towards the topic at hand. This can lead to complications when trying to make inferences or draw comparisons from the qualitative data collected in response to open-ended qualitative questioning. This was overcome by reinforcing the direction of the interview with the prepared Interview Question Form (Appendix 5).

3. **Online interviewing**: Interviewing using Microsoft Teams had great benefits in enabling participants to engage in the research at their convenience, from home if they wished, to be more comfortable in answering questions freely without potential pressure from employers

also present in an office environment. This also made replicating the interview process simple for the researcher, as there was less time for informal engagement with the participants prior to the interview taking place, and less chance of participants being called away from the interview. However, this made observations, such as body language and behaviour, more difficult to make. This was mitigated using recorded video calls, which could be played back in reference to the transcripts collected. Still, in a face-to-face interview, these observations can be captured fully.

4. **Reliance on the quality of participants**: The political nature of the research, despite not being partisan, may have led some participants to communicate in line with their corporate policy rather than their experiences or personally held beliefs. This means that the research relies on the trustworthiness of the responses given and the availability of expertise. Where, in some instances, the most specific expert may not have been available, other individuals may have stepped in to engage in the research who were not as well positioned to answer the questions. There could also be an element of recency bias in responses, whereby participants place greater importance on the most recent developments in policy as opposed to those further back in time. Given the nature of the first question, casting back over a 20-year period, the quality of responses relies on gathering a range of expertise that covers the entire period, as opposed to interviewing participants only with roles relevant to the research for the most recent years. To mitigate this, participants with known, relevant experience of biomass policy from the beginning, middle, and end of the 20 years in question were targeted for interview.

4. Results

As the previous chapter outlined, the research activity was designed to gather insights on the political economy of the UK and the subsequent impacts on biomass use. This was done through the thematic analysis of responses collected during semi-structured interviews with experts from across the UK biomass and bioenergy sector. The qualitative data collected is presented below in two forms. The first section presents the results of coded thematic analysis structured around the interview questions, which is followed by a section that presents observations gathered by the researcher at the time of interviewing and finishes with reflections on the research process and product. The themes which emerge in the data below will inform the discussion that follows this chapter.

A total of 26 participants were interviewed summarised in Tables 1 & 2 below, generating 564 coded responses against the 8 questions posed. With a total 48 individuals approached for interview, this represents a 54% success rate. Of the interview profiles identified in the previous chapter for targeting, interviews were obtained with at least one individual fulfilling every profile. The most successful channel for obtaining interviews was by directly approaching individuals via email or via direct messaging on social media, however the public social media callout supported this, as individuals directly approached for interview often noted the public callout but appreciated being directly approached. Of the remaining 22 individuals who were approached for interview, 11 did not respond to request for interview, and the other 11 indicated an interest in taking part. Amongst the 11 who did indicate an initial interest in taking part, 6 stopped responding after being sent the Consent Form and PIS, and 5 opted to decline the interview (which is approximately 10% of the total number of individuals approached for interview). Amongst the 5 who declined the request, 4 participants indicated that they were being discouraged from participating in the research by their organisations due to the nature of the research questions. This was due to the 'political' nature of the questions being asked, which were said to be provocative, or because the organisation was discouraging employees from taking part in any research of this kind. 1 participant elected to decline the request as they didn't feel as though they had the time to commit to an interview due to an upcoming career change.

Overall, this method of targeting individuals for interview proved very successful, ensuring interviews with key individuals in the UK biomass and bioenergy field from policy, industry, and relevant NGOs. Whilst time had been set aside to interview additional participants after initial coding had taken place, it was not necessary to go to another round of interviews, as there were no new themes emerging to develop codes for. Upon reaching this point of saturation within the data, it was decided that the 26 interviews conducted were sufficient to draw meaningful conclusions that support the research

questions. Using NVivo, the participant responses were aggregated and coded against each question as sub-themes, which developed over the course of the inductive coding process.

Table 1 - The 26 participants who took part in research interviews, their self-stated expertise, and classification within 'Stakeholder' and 'Focus' groupings, as well as the type of contact they were in relation to the researcher (1st – Direct, 2nd – Indirect, New – Newly Established as a result of the research).

Case I.D.	Expertise	Stakeholder Group	Focus Group	Contact Type
01	Forestry, bioenergy policy.	Policy	Energy	1st
02	Miscanthus cultivation, agriculture.	Industry	Environment	2nd
03	Natural asset management for local government.	Policy	Environment	New
04	Biomass and bioenergy policy development.	Policy	Energy	1st
05	Bioenergy systems analysis.	NGO	Energy	2nd
06	Forestry.	Policy	Environment	2nd
07	Small to medium scale bioenergy production.	Industry	Energy	1st
08	Carbon capture and storage, land use.	Policy	Energy	2nd
09	Willow cultivation, agriculture.	Industry	Environment	1st
10	Energy research and innovation policy.	Policy	General	2nd
11	Large scale bioenergy generation.	Industry	Energy	New
12	Environment and energy policy development.	NGO	General	New
13	Trade association, bioenergy generation.	Industry	Energy	1st
14	Energy policy analysis.	Industry	Energy	New
15	Large scale bioenergy generation, biomass supply chains, energy policy.	Industry	Energy	1st
16	Environmental and agricultural science.	Policy	Environment	2nd
17	Climate, carbon budget and net zero policy.	Policy	General	New
18	Transport policy.	NGO	Transport	New
19	Environmental policy, bioenergy generation.	NGO	General	New
20	Power plant deployment and conversion to biomass, energy policy, net zero.	Policy	Energy	2nd
21	Energy policy, global climate change politics.	Policy	General	New
22	Bioenergy policy, bioenergy with carbon capture and storage, environmental politics.	NGO	General	New
23	Environmental science, ecology, agriculture, feedstock cultivation.	Industry	Environment	1st
24	Transport fuel policy.	Policy	Transport	2nd
25	Transport fuel policy, fuel industry.	Industry	Transport	New
26	Environmental and social governance, bioenergy production, bioenergy innovation.	Industry	Energy	1st

Table 2 - A table showing the 26 participants who took part in research interviews and their classifications within 'Stakeholder' (Industry = 10; Policy = 11; NGO = 5) and 'Focus' (Energy = 11; Environment = 6; General = 6; Transport = 3) groupings.

Participant Breakdown		Focus Grouping				
		Energy	Environment	General	Transport	*Totals*
Stakeholder Grouping	Industry	6	3	0	1	*10*
	NGO	1	0	3	1	*5*
	Policy	4	3	3	1	*11*
	Totals	*11*	*6*	*6*	*3*	*26*

4.1. Coded thematic analysis.

Table 3 – A table showing the interview questions, number of participants who responded to the question, and the number of responses coded to the question.

Question	Participants responded	Coded Responses
(Q1a) What policies drove the most significant deployment of bioenergy that led to carbon emission reductions in the UK over the last 20-year period?	25	78
(Q1b) What were the drivers for those policies at the time?	24	78
(Q1c) What was the impact of those policies and when was the impact felt?	15	27
(Q2a) What impact has the introduction of net zero had on the deployment of bioenergy in the UK?	26	116
(**Q2b**) How has the UK's net zero legislation impacted bioenergy deployment?	7	7
(Q3a) What is using biomass to achieve net zero going to cost the UK leading up to 2050, and how will it benefit the UK?	26	109
(Q3b) Who currently benefits the most from biomass use in the UK, and who will benefit from using biomass to achieve net zero by 2050?	26	64
(Q3c) How do the public benefit from the UK using biomass to achieve net zero?	24	85

Table 3 shows that the number of participant responses and coded responses varies, highlighting that participants were able to engage with some topics more than others. For example, Q2a focused on the impact of net zero, of which every participant had something to say (26 responses), and the number of coded responses indicates that participants also had lots to say on this topic (116 responses). In contrast, the follow-up question Q2b on the specific impact of net zero legislation elicited the fewest respondents of all questions (7 responses) from the lowest number of participants (7 respondents). The only other question that participants struggled to respond to in this way was Q1c on the specific impact of policies (15 respondents). This implies that participants struggled to link legislation and policy to demonstratable impacts or lacked the expertise to do so. However, given responses to Q3c on how the public benefits from increased biomass use, in which participant responses talk of 'behind the scenes' benefits (explained later in this chapter), perhaps this is also just a common theme within biomass policy; that the policy and the resulting impact are complex and difficult to link together.

Overall, the number of participants able to engage in each question, and the number of individual responses coded to sub-themes implies that the participants were well placed to answer the questions posed, as they had the relevant expertise and knowledge. This reflects well on the research design and demonstrates that the interview process identified and secured interviews with the individuals best placed to address the questions posed, as intended. Participant responses to individual questions are analysed in the following sections.

4.1.1. Q1a – Influential policies.

Table 4 - A table showing the number of coded responses per sub-theme in relation to Q1a, asking what the most influential policies were that drove bioenergy deployment and delivered carbon emission reductions in the UK, during the past 20 years.

(Q1a) What policies drove the most significant deployment of bioenergy that led to carbon emission reductions in the UK over the last 20-year period? Sub-themes	Coded Responses (78)
(RO) Renewables Obligation	14
Converting Power Plants	12
(RTFO) Renewable Transport Fuel Obligation	10
(CfD) Contracts for Difference	8
European Policy	8
(RHI) Renewable Heat Incentive	7
(FITs) Feed in Tariffs	3
Energy Crops Scheme	3
(ARBRE) Arable Biomass Renewable Energy	2
Bioenergy Strategy (2000s)	2
Climate Change Act	2
Waste Management Policy	2
(CHPQA) Combined heat and power quality assurance scheme	2
Clean Growth Strategy	1
Funding Energy Research	1
Smart Export Guarantee	1

Participant responses to Q1a demonstrated a clear recognition of the role that the conversion of large-scale power plants from coal to biomass had to play in the deployment of bioenergy, and the associated carbon emission reductions in the energy sector. Participants highlighted the impact of the 'Renewables Obligation (RO)' (14 responses) and the 'Contracts for Difference (CfD)' (8 responses) mechanisms as key components of incentivising the growth of bioenergy, but also pinpointed the conversion of existing power plants at Drax, Lynemouth, and MGT Teesside as a specific policy from government itself. Whilst the RO and CfD mechanisms have maintained financial incentives and support from government to switch from coal to biomass, participant responses highlighted the desire to convert existing power plants separate to these policies, therefore justifying the inclusion of the separate 'converting power plants' (12 responses) sub-theme. One participant noted that in the initial stages of the CfD mechanism being introduced, agreements "were bilaterally negotiated between

government and the larger players" (Case ID 13) rather than going through the intended CfD auction process.

Additionally, specific policies such as the 'Renewable Transport Fuels Obligation (RTFO)' (10), the Renewable Heat Incentive (RHI) (7 responses), and 'European policy' (8 responses) such as the Renewable Energy Directives (RED) (with influence being greater prior to the United Kingdom's exit of the European Union) were identified as drivers for carbon emission reduction through bioenergy deployment. Of the top six most significant sub-themes in the data, five are made up of policy focused on energy generation at scale, with the RTFO being the standout centred on transport emissions (also at scale). Identified as less significant within the data are the 'Arable Biomass Renewable Energy (ARBRE)' (2 responses) and 'Energy Crops Scheme (ESC)' (3 responses) sub-themes, both of which were linked to the establishment of domestic biomass feedstocks within the agricultural sector. Participants would often interrelate the policies mentioned, implying that they worked in parallel to stimulate bioenergy deployment.

Table 5 – A table showing the number of coded responses per sub-theme in relation to Q1a, categorised by 'Stakeholder Group'.

	Stakeholder Group			
(Q1a) Sub-theme	*Policy*	*Industry*	*NGO*	*Totals*
(RO) Renewables Obligation	4	7	3	14
Converting Power Plants	4	4	4	12
(RTFO) Renewable Transport Fuel Obligation	2	4	4	10
(CfD) Contracts for Difference	2	5	1	8
European Policy	3	3	2	8
(RHI) Renewable Heat Incentive	2	5	0	7
(FITs) Feed in Tariffs	1	2	0	3
Energy Crops Scheme	1	2	0	3
(ARBRE) Arable Biomass Renewable Energy	2	0	0	2
Combined heat and power quality assurance scheme	0	0	2	2
Bioenergy Strategy (2000s)	1	1	0	2
Climate Change Act	2	0	0	2
Waste Management Policy	1	1	0	2
Clean Growth Strategy	0	1	0	1
Funding Energy Research	1	0	0	1
Smart Export Guarantee	1	0	0	1
Totals	27	35	16	78

Analysis of the sub-themes categorised by stakeholder grouping provides insight into the differing perspectives of stakeholders engaged in the bioenergy sector. Policy stakeholders mentioned the broadest range of policies that had an influence on bioenergy deployment and led to carbon emission

reduction; however, they were the largest group interviewed (11 participants). Industry stakeholders (10 participants) clearly focused on policies that financially incentivised a phase-out of fossil fuels and encouraged renewable energy, with the 'RO', 'CfD', and 'RHI' as the most frequently coded sub-themes. The NGO group were the smallest group interviewed (5 participants), but across NGO participants, there was consensus that the 'converting power plants' and the 'RTFO' sub-themes were most significant.

4.1.2. Q1b – Drivers for influential policies.

Table 6 – A table showing the number of coded responses per sub-theme in relation to Q1b, asking what the drivers were for influential policies.

(Q1b) What were the drivers for those policies at the time? Sub-themes	Coded Responses (78)
GHG Reduction	22
Economic	17
Environmental	8
Energy Security	7
Carbon Accounting	5
Social	5
Diversify Energy Resources	4
Non-Biomass Policy Focus	4
Biomass Perception	3
Increase Domestic Production	2
Industry Engagement	1

Analysis of the sub-themes which emerged during Q1b showed a clear consensus from participants that the primary drivers for the policies outlined in response to Q1a were 'greenhouse gas (GHG) reduction' (22 responses) and 'economic' (17 responses) factors. Responses in the 'GHG reduction' sub-theme focused on the desire to incentivise decarbonisation in respect of existing carbon budgets and climate mitigation activity, whilst responses in the 'economic' sub-theme centred on keeping existing power stations switched on, opportunity for economic growth, and job creation. Although not represented in the data as significantly as the top two sub-themes, participants also highlighted the role of environmental factors and the goal of energy security as motivators for policy. Arguments in the 'environmental' (8 responses) sub-theme included biodiversity targets and the threat to nature. Still, they were often interrelated with economic drivers and framed to mitigate the impact of industry on the environment, with one participant noting "policy makers would like to have an agricultural industry which is economically viable and environmentally sustainable" (Case ID 16). 'Energy security'

(7 responses) insights were primarily focused on securing a reliable source of energy like that of coal and reducing dependency on more volatile sources of fuel, in the context of ongoing geopolitical tensions.

Table 7 – A table showing the number of coded responses per sub-theme in relation to Q1b, categorised by 'Stakeholder Group'.

	Stakeholder Group			
(Q1b) Sub-theme	*Policy*	*Industry*	*NGO*	*Total*
GHG Reduction	13	7	2	22
Economic	8	6	3	17
Environmental	7	0	1	8
Energy Security	4	3	0	7
Carbon Accounting	1	0	4	5
Social	3	0	2	5
Diversify Energy Resources	2	2	0	4
Non-Biomass Policy Focus	2	2	0	4
Biomass Perception	2	0	1	3
Increase Domestic Production	1	1	0	2
Industry Engagement	1	0	0	1
Totals	44	21	13	78

When analysing the sub-themes in relation to the stakeholder groupings, clear differences between the groups emerge. Whilst the 'GHG reduction' and 'economic' sub-themes are important across the groups, there are clear differences in the importance of the 'environmental' and 'social' (5 responses) sub-themes between industry and policy, with the former negating to mention either as a key motivator for policy. Despite industry focus on GHG reduction and economic growth, which could be viewed as a vehicle with which to deliver environmental and social objectives, industry participants didn't explicitly state these objectives in their responses. Instead, they chose to highlight the incentivisation of carbon reductions to meet carbon budgets, and the economic opportunities associated with that. In contrast, policy responses placed importance on 'environmental' drivers as the sub-theme with the third highest number of responses. However, all policy participants (11) mentioned GHG reduction to mitigate climate change or meet carbon budgets, with two opting to mention GHG reduction on two separate occasions within their answer, meaning there were 13 instances of GHG reduction as a driver from 11 participants. This highlights the importance of existing science-based targets for GHG reduction within policy stakeholders, and the commitment to decarbonisation as a route to mitigating climate change. Amongst NGO responses the 'carbon accounting' (5 responses) sub-theme was the most mentioned, and responses in this sub-theme referenced carbon accounting frameworks being influential in policy, as they rate biomass as carbon

neutral. This was also referenced in policy responses and interrelated with the 'biomass perception' (3 responses) sub-theme, in which participants from policy and NGO groups mentioned how the perception of biomass as a carbon neutral source of fuel and energy changed over the course of the 20-year period being analysed.

4.1.3. Q1c – Impacts of influential policies.

Table 8 – A table showing the number of coded responses per sub-theme in relation to Q1c, asking what the impacts were of influential policies.

(Q1c) What was the impact of those policies and when was the impact felt? Sub-themes	Coded Responses (27)
Fossil phase-out	9
Negative Behaviours	11
Stimulate New Domestic Supply	7

Only 15 out of the 26 participants interviewed were able to provide specific examples of policy impact, with industrial participants able to provide the most responses. Participants struggled to answer the second half of the question and pinpoint when impact was felt, highlighting the difficulty of connecting specific policies to outcomes, therefore the 'when' element of this question isn't recorded. Responses were coded into just three sub-themes; 'fossil phase-out' (9 responses), 'stimulate new domestic supply' (7 responses), and 'negative behaviours' (11 responses). The 'fossil phase-out' sub-theme included responses that pointed to biomass use, which displaced fossil fuel usage, and the 'stimulate new domestic supply' sub-theme focused on the development of biomass feedstocks in the UK. The 'negative behaviours' sub-theme centred on activity because of policies which the participants deemed negative, such as the incentivisation of low-quality or dangerous biomass systems, subsidies being exploited, or perceived policy failure leading to negative perceptions of biomass. One extreme case was demonstrated by a participant who noted how "There was an awful lot of stuff that was not displacing existing carbon emissions but was actually burning wood and still is burning wood to generate a subsidy of one sort or another." (Case ID 07).

Table 9 – A table showing the number of coded responses per sub-theme in relation to Q1c, categorised by 'Stakeholder Group'.

	Stakeholder Group			
(Q1c) Sub-theme	*Policy*	*Industry*	*NGO*	*Total*
Negative Behaviours	3	6	2	11
Fossil phase-out	3	5	1	9
Stimulate New Domestic Supply	2	4	1	7
Totals	8	15	4	27

Comparing responses by stakeholder grouping, industrial participants were most able to speak about policy impact; this focused primarily on the 'negative behaviours' sub-theme and focused on the details of policy subsidies, which drove bad practices within the renewable heat and renewable fuel sectors. Industry responses within the 'fossil phase-out' sub-theme, were not directly connected to carbon emission reduction in the responses. In contrast, NGO responses in the 'negative behaviours' sub-theme focused on the potential for policy to have focused on other renewable energy sources if it had not been financially incentivising bioenergy, instead financially supporting sources such as solar and wind. Policy stakeholders provided a more balanced response, pointing to the 'fossil phase-out' sub-theme but also considered the 'negative behaviours' that the policy has driven.

4.1.4. Q2a – Impact of net zero.

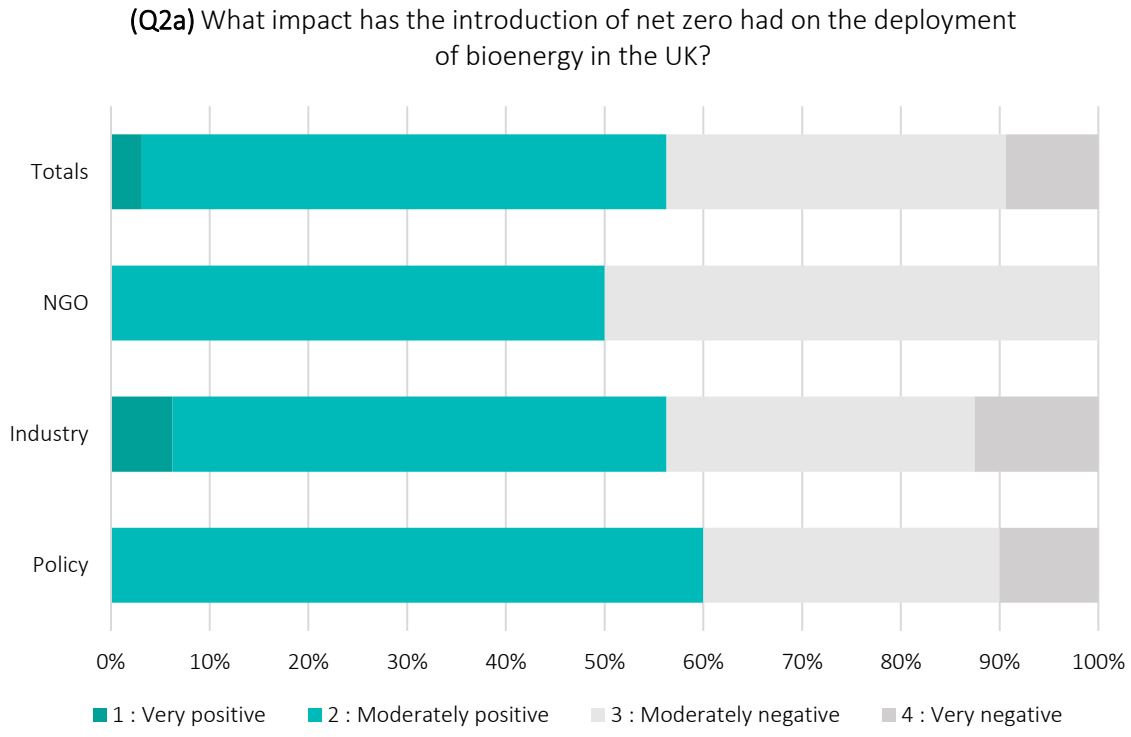

Figure 9 – A graph showing the sentiment of response towards the impact of net zero on bioenergy in the UK, in percentages, categorised by 'Stakeholder Group'.

In response to the question on the impact of net zero on bioenergy deployment, participants often gave more generalised responses, in addition to topic specific impacts which were coded to sub-themes. The generalised responses participants appraised net zero as an overall approach and considered its effectiveness in impacting policy, industry, and society related to biomass more broadly. Therefore, these responses were coded to a 'general' sub-theme. The 'general' sub-theme responses were then coded for sentiment to determine participant perspectives on the impact of net zero and any discernible changes in policy since the commitment to achieve net zero by 2050 was legislated for in 2019. Whilst NVivo offers an auto-coding function for sentiment, this can sometimes lack the context in which a word is said or not pick up on sarcasm or irony, which can alter the meaning of the word. Therefore, the sentiment of participant responses was coded by the researcher by combining the words they used, the tone of their voice, and the body language captured through the interview recording alongside the context of the discussion. Within the 'moderately positive' codes, participant responses included how net zero had reinforced "the need for us to be here" (Case ID 11), with the participant having already been involved in the implementation of bioenergy to achieve carbon reductions long before net zero became a target. In contrast, 'moderately negative' codes emphasised how the introduction of net zero had a soft impact on the perception of bioenergy, stating: "I think there has been a bit of a shift, almost a rollback in sentiment and attitudes towards bioenergy" (Case

ID 13). Responses that fell into the 'very positive' or 'very negative' coding were qualified with a use of stronger wording and emphasis of tone in the participant's response. For example, within the 'very negative' responses, participants bemoaned the lack of impact setting a net zero target had, demonstrating that "it's not pushing people towards that and certainly not when it comes to my particular sector" (Case ID 07). Responses coded 'very positive' challenged this assertion, explaining that "the longer-term prospects of bioenergy have massively improved as a result of the legislation of net zero" (Case ID 14). With both these examples of 'very positive' and 'very negative' coded responses being from industry, this demonstrates the unequal impacts that the introduction of net zero has had on bioenergy within the sector.

Overall, 56% of coded responses referenced a positive discernible impact of net zero on biomass, with 53% of the responses falling into the 'moderately positive' sentiment coding and 3% 'very positive'. When the data is segregated by stakeholder group, it highlights that whilst NGO responses discerned the smallest impact of net zero among the groupings (only indicating 'moderately positive' (50%) and 'moderately negative' (50%)), industry participants had the most varied responses to the question; they were the only group to return both 'very positive' and 'very negative' sentiment coding.

Table 10 – A table showing the number of coded responses per sub-theme in relation to Q2a, categorised by 'Stakeholder Group'.

	Stakeholder Group			
(Q2a) Sub-theme	*Policy*	*Industry*	*NGO*	*Total*
Bioenergy with Carbon Capture and Storage	11	6	5	22
The future role of biomass	2	9	2	13
Sustainable Aviation Fuel	6	4	0	10
Carbon focus	3	4	2	9
Rethinking policy	4	2	0	6
Domestic focus	4	1	0	5
Co-benefits focus	3	0	0	3
Hydrogen	2	0	1	3
Totals	35	26	10	71

Beyond the 'general' sub-theme, several topic specific sub-themes emerged from the data. Participants demonstrated that 'bioenergy with carbon capture and storage (BECCS)' (22 responses) has been a primary focus for bioenergy since the introduction of net zero, which has been the most popular sub-theme amongst policy and NGO participants. 'The future role of biomass' (13 responses) sub-theme emerged as the second most frequent, as several participants pointed to the increased focus on biomass and bioenergy as a pathway to achieve net zero in the future, and the recognition in

several sectors, such as aviation and heavy industries, of the importance of biomass in making net zero more achievable in 'difficult to decarbonise' areas. This sub-theme was most popular with industry participants and was often interrelated with responses on BECCS and the 'sustainable aviation fuel' (SAF) (10 responses) sub-theme, with the latter being the third most frequent response. Also significant was the 'carbon focus' (9 responses) sub-theme, which aggregated participant responses and indicated an increased focus on carbon following the introduction of net zero. All stakeholder groups mentioned the 'carbon focus' sub-theme, and it was more frequently mentioned than the 'co-benefit' (3 responses) sub-theme, which was only mentioned by policy participants. The 'co-benefit' sub-theme grouped responses indicated the non-carbon factors, such as biodiversity and restoring nature, involved with net zero became the focus post-2019.

4.1.5. Q2b – Impact of legislation.

Table 11 – A table showing the number of coded responses per sub-theme in relation to Q2b, focused on the impact of net zero legislation.

(Q2b) How has the UK's net zero legislation impacted bioenergy deployment?	Coded Responses (7)
Sub-themes	
Policy certainty	4
No impact	3

In follow up to Q2a, sub-themes coded to Q2b were specifically focused on the impact of the legislation itself, and any change in policy. Just 7 out of 26 participants were able to answer this question, with 4 indicating that legislation delivered 'policy certainty' for the long-term, implying that the legislation itself was beneficial for bioenergy deployment in the UK. For example, one participant explained how the legislation had helped encourage policy development more generally, by saying "I've seen a really big push policy wise to do something to meet net zero because we are legally obliged to" (Case ID 08). 3 participants determined that the legislation had 'no impact', indicating that other policies and schemes provided the impetus for bioenergy deployment, and that they didn't "think that net zero policy per se had a major effect." (Case ID 23).

Table 12 - A table showing the number of coded responses per sub-theme in relation to Q2b, categorised by 'Stakeholder Group'.

	Stakeholder Group			
(Q2b) Sub-theme	*Policy*	*Industry*	*NGO*	*Total*
No impact	0	3	0	3
Policy certainty	3	1	0	4
Totals	3	4	0	7

A breakdown of responses by stakeholder grouping revealed that where any discernible impact of net zero legislation had been recognised by participants, there were differing views between policy and industry participants. Whilst NGO participants couldn't speak to any impacts, policy participants believed that the introduction of the legislation set a clear path forward for other policy to follow, delivering policy certainty. In contrast, whilst there was some agreement on this point by one industry participant, the others who responded to this question were clear that the legislation hasn't had an impact. This could speak to the time it takes for policy to translate from design to delivering impact, with policy participants recognising the overarching net zero legislation providing a guide for future policy design, whilst industry participants await the impact of future policy.

4.1.6. Q3a – Costs and benefits of net zero biomass.

Table 13 – A table showing the number of coded responses per sub-theme in relation to Q3a, focused on the trade-offs associated with using biomass to achieve net zero.

(Q3a) What is using biomass to achieve net zero going to cost the UK leading up to 2050, and how will it benefit the UK?	Coded Responses (109)		
Sub-themes			
Benefits	(54)	Costs	(55)
Economic opportunities	12	Financial	18
UK global leadership	9	Land use	11
Ecosystem services	8	Air quality	8
Resource efficiency	7	Reliance on imports	5
Complementary energy	5	Environmental degradation	4
Energy security	4	Social	3
Cost saving	2	Distracting from alternatives	2
Essential for net zero	2	New infrastructure	2
Negative emissions	2	Technical challenge	1
Reduce fossil use	2	Training needs	1
Reduce energy bills	1		

For Q3a on the costs and benefits of utilising biomass to achieve net zero by 2050, participant responses were coded to sub-themes split into 'benefits' (54 responses) and 'costs' (55 responses), as defined by the participant during the interview. The most significant benefits identified by participants were captured within the 'economic opportunities' (12 responses), 'UK global leadership' (9 responses), and 'ecosystem services' (8 responses) sub-themes, with 'resource efficiency' (7 responses) also significant. Among the 'economic opportunities' identified by participants, there was a focus on the jobs that increasing biomass supply-chain activity could bring, the opportunity for economic growth within industry, and the potential for rural stakeholders, such as those involved in forestry or agriculture, to see increased financial benefits. One participant highlighted "And that's across the supply chain all the way from growing the crops to actually converting the crops to distributing the energy that you need from the crops. It's a huge stimulator for economic through growth, through jobs creation." (Case ID 26). This was followed by the 'UK global leadership' sub-theme which recognised that the bioenergy sector in the UK has the knowledge and expertise to export around the world, not only to attract financial investment, but also to contribute towards the UK's geopolitical power. This was demonstrated by one participant who stated "We work closely with

colleagues in other countries to understand what they're doing, but if we can hone the skills in the UK to develop a good pipeline of future engineers and scientists, then that's a real value to the UK economy and it's something that we can sell and promote to the rest of the world." (Case ID 08).The third most frequently mentioned sub-theme, 'ecosystem services', captured the potential for purpose-grown biomass feedstocks to deliver environmental benefits such as increased water retention in soil, contribution to soil health, and boosting biodiversity. The 'resource efficiency' sub-theme included participant responses that focused on using wastes and residues to promote a more circular economy, and the potential for bioproduct creation alongside the production of heat and/or power.

In contrast, the most significant costs of using biomass to achieve net zero identified by participants were 'financial' (18 responses), 'land use' (11 responses) and 'air quality' (8 responses). Whilst being broad in its description, the 'financial' sub-theme focused on the risks involved in the variable cost of biomass feedstocks in relation to global demand, the subsequent financial impact on biomass pathways such as BECCS and SAF, and the cost that will entail if those pathways are encouraged by policy. Many participants focused on how "BECCS is going to be quite expensive and that's one thing that we really need for net zero" (Case ID 01). After this, participants' concerns about the land required to produce the biomass required in the UK were captured in the 'land use' sub-theme. This included consideration of the UK's land capacity, with one participant noting "one of the challenges I guess we're always going to have is we're land constrained country" (Case ID 15), and the pressures on demand for land to support food production, rewilding, or other renewables such as solar and wind. 'Air quality' was the third most frequently mentioned cost, with participants citing concerns for increased particulate matter from the processing, transportation, and combustion of biomass, as well as stating a requirement for continued technological development to mitigate this cost. One participant put it simply, by saying "biofuels still have air quality impacts if they're burned." (Case ID 24) highlighting a key cost of biomass combustion.

Table 14 – A table showing the number of coded responses per sub-theme in relation to the benefits in Q3a, categorised by 'Stakeholder Group'.

Benefits	Stakeholder Group			
(Q3a) Sub-theme	*Policy*	*Industry*	*NGO*	*Total*
Economic opportunities	3	9	0	12
UK global leadership	2	3	4	9
Ecosystem services	5	3	0	8
Resource efficiency	3	2	2	7
Complementary energy	2	3	0	5
Energy security	2	2	0	4
Cost saving	1	1	0	2
Essential for net zero	1	1	0	2
Negative emissions	0	2	0	2
Reduce fossil use	1	1	0	2
Reduce energy bills	1	0	0	1
Totals	21	27	6	54

Analysis by stakeholder group reveals significant focus from industry participants on the 'economic opportunities' sub-theme, which is by far the most frequent sub-theme mentioned in their responses. Industry participants were the only stakeholder group to mention more benefits than costs, and the only group to identify 'negative emissions' (2 responses) as a benefit. Participants in the policy stakeholder grouping mentioned fewer benefits overall, with the most frequently mentioned sub-theme being 'ecosystem services', whilst also acknowledging the 'economic opportunities' and importance of 'resource efficiency' in their responses. Participants from NGOs, being the smallest group interviewed (5 responses), recognised the potential for the 'UK global leadership' on topics such as BECCS to enable exportable knowledge and expertise. The only sub-themes to gain consensus across all three groups were the 'UK global leadership' and 'resource efficiency' sub-themes.

Table 15 – A table showing the number of coded responses per sub-theme in relation to the costs in Q3a, categorised by 'Stakeholder Group'.

Costs	Stakeholder Group			
(Q3a) Sub-theme	*Policy*	*Industry*	*NGO*	*Total*
Financial	9	9	0	18
Land use	2	3	6	11
Air quality	3	3	2	8
Reliance on imports	1	1	3	5
Environmental degradation	3	0	1	4
Social	2	1	0	3
Distracting from alternatives	0	1	1	2
New infrastructure	2	0	0	2
Technical challenge	1	0	0	1
Training needs	1	0	0	1
Totals	24	18	13	55

Analysis of the costs categorised by stakeholder grouping demonstrates further differences in perspectives between policy, industry, and NGOs. The most frequent concern for policy and industry participants fell into the 'financial' sub-theme, focusing on the cost of achieving large-scale BECCS or SAF production and consideration for the level of subsidy required. However, industry participants' concerns communicated this as an upfront type of cost, with a focus on the capital expenditure needed to plant purpose grown biomass crops, develop critical infrastructure, or to adhere to policy or regulatory requirements. These costs seemed difficult to predict, with one participant asking "How clear is your crystal ball? And then obviously there's going to be cost to do with technology development and research to contribute to cost reduction." (Case ID 26). NGO participants had more to say on the cost element of the question than the benefits element. The most frequently mentioned sub-theme by NGOs was the 'land-use' sub-theme, putting the growth of biomass feedstocks in the context of the wider land system and the competition for land to grow biomass versus other uses, such as food production or other renewable energy sources. There was consensus among participants from all three stakeholder groups on the cost of 'land use', as well as the costs to 'air quality', and a concern for the 'reliance on imports' (5 responses) captured in a sub-theme which highlighted the geopolitical risks associated with international biomass supply.

4.1.7. Q3b – Beneficiaries of biomass.

Table 16 – A table showing the number of coded responses per sub-theme in relation to Q3b, focused on the current and future beneficiaries associated with using biomass to achieve net zero.

(Q3b) Who currently benefits the most from biomass use in the UK, and who will benefit from using biomass to achieve net zero by 2050?		Coded Responses (64)	
Sub-themes			
Current Beneficiaries	(39)	Future Beneficiaries	(25)
Bioenergy Subsidy Receipt	7	Current Incumbents	7
Energy Sector	7	Agriculture	6
Drax	6	Landowners	5
Government	4	Foresters	3
Landowners	4	Private Engineering	2
Agriculture	4	Biomass Transportation	1
Waste Processors	3	Non-power sectors	1
Forestry	2		
Society	2		

Participant responses to Q3b on the current and future beneficiaries of biomass were coded into sub-themes within 'current beneficiaries' (39 responses) and 'future beneficiaries' (25 responses) to compare the projected change in the distribution of benefits moving to 2050. The major beneficiaries of biomass currently were identified as those currently in receipt of government subsidy to utilise biomass, under the sub-theme 'bioenergy subsidy receipt' (7 responses), and the 'energy sector' (7 responses) sub-theme, which highlighted the role of biomass in supporting the energy grid and existing industrial assets who benefit from utilising biomass. Also significant was the mention of 'Drax' (6 responses), the third most frequently mentioned beneficiary, where participants specifically mentioned the company and the government subsidy Drax receives for its operations. The top three sub-themes demonstrate a clear perception that participants consider the primary beneficiaries of biomass to be the subsidised energy sector, with one participant summarising this by saying "Obviously more specifically I think the plants benefit a lot. I think that especially the former coal ones, we've enabled their transition, we've enabled them to remain around longer than perhaps they would've done without these incentives." (Case ID 08). This perception is continued in the 'future beneficiaries' sub-theme, with the most frequent response demonstrating that participants believe that 'current incumbents' (7 responses) will continue to benefit from biomass moving towards net zero by 2050.

This is partially due to their existing assets and a requirement to utilise CCS in the future, with one participant making it clear that "If you are a smaller scale biomass power plant that didn't initially think about having space for CCS, you are going to lose out in that march. And the likelihood there is that once you come to the end of your existing contractual arrangements, whether that's on the RO or the CFD, you are unlikely to extend that." (Case ID 13). However, responses in the 'agriculture' (6 responses) sub-theme indicated that a shift to increase domestic production of biomass feedstocks could deliver increased benefits to farmers in the future through rural jobs, the potential for diversifying farm production, and government subsidy to incentivise feedstock development.

Table 17 – A table showing the number of coded responses per sub-theme in relation to the current beneficiaries in Q3b, categorised by 'Stakeholder Group'.

Current Beneficiaries	Stakeholder Group			
(Q3b) Sub-theme	*Policy*	*Industry*	*NGO*	*Total*
Bioenergy Subsidy Receipt	4	3	0	7
Energy Sector	2	5	0	7
Drax	3	2	1	6
Government	2	1	1	4
Landowners	2	0	2	4
Agriculture	3	1	0	4
Waste Processors	1	0	2	3
Forestry	1	1	0	2
Society	2	0	0	2
Totals	20	13	6	39

When analysing the 'current beneficiaries' responses to Q3b aggregated by stakeholder group, the only sub-themes with consensus across all groups are the 'Drax' and 'government' (4 responses) sub-themes. Participants pointed to 'government' benefitting from the current use of biomass to enable the energy sector to deliver both carbon emissions and reliable energy, as well as allowing for policy relief from larger industry stakeholders, such as energy from waste companies who potentially employ large numbers of people. One participant highlighted government benefit by stating "I certainly think there are political winners, and the political winners are basically, well within the UK it's been the government in power since biomass use increased, and particularly since net zero." (Case ID 21). Policy stakeholders were the only group to mention 'society' (2 responses) as a beneficiary, citing the role of biomass in the continued mass consumption of resources used to support lifestyles in the UK. Industry responses fell mainly into the 'bioenergy subsidy receipt' and 'energy sector' sub-themes, reflecting the view that existing, large-scale bioenergy operations gain the most benefit from biomass use, particularly due to government subsidy and support.

Table 18 – A table showing the number of coded responses per sub-theme in relation to the future beneficiaries in Q3b, categorised by 'Stakeholder Group'.

Future Beneficiaries	Stakeholder Group			
(Q3b) Sub-theme	*Policy*	*Industry*	*NGO*	*Total*
Current Incumbents	1	3	3	7
Agriculture	2	2	2	6
Landowners	2	1	2	5
Foresters	1	1	1	3
Private Engineering	0	0	2	2
Biomass Transportation	0	0	1	1
Non-power sectors	0	1	0	1
Totals	6	8	11	25

When considering the responses in the 'future beneficiaries' sub-theme, participants from all stakeholder groups identified large-scale 'current incumbents' (7 responses), including (Drax and airline companies) as the ones who will most likely benefit from biomass use to achieve net zero. This was primarily due to their ability to procure biomass feedstocks for BECCS and SAF, existing assets being primed for future carbon capture and storage capabilities, and the direction of travel from policy seemingly favouring large-scale negative emission projects or decarbonising aviation. This was followed by 'agriculture' (6 responses), 'landowners' (5 responses), and 'foresters' (3 responses), mainly driven by a perceived push towards increasing the domestic supply of biomass feedstocks in the UK and the potential subsidies used to incentivise this. There were anecdotal responses on the potential for 'private engineering' (2 responses) and consultancy firms, those involved in 'biomass transportation' (1 responses) and 'non-power sectors' (1 responses) to benefit also.

4.1.8. Q3c – Public benefits of biomass.

Table 19 – A table showing the number of coded responses per sub-theme in relation to Q3c, focused on the public benefits associated with using biomass to achieve net zero.

(Q3c) How do the public benefit from the UK using biomass to achieve net zero? Sub-theme	Coded Responses (85)
Direct	(54)
Behind the scenes	24
Job creation	11
Cost saving to net zero	8
Air quality	3
More nature	2
Rural economy	2
Moral benefit	1
Rural heating	1
Utilising waste	1
Valuable by-product	1
Indirect	(31)
Ecosystem services	17
Climate change mitigation	14

Upon analysing the responses to the final question on the benefits to the public of utilising biomass to achieve net zero, two distinct themes emerged in the data, with the notion that benefits can be direct and indirect. Therefore, the sub-themes were coded against either 'direct' (54 responses) or 'indirect' (31 responses) benefits. The major theme in participant responses on 'direct' benefits was the notion that the public benefits of biomass to achieve net zero would be 'behind the scenes' (24 responses), demonstrated by one participant who stated, when considering biomass in the energy system, that "if it all works okay, and if we're hitting at zero, the public will just kind of appreciate that benefit and never really know what the challenges that went into make it happen." (Case ID 05). Within this sub-theme, participants pointed to the small but significant role that biomass must play in a future energy context, the complexity of bioenergy, and public priorities as being drivers of the disconnect between biomass utilisation and recognition of a discernible benefit. Participants argued that the quantifiable benefit of using biomass to achieve net zero will be harder to discern from a public standpoint, whilst negative emission technologies such as BECCS will allow for some maintenance of the status quo

(behaviours such as flying and eating meat), the public will probably not be exposed to BECCS at large and so will not connect the action to the impact. This is not just at a national level; even at a local policy level, benefits can still be hard to demonstrate to the public.

After 'behind the scenes' benefits, the next two benefits are indirect to the public, in the secondary benefits of 'ecosystem services' (17 responses) that biomass can support, and in the contribution of biomass to 'climate change mitigation' (14 responses) by reducing carbon in the atmosphere and national scale achievement of net zero. Responses in the 'ecosystem services' sub-theme focused on benefits such as increased water retention in soils providing flood resilience, increased soil nutrient content benefitting farming and food, enriched natural spaces and associated impacts on air quality, increased biodiversity. These benefits were often interlinked, with one participant bringing this together to explain that "The farmer wins, they get better income, society wins because they've got better land for food security, but also, and then biodiversity, ecology, wind, but also and then general public win because these fields that are producing clean air, cleaning water and also places to enjoy as well rather than these monoculture fields." (Case ID 09).

Table 20 – A table showing the number of coded responses per sub-theme in relation to public benefits in Q3c, categorised by 'Stakeholder Group'.

	Stakeholder Group			
(Q3c) Sub-theme	*Policy*	*Industry*	*NGO*	*Total*
(Direct) Behind the scenes	7	8	9	24
(Indirect) Ecosystem Services	7	10	0	17
(Indirect) Climate change mitigation	5	6	3	14
(Direct) Job creation	4	4	3	11
(Direct) Cost saving to net zero	3	3	2	8
(Direct) Air quality	1	2	0	3
(Direct) More nature	1	1	0	2
(Direct) Rural economy	0	2	0	2
(Direct) Utilising waste	1	0	0	1
(Direct) Valuable by-product	1	0	0	1
(Direct) Moral benefit	0	1	0	1
(Direct) Rural heating	0	0	1	1
Totals	30	37	18	85

Analysis of the coded responses broken down into stakeholder groups demonstrates that apart from 'behind the scenes' and 'climate change mitigation', the only other sub-themes to gain consensus across all three stakeholder groups were the 'job creation' (11 responses) and 'cost saving to net zero' (8 responses) sub-themes. Responses to the former focused on jobs driven by a desire to increase

domestic biomass production and use, increasing the requirement for people to manage biomass and land, specifically in rural areas. Responses in the 'cost saving to net zero' sub-theme focused on two motivations: the use of BECCS being part of the lowest cost pathway to achieve net zero from an economic standpoint leading to benefits for society, but also the cost to people's lives in terms of negative emissions enabling less of a requirement for behavioural change to achieve net zero.

4.1.9. Discourse pathway analysis.

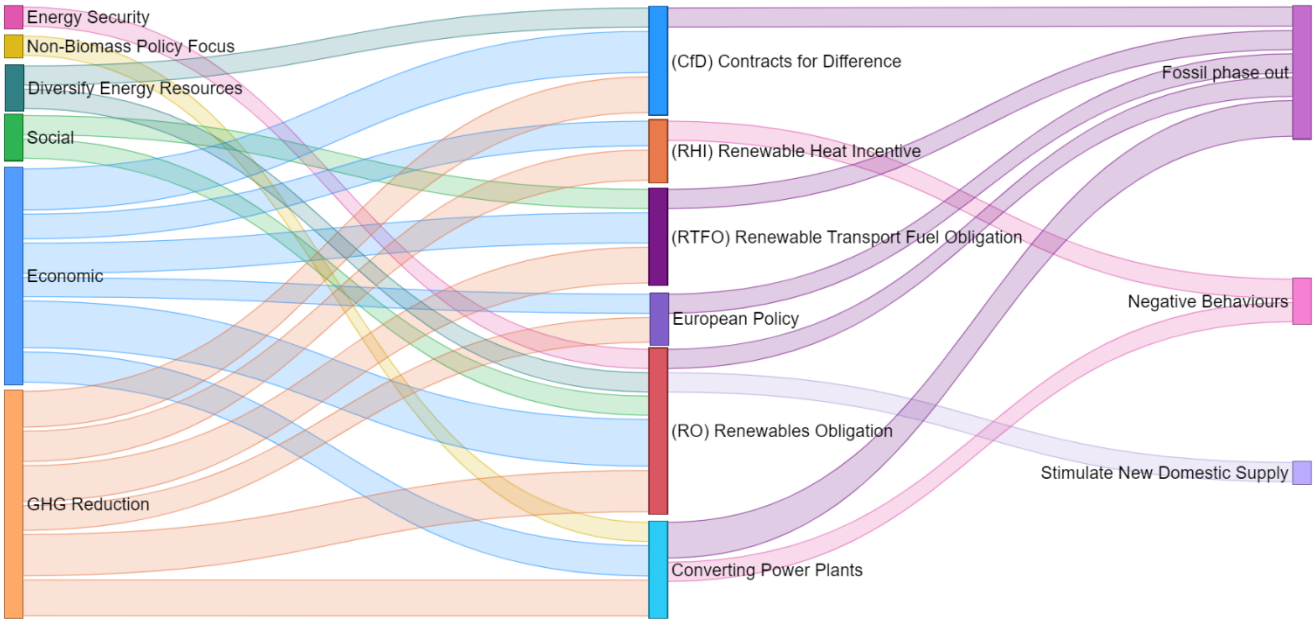

Figure 10 – A Sankey diagram showing the most significant links between drivers for policy, the policies themselves, and impacts of policies stated by participants, where 3 or more participants had mentioned both a specific driver, policy, or impact.

To gather insight into the dominant narratives emerging from the data in NVivo, analysis was done to highlight the primary 'discourse pathways' represented in participant responses. To do this, sub-themes coded to each question were exported from NVivo alongside the Case ID, to provide a list of sub-themes that each participant had coded to them for Q1a, Q1b, and Q1c. This enabled the formation of pathways in participant responses, beginning with the drivers coded to Q1b, which participants argued were the main motivations for pursuing the policies they stated in Q1a. These policies are then linked to the impacts they stated in response to Q1c, creating a 'Driver – Policy – Impact' discourse pathway. This is represented in a Sankey diagram (see Figure 10), where the nodes are the sub-themes collating coded responses, and the links between the nodes are thicker, depending on the number of participants coded to both nodes on either side. This provides insight into the more dominant narratives that link drivers to specific policies and subsequent impacts through 'discourse pathways'. For example, the diagram shows the drivers for converting power plants to run on biomass were a non-biomass policy focus, economic factors, and greenhouse gas reduction targets, resulting in

both a phase-out of fossil fuels and negative behaviours. However, the strongest drivers were economic and greenhouse gas reduction targets, and the strongest impact was the phase-out of fossil fuels.

4.2. Observations and reflections.

4.2.1. Observations made at the time of interviewing.

> *"I think that's been a bit of a challenge, coordinating across the two departments at the right time. I think the appetite is probably there, but it's very chicken and egg." (Case ID 08)*

During the interview, it became clear that there were many niche areas of expertise and knowledge within the sample of participants sourced from the UK biomass and bioenergy field. Each participant addressed the broad questions from a very different perspective despite the common themes that emerged from the data, as evidenced in the coded results. The siloed nature of the participants was reflected in their responses, which began to point towards a lack of consensus and a lack of joined-up thinking between various stakeholders at various levels as interviews went on. For example, different government departments are involved in the utilisation of biomass for different political objectives, not collaborating on an overarching biomass policy but rather separately developing policy which includes biomass amongst other sources of energy or resources. Siloed policymaking was also reflected in industry responses, such as stakeholders at different positions in a biomass supply chain pointing to dysfunctional business-to-business relationships, representing a disjointed and unequal biomass system. For example, domestic biomass producers face pressures from energy generators to reduce their sale prices or arguments over who owns the carbon removal and subsequent benefits because of the biomass carbon sequestration that occurs during the growth process. Participants argued that these differences fuel competition within the industry and within policy, too, causing them to work together at arm's length.

> *"…let's use the word, Drax." (Case ID 02)*

It also became clear throughout the interview process that Drax, the scale of its global operations, and the subsidy it receives from the government are a dominant narrative within UK biomass discourse. 20 out of 26 participants explicitly referenced Drax in their responses, with several of the remaining 6 opting not to mention Drax by name for various reasons but implying it through mention of 'larger' stakeholders who 'receive subsidies'. For many participants, it is the conversion of Drax's power plant from coal to biomass, which drove major carbon emission reductions. However, scepticism over the

legitimacy of the reductions remains. Participants implied the scale of Drax and their international operations made it difficult to trust and contributed to a perceived image problem with biomass from within the UK public, as Drax and biomass are synonymous with one another in the media. They argued that net zero development in political discourse has legitimised Drax's ambition to deliver negative emissions at the scale the IPCC and the UK's CCC predict will be required. This, participants argue, legitimises their business case for continued government subsidy beyond 2027 to develop their BECCS facilities. That "big player" power plants such as the ones at Drax, MGT Teesside, and Lynemouth were awarded subsidies off the back of bilateral negotiations between them and government, as opposed to a classic CfD auction mechanism, shows the power that large-scale facilities with huge financial assets held over government at the time of negotiation. Responses highlighted how the conversion of the large-scale coal power plants was "low-hanging fruit", getting the UK off coal by dropping in biomass. This enabled policymakers an easier pathway to achieve carbon emission reductions, as they could focus on and negotiate with a limited number of sites, as opposed to the many small to medium scale generators also based in the UK at the time.

"I think a lot of the history of biomass has been, from different people's perspectives, someone getting it wrong." (Case ID 20)

The impact of public perception on UK biomass stakeholders and the catalysing effect that participants perceive Drax's media representation to have had on fostering a negative public perception of biomass was mentioned frequently as a primary challenge for the sector. Throughout the interviews, there was a perception that the public image of biomass is a barrier to its future deployment, despite the potential public benefits that BECCS could have in enabling less societal change, as removals would allow for more continuation of high-carbon activities, such as consuming meat, and dairy products, or flying. However, negative perceptions were not reserved for the public alone. Amongst industry responses, there was a consensus that perceived policy failures have soured the perceptions of biomass feedstocks, such as purpose-grown energy crops, within the agricultural community and more broadly. The perceived result of projects such as project ARBRE designed to demonstrate electricity generation from purpose-grown energy crops, left agricultural stakeholders financially burdened, as the project's failure meant the farmers did not recoup financial costs to plant and manage biomass feedstocks. With farmers more directly connected to local communities and their land, which is often retained within families for generations, situations like this have generated a long-standing negative perception of energy crops, which will become a challenge for the UK's ambition to increase domestic biomass supply in the future. Overall, participants gave a sense that the feeling amongst the farming community and potential domestic biomass producers in the UK is low.

"I'm actually in the process of rebranding my business and distancing myself from the word biomass because I feel as though it's got so many negative connotations in the media, general public, and within politics as well." (Case ID 09)

In addition to the perceived negative public image of biomass, the participant responses highlighted the idea that the benefits of biomass use for the public are not tangible or visible. This is in stark contrast to the risks associated with biomass use being made visible to the public in the media. Therefore, it is difficult for the public to appreciate the positives involved in the trade-offs associated with increasing biomass use to achieve net zero. Throughout the interviews, participants pointed to the complexity of biomass systems as a driver for the lack of publicly recognisable benefits whilst acknowledging that biomass has a relatively small role to play in the energy system despite its unique potential to deliver negative emissions. Responses implied that industry is providing government with a service, a direct benefit, and that this in turn translates to indirect benefits for the public. Some participants alluded to the geographical distance between biomass feedstock production and end use as a factor in this, leading to a disconnection between industrial scale biomass use in the UK, and farmers in local communities who are not currently able to benefit from incentivised domestic production. Some of the negative public image is perceived to be catalysed by recent efforts to increase tree planting targets in response to climate change, which participants identified as disconnected from bioeconomy goals, and has emboldened the forestry sector to demand more land for increasing forest coverage. Participants identified sectoral competition between the forestry and agricultural sectors for land, as well as competition for preferential treatment for their respective biomass feedstocks from policy stakeholders.

One point which gained consensus among industry stakeholders, from agricultural participants to those from the energy sector, was the desire for long-term clarity and assurances. However, participant responses demonstrated differing perceptions of the meaning of "long-term" within the biomass sector. From a farmer's perspective, the long-term is decades, with farmers needing to know that when they put crops in the ground, there will be returns year after year, maximising the benefits they can get from their land. From an industry perspective, a decade is a long time in business terms. Still, more specifically long-term is knowing what comes next once government support ends, such as subsidies for renewable energy generation. But from a policy perspective, long-term can be as little as five years, determined by the current electoral cycle in the UK, as politicians seek to win over voters and form government. Industry participants lamented what they perceive to be "short-termism" in policy, particularly as the inherent links between biomass and nature require the policy to be longer term than the policy environment is capable of. Some participants highlighted staff turnover within policy

circles as a key driver for the policy environment lacking the ability to go beyond a five year "long-term" policy decision. This, they argue, is due to the loss of expertise and knowledge on the complexities of biomass and related policy when staff inevitably move roles. This leads to what industry perceive as a lack of clarity and direction, which they desire to commit resources to, and invest in, particular biomass technology pathways.

4.2.2. Reflecting on the research process and product

The potential impact of bias in this research was considered from the very beginning, in the design of the research interviews and sourcing of participants, as well as the analysis of the data presented in this chapter. However, researcher bias in qualitative research is unavoidable, given that you cannot separate the researcher from the process and product of the research (Galdas 2017). Therefore, efforts have been made (as outlined in Chapter 2: Methods) to ensure that the interpretation of the data, the results generated, and the subsequent conclusions made, are presented as objectively as possible. Supported by anecdotal quotes from the participants themselves and context from the coded data analysis, the observations in this chapter represent themes which emerged from the data.

Given that the observations are presented through the perspective of the researcher, it is important to acknowledge the potential biases introduced into the study because of the researcher's role in the process. This is done via reflexive writing (Olmos-Vega, Stalmeijer *et al.* 2023), which captures the researcher's motivations and experiences that shaped the research product and process, as well as the observations presented below. The value of reflexivity is not to completely eradicate the presence of bias or value assumptions on the part of the researcher but to clarify the impact of the researcher's role in developing the research methodology, carrying out the research activity, and the conclusions made as a result of the research (Mackieson, Shlonsky *et al.* 2019).

Before conducting this study, the researcher's prior work experience in biomass and bioenergy enabled the development of a network of professional connections and the establishment of recognition within the field due to association with a major research consortium, the Supergen Bioenergy Hub. Being the United Kingdom's leading research centre on biomass and bioenergy, the Hub's reputation means it is known amongst industrial, academic, and non-governmental organisations as an independent scientific body that produces research on the development of bioenergy systems. As a result of this work, the researcher had prior professional connections with 8 participants whom he met during formal meetings between the Hub and the organisations they worked with. This meant the researcher had some limited knowledge of their expertise in the field and work history when approaching them for an interview, but nothing more than was publicly available on professional networking platforms such as LinkedIn. To counteract the potential for bias due to this, profiles of the individuals sought for

interview were created before sourcing. Individuals who were suggested to fill those profiles were then considered by the researcher and peer examined by his supervisors, depending on the individual's ability to answer the research questions because of their work history, expertise, and knowledge. Primary targets for interview were approached first, with second and third choice candidates identified for each profile sought after.

As well as existing connections due to the researcher's experience with the Supergen Bioenergy Hub, was the researcher's exposure to the dominant narratives in the media and public debate over biomass and bioenergy. Headlines in the UK media have been polarising and controversial. Due to the nature of biomass extraction from our environment, this can become an emotive topic for individuals on both sides of the debate. With respect to the impact on the research, this only underlines the importance of robust scientific evidence in informing public policy. It has also emboldened the researcher to play an independent scientific role through the impartial gathering of insights and perspectives to contribute to the robust scientific evidence required to support policymakers in making decisions. The use of political economy as a theoretical framework and lens with which to view the data presented below is intended to highlight the reality of non-technical factors impacting UK bioenergy deployment and cut through the emotion and controversy that plays out in public discourse.

Throughout the interview process, the researcher maintained a strict focus on the prepared Interview Question Form (Appendix 5) to limit the impact of personal bias by asking each participant the same questions. At times ad-hoc questions were needed for clarification or additional context, which could have opened the interview process up to researcher bias should topics become of interest, however these follow up questions were only limited to specific terms, phrases, or situations that the participant had already mentioned briefly; they were not preconceived by the researcher. Overall, approaches in the design of this research minimised the impact of potential bias and maximised the quality of evidence-based conclusions made because of the data collected, contributing to the reliability and value of this research.

Conducting the interviews online enabled participants to participate in the research at their convenience and discretion. For some participants, this was important due to the nature of their employer or their position, and it enabled them to speak freely on topics if they should wish. Whilst the political economy is not 'political' in the sense that it may be partisan, the nature of the research led some potential participants or their employers to view the interviews with caution, either denying the request for an interview or putting forward an alternative participant from the public relations department. This proved challenging for stakeholders involved in policy, such as those within various government departments, some of whom were discouraged from engaging in the research. Interviews

were conducted during working hours, but the researcher's schedule flexibility meant participants had the choice to propose a convenient time which suited them. Most of those who did engage with the research could do so from home, as opposed to being overheard by colleagues in a work environment. Therefore, the ability to work from home has improved access to expertise and knowledge of the research.

One drawback of interviewing over Microsoft Teams was that the automatic transcription captured during the interviews was lacking, leading to additional manual processing time after the interview took place. Often, the transcriptions were unable to discern certain words, phrases, and technical jargon associated with biomass and bioenergy. For example, the word "miscanthus", or the acronym "BECCS" for bioenergy with carbon capture and storage, was not captured correctly, meaning the transcriptions had to be processed after the interviews to ensure accuracy. Thankfully, audio and video captured during the interviews supported the processing of accurate transcriptions. This had an unintended positive impact on the research, as it prompted the researcher to take additional time to reflect on the interview recordings after the interviews had taken place and contributed to the understanding of the themes and topics shared by participants in their responses. This, however, would have been enriched during an in-person interview process, as interviewing online lacks the opportunity for rapport building with the participants prior to the interview taking place and restricts the researcher from properly observing body language in response to questioning.

At an average of approximately 45 minutes per interview, the 26 total interviews that were completed generated a vast amount of data, which posed a challenge to the research. The sheer amount of qualitative data generated by the semi-structured interview process increased the time required to manually process and code the data in NVivo and the manual processing of transcriptions that had to occur before coding. Steps were taken to anonymise the transcriptions and remove researcher questions picked up in the transcription before the inductive coding process began. During coding, the open-ended semi-structured nature of the questioning made generating inferences complex at times, going line-by-line to ensure a broad coding context. This required additional time to enable the researcher to develop a deeper understanding of the data and the contexts behind answers given and to accurately develop a set of codes representative of the participant's responses within the framework of the semi-structured questioning.

4.3. Results summary.

The results presented in this chapter provide insights into the political and economic factors impacting the deployment of bioenergy systems in the UK through the thematic analysis of coded responses gathered from semi-structured interviews with policy, industry, and non-governmental experts in the

UK biomass and bioenergy sector. This was to elicit responses in support of two primary research questions:

How has policy impacted the sustainable use of bioenergy to achieve carbon emission reductions in the UK since 2000?

How does the UK's political economic situation determine who benefits from, and who pays for, the deployment of sustainable bioenergy systems, to achieve net zero by 2050?

Firstly, the coded thematic analysis of interview responses provided insight into the policies responsible for bioenergy deployment in response to Q1, where participants highlighted the importance of economic factors and greenhouse gas reduction targets that incentivised policy to encourage the replacement of fossil fuels with biomass to achieve carbon emission reductions. This has led to the phase-out of fossil fuels, however, not without unintended consequences. Whilst responses to Q2 imply the introduction of net zero into law in 2019 has not had a discernible impact on the deployment of bioenergy, it has redefined the role of biomass in the energy system and the economy, particularly around the opportunity to generate negative emissions. However, there are concerns that whilst biomass has a role to play in the pathway to achieving net zero, the potential benefits of its use must be weighed up against the costs, considering the financial investment and government subsidy required, as well as questions around the impact on land use and air quality. Participant responses to Q3 highlighted that the current beneficiaries of biomass use in the UK are those involved in the energy sector or in receipt of government subsidies, and responses to Q3b indicated this is likely to be the case with continued biomass use. However, there is a perception that the UK will seek to increase domestic biomass production in the coming decades. This is projected to lead to increased benefits for those involved in the growth of biomass feedstocks, such as landowners, foresters, and farmers, and it also raises new questions about the environmental and social sustainability of UK biomass use.

Secondly, reflections on the research interview process and observations made by the researcher point to a siloed policy environment, limited coordination on biomass policy across government departments, and competition between bio-based sectors for policy influence and preference. A common theme amongst participant responses was the impact of dominant narratives in the media fostering a negative public perception of biomass, attributed to the operations of large-scale biomass operations, such as those at Drax. These costs, laid bare in media headlines, are contrasted with what participants perceive to be the benefits of biomass being ‘behind the scenes’ as shown in responses to Q3c on the public benefits of biomass use. This is down to what participants identify as the

complexity of biomass systems and the small but significant role biomass is projected to play in a net zero energy system, which leads to a disconnect between biomass utilisation and a discernible public benefit. In contrast to direct benefits (such as increased jobs or rural heating opportunities), the national-scale benefits of biomass (such as carbon removal potential, promoting soil health, or increasing water retention) are seen as indirect and more difficult to portray in narratives aimed at promoting biomass use more positively in public policy discourse. Overall, the insights gathered and presented in this chapter have answered the primary research questions as designed, and these points will be explored in the context of the UK's political economy within the discussion of the next chapter.

5. Discussion

The aim of this research was to address three primary research questions. Firstly:

1. **How does the political economy of energy transitions impact their success in replacing fossil fuels and reducing carbon emissions?**

This question was addressed by a review of existing literature on the political economy of renewable energy transitions. The literature review also demonstrated a gap in existing work on political economy, biomass use, and net zero, which this research seeks to address. Those findings will be used to contextualise the discussion found below. The design of a qualitative research activity centred around a semi-structured interview process with experts from across the United Kingdom's biomass and bioenergy sector, then sought to address the following primary research questions aimed at filling the gap in existing literature:

2. **How has policy impacted the sustainable use of bioenergy to achieve carbon emission reductions in the UK since 2000?**
3. **How does the UK's political economic situation determine who benefits from, and who pays for, the deployment of sustainable bioenergy systems, to achieve net zero by 2050?**

The insights gathered and presented in the previous chapter are presented below as a set of themes which align with the structure of the questions used in the interview process, and the implications for future biomass policy frameworks are discussed. It begins with a discussion of the influencing factors, policies, and impacts related to bioenergy deployment in the UK, exploring the impact of policy mixes and power dynamics on the success of policy incentivising sustainable bioenergy. The challenges and deficiencies in the policymaking environment are then highlighted, and the impact of siloed policymaking and the competing interests both within policy and industry are discussed. Following this, the future of biomass in the UK is contextualised alongside the challenge of achieving net zero by 2050 and the need for negative emissions. The discussion then switches from considering the 'what' to the 'who' by exploring the biomass policy beneficiaries and how the benefits distribution might change leading up to 2050. Finally, the impact of public perception is analysed in the context of biomass 'behind the scenes'.

5.1. Policy influence and drivers for bioenergy deployment.

Responses to Q1 in Tables 4 through to 9 show that the policies most influential in enabling the deployment of bioenergy over the past 20 years, as identified by participants, were the Renewables Obligation (RO), the conversion of coal power plants to biomass, Renewable Transport Fuel Obligation (RTFO), Contracts for Difference (CfD), European policy such as the Renewable Energy Directives (RED), and the Renewable Heat Incentive (RHI). These key policies involve a technology-agnostic approach designed to financially incentivise the displacement of fossil fuels in favour of building the capacity of

renewable or low-carbon sources of energy. For example, the fixed pricing for electricity under the CfD protects both the consumer and the producer, and this assurance gives industry the confidence to invest in the development of renewable electricity generation. In exchange, the government are securing low-carbon energy supply to meet their greenhouse gas reduction targets, whilst ensuring the national provision of energy at an affordable rate, therefore upholding their social contract with society. However, as Spivey (2020) identifies, this makes clear the state's position of power in determining the financial benefits accrued by private interests in the energy sector. This demonstrates the limitations of the state in capitalist economies in enacting radical change through renewable energy projects, as tension exists between ensuring national energy provision is affordable for society and protecting the financial assets of incumbent energy producers.

This tension is highlighted in the conversion of coal fired power plants to biomass as a specific policy. Participants treated this separately to the incentives offered by the other policies, by referring to bilateral negotiations between developers of large-scale low-carbon electricity projects and the UK government. These were offered under the Final Investment Decision for enabling Renewables (FIDeR) scheme, in which the government awarded £16.6 billion of contracts to developers early, in order to prevent delays in developers securing investment into new renewable generation (National Audit Office 2014). Amongst the 8 contracts awarded, 5 were in support of offshore wind farm development, 2 were for the conversion of the Drax (3rd unit) and Lynemouth coal plants to biomass, and 1 was for the Teesside Renewable Energy Project with a biomass combined heat and power (CHP) plant. This decision was subject to an inquiry by the National Audit Office (NAO) in 2014 regarding the value for money the FIDeR scheme provided consumers and taxpayers. Ultimately the NAO found that despite increasing industry confidence in renewables in the short-term, the scale of the funding (without price competition) restricted the then Department for Energy and Climate Change in their ability to fund future projects under the newly introduced CfD, and risked delivering excessive returns to developers without any contractual clauses that enabled the clawback of consumer money where necessary (National Audit Office 2014). This deficiency was addressed in the subsequent CfD scheme; however, this example demonstrates that future policy mechanisms for biomass should consider price volatility and put in place measures to protect consumers and that extraordinary policy decisions like the FIDeR scheme can open bioenergy deployment to increased scrutiny.

Future policy mechanisms for biomass should consider price volatility and put in place measures to protect consumers, through clauses that enable the clawback of public funds.

However, the FIDeR scheme alone has not promoted the deployment of bioenergy. These projects have continued to benefit from government subsidies via the RO and, consequently, the CfD and will continue to do so until 2027, when the CfDs end. Participants often listed several policies, pointing to the synergy between individual policies combining to support bioenergy deployment through a policy mix. Edmondson, Kern *et al.* (2019) outline how sustainable policy mixes for a successful renewable energy transition should incentivise beneficiaries to generate positive feedback that mobilises additional support for the transition to help overcome future political challenges. However, participant responses indicate the policy mix stimulating bioenergy deployment has not led to positive feedback, despite aiding in the phase-out of fossil fuels, with participants highlighting the negative behaviour within the bioenergy sector that was incentivised by select policies within the mix. Specifically, the RHI and the decision to convert coal power plants to use biomass are associated with perceived negative behaviours, such as the incentivisation of low-quality biomass heating systems being installed, the exploitation of generous subsidies leading to more biomass being used than is required, and policy failure leading to negative perceptions of biomass use.

Furthermore, the perceived ongoing challenge around the public perception of biomass in the UK implies that positive feedback loops have not prevailed in mobilising definitive political support for continued biomass use in the manner the UK has done to date. This is evidenced in the UK government commissioned 'Public Dialogue on the role of biomass in achieving net zero' in 2023, in which "participants expressed concerns that the Biomass Strategy could become dominated by the profit motives of the energy sector, rather than the need to achieve net zero." (DESNZ 2023). However, responses to Q1b in Table 7 show that the private sector prefers mechanisms which incentivise a move away from fossil fuels towards biomass, in exchange for financial subsidy, with one participant noting, "it's a subsidised industry, we will be a subsidised industry" (Case ID 11). This presents a challenge to policy, given the expectation from industry that government subsidies will have to continue to support the economic viability of future biomass operations, whilst insights from the Public Dialogue demonstrate public concerns that profitability will be placed before people and planet. In contrast, policy stakeholders linked bioenergy deployment to a broad range of policies and were less focused on those which exchange subsidies for fossil phase-out. Considering this, a key requirement for any future policy framework on biomass should consider how to incentivise beneficiaries to develop

positive feedback loops, encouraging them to consider the whole system impacts of their biomass operations, potential trade-offs, and how to distribute and communicate the benefits more widely.

Future biomass policy should incentivise beneficiaries to develop positive feedback loops within the system they operate, distributing and communicating benefits more widely.

Table 21 – A table summarising the key policies which participants highlighted as influential, with a brief description of each policy, the industry impacted, and the year introduced.

Policy Name	Description	Industry Impacted	Year Introduced
Renewables Obligation (RO)	Requires electricity suppliers to source a certain percentage of their electricity from renewable sources.	Electricity	2002
Renewable Transport Fuel Obligation (RTFO)	Requires fuel suppliers to blend increasing amounts of renewable and sustainable transport fuels into their fuel mix.	Transport	2008
EU Renewable Energy Directives (RED)	Sets binding targets for the use of renewable energy across all sectors of the European Union's economy.	Various sectors	2009
Renewable Heat Incentive (RHI)	Provides financial incentives for households and businesses to install renewable heating systems.	Heating	2011
Contracts for Difference (CfD)	Provides long-term contracts between the government and generators, guaranteeing a fixed price for electricity. Replaces the Renewables Obligation.	Electricity	2014

Given that the policies being discussed are aimed at providing financial incentives in exchange for a phase-out of fossil fuels, it is no surprise that the only two drivers for policy to be mentioned by all stakeholder groups interviewed were greenhouse gas reduction targets and economic drivers: the reduction of carbon emissions in exchange for cash. Participant responses coupled the ambition to decarbonise and meet the UK's carbon budgets via bioenergy with the opportunity to maintain the financial status quo; a continued focus on jobs, retaining existing financial assets, and opportunities for economic growth. Underlying the continued focus on economic growth and carbon emissions is a concern for environmental sustainability (and, to a lesser extent, social sustainability) on the part of policy participants. In contrast, industry responses did not include either of these as drivers for policy. This points to the varied political agendas which policymakers are seeking to address at any one time, with additional concerns for energy security primarily focused on securing a source of energy like that of coal – the profile of biomass as a dispatchable source of power was levied as protection against ongoing geopolitical tensions impacting gas supply. Where drivers other than greenhouse gas reductions or economic opportunities were mentioned, they were often framed alongside economic

drivers, such as seeking a 'win-win' scenario where environmental sustainability gains also enabled gains in bioenergy crop yield and subsequently increased financial return. This demonstrates the tension between industrial and policy objectives, where industrial capitalism fails to address problems of environmental degradation and climate change, leading to policy intervention that incentivises markets to try and mitigate negative impacts (Pilgrim and Harvey 2010).

In contrast to policy and industry, results in Table 7 in response to Q1b show that NGO responses were keen to point out the impact of global policy enabling government and the private sector to utilise biomass to achieve carbon emission reductions. Under the United Nations Framework Convention on Climate Change (UNFCCC), biomass is viewed as carbon neutral, whereby the carbon dioxide released during combustion is offset by the carbon dioxide sequestered during the growth period of the biomass feedstock. The carbon dioxide emissions of combusting biomass are therefore not captured in national greenhouse gas emission budgets. This has been particularly useful in the UK context, as since the conversion of the Drax and Lynemouth coal power plants to biomass, the plants have imported biomass wood pellets from North America. The result of this has been policy relief for the UK government, which has been able to incentivise the phase-out of coal using biomass imports whilst retaining a dispatchable baseload of power supply. This has contributed towards the UK's path to ending coal use in 2024 and upheld the national provision of energy. In turn, government have not had to push policy change in other areas to achieve carbon emission reductions, which may have proven more politically challenging, such as driving societal behaviour change to reduce domestic car use, flying abroad, or consuming meat and dairy. Similar to the findings of van der Horst and Evans (2010), who demonstrate how the process of capitalism cannot be decoupled from political, economic, or ecological forces. This demonstrates how certain policy conditions have enabled the removal of carbon from specific social and ecological contexts in the UK. By minimising climate impact to accountable carbon footprints using biomass imports, often intangible to citizens and society, the UK has relied on a technofix to provide policy relief and empowered powerful incumbents to operate the status quo. But, as Backhouse and Lorenzen (2021) argue, this enables technology to determine knowledge formation and developers to exert power over future infrastructure and technological path dependencies, leading to a bioeconomy driven by the needs of industry as opposed to wider society. Therefore, any future policy framework needs to consider these power dynamics if it is to overcome

the impact of powerful incumbent interests and deliver a bioeconomy that prioritises people and the planet rather than continued focus on people and profit.

Policymakers should address existing power dynamics to ensure policy is driven by societal need as opposed to industry desires.

5.2. Challenges and deficiencies in the policymaking environment.

Responses to Q1c outlined in Tables 8 and 9 showed behaviour deemed negative by participants to be the most frequent impact of the policies identified as influential in driving the deployment of bioenergy, alongside the phase-out of fossil fuels and the stimulation of a new supply of domestic biomass feedstocks. This presents a mixed image of biomass in the UK and is representative of the general sentiment observed during interviews, reflected in the most significant links between responses on policy drivers, policies, and policy impacts, which point to a dominant narrative. Overall, industry participants had the most to say about the impact of policy from first-hand experience acting and interacting within the industry. The negative behaviour outlined focused on the abuse of policy mechanisms by bad actors to exploit or game the system and reap financial benefits. For example, setting tiered thresholds for different biomass boiler systems incentivised the installation of boilers that were able to supply much larger amounts of energy (and utilise greater volumes of biomass) than the system required. Or overly generous payments to heat buildings with biomass that incentivised bad actors to keep the heating on, even when it was not required, the economics of which meant they were being paid to heat their buildings. Ultimately, the mix of policies outlined delivered the phase-out of fossil fuels with increased biomass use but did not fully anticipate the complexity of biomass markets and underestimated the ease at which the system could be exploited. This, in turn, has fostered some bad practices within industry, which feed into the negative behaviours observed by participants.

Inequality within the sector was highlighted by participant responses, particularly due to the siloed nature of both the policymaking environment and the industry. Competition between different areas of the biomass sector for preferential treatment by policymakers was evident. For example, biomass producers involved in the development and growth of purpose-grown energy crops noted how the increased focus on tree planting in public policy discourse had emboldened the forestry sector, catalysed by recent media coverage of Drax operations in North America (Crowley 2024), leading to increased policy focus on tree-planting over energy crops. This increased focus has benefitted landowners and farmers, who are now able to receive financial rewards for tree-planting or managing woodland and leads to a perception that one biomass feedstock is preferred over another. In addition

to tensions between feedstock producers, results also show tension between producers and users of biomass, due to the development of domestic biomass supply for use in the UK. This has raised questions over who benefits from the value of the biomass and the carbon sequestered when it is grown. One grower noted that current long-standing beneficiaries of imported biomass, such as Drax, consider the carbon in the biomass theirs and therefore seek renumeration for future carbon capture, such as carbon credits, as they consider themselves as generating the removal. However, the carbon is sequestered when the biomass is in the grower's hands. This tension is something that results indicate policy has yet to address fully and leads to an inequality within biomass systems, resulting in a fragmented sector made up of actors competing for policy influence.

But behind the siloed biomass sector, there is the siloed nature of policymaking, highlighted by policy responses from individual government departments, which demonstrate the differences in objectives and priorities that they work for. Whilst overarching government policy, such as net zero, can unite government departments of differing perspectives around a common issue, this is not the case for biomass. When considering policies influential in the deployment of bioenergy, participants from the Department for Environment, Food, and Rural Affairs (Defra) were the only policy participants to mention incentives for establishing energy crops or domestic markets for their use; participants from the Department for Energy Security and Net Zero (DESNZ) were the only policy participants to mention incentives for replacing fossil fuel usage with renewable sources of energy; and participants from the Department for Transport (DfT) only mentioned incentives for increasing the amount of biomass-derived fuels in petrol. Even in the case of net zero, responses show the impacts of department thinking on biomass are distributed differently, with Defra recognising the focus on domestic biomass production, DESNZ focused heavily on Bioenergy with Carbon Capture and Storage (BECCS), and the DfT considering Sustainable Aviation Fuel (SAF). One factor in this, as one participant noted, is the fact that overarching government policy is divided into "effort shares" (Case ID 16); however, hard policy remit boundaries mean government departments are not concerned with other departmental remits. The result is a lack of joined up policy on biomass and policymakers working at arm's length, which inevitably means issues such as greenhouse gas reductions and removals, land, air quality, economic opportunity, social co-benefits, the environment, and sustainability, span all three departments without an overarching mandate for cohesion. With most of the biomass use occurring via the import of wood pellets for use at large-scale power plants, like Drax and Lynemouth, the UK's approach to biomass use has suited the political economy, not least because energy and biomass sustainability has fallen into the remit of one single government department. But with changes to the future of biomass use in the context of net zero, this may require a shift towards a model that involves multiple

government departments working more collaboratively, reflecting the interlinkages between biomass, the environment, climate, nature, and people.

Ensure policymaking in practice reflects the interlinkages between biomass, the environment, climate, nature, and people, by shifting towards greater inter-departmental collaboration.

Beyond competition between biomass sectors, or government departments for biomass feedstocks, there are also competing stakeholder definitions of 'long-term' which undermine biomass policy. Policy development tied to five-year electoral cycles has led to a perception of short-termism on behalf of industry and NGOs, who criticise the lack of long-term clarity from government. Industry is particularly keen to understand the direction of travel beyond the five-year electoral cycle and wants assurances as to the long-term direction of travel so that they can invest with confidence, knowing their technology is supported and will provide financial return on investment. However, this issue is magnified for the agricultural and forestry sectors, for whom long-term means generations. Farms are culturally important and connected to local communities, often passed down through generations, and so farmers seek assurances on the future of farming well beyond the five-year electoral cycle. This also means that any perceived policy failures quickly lead to negative perceptions of purpose-grown biomass feedstocks; farmers need assurances over much longer timeframes that the upfront costs of establishing new biomass feedstocks will see returns and help to secure their farms for generations to come. This is more distinct for the forestry sector, for whom trees can take decades to grow and reach maturity, leading to a mismatch between policy cycles and forest lifecycles. Stability within policy provides assurances for jobs and investment, securing the forest's future and the associated co-benefits, such as carbon sequestration, ecosystem services, and conservation, for decades to come. Policy will also determine how the forest is managed, with business models dictating harvest and markets for wood-based products. The absence of long-term assurances reinforces the need for policy mixes that generate positive feedback loops and build capacity for the mobilisation of long-term political support (Johnstone and Stirling 2020). It is acknowledged that this has been difficult during recent years, with policy participants noting how ever-changing government priorities mean long-term projects are not prioritised, leaving government departments "firefighting" (Case ID 01).

5.3. The impact of net zero and the need for negative emissions.

Net zero was legislated for by the UK government in 2019 when the Climate Change Act of 2008 (GOV.UK 2008) was amended, committing the UK to reduce greenhouse gas emissions by 100% in 2050 compared to 1990-levels, as opposed to 80%. For this reason, participants were asked what impact

net zero has had on the deployment of bioenergy since 2019. Generalised responses to Q2a displayed in Figure 9 demonstrated that participant sentiment towards the impact of net zero on bioenergy was largely muted, indicating that overall, they perceived net zero to have had little discernible impact (either positively or negatively) on the deployment of bioenergy. A primary driver for this is that much of the influential policy discussed by participants in the previous question went unchanged upon the introduction of net zero into law. The RO, RTFO, CfD and RHI had all been implemented as they operated under the previous '80% reductions by 2050' target, in line with existing carbon budgets, and the new goal did not change this. However, rather than the law itself having an immediate impact, one thing net zero provided was longer-term clarity on the direction of travel from the government on the key issue of decarbonisation. Participants praised the clear target that industry and society could get behind as an overarching measure with which to unite public and private organisations, which then opened space within public policy discourse as to how to achieve net zero.

The context of the past five years and the impact on policymaking in the UK is also important to consider. Since 2019, there has been a global pandemic, five different prime ministers of the UK, and major geopolitical events such as the invasion of Ukraine by Russia. These issues, and more, factor into a host of political and economic problems, such as a surge in the price of energy, inconsistent tax policy, and a severe recession, leading to a cost-of-living crisis. This has put consistent pressure on UK policymakers to react, with urgency, involving major shifts in national priorities and often leading to the reprioritisation of policy resources. Despite this, net zero continues to be a major force on the political agenda. This is evident in the election of a Labour government in 2024, who campaigned on a platform that included the creation of a publicly owned energy company, 'Great British Energy', to drive investment in renewable energy technologies to achieve net zero (GOV.UK 2024). This includes a commitment to decarbonise the electricity system by 2030.

Beyond general sentiment or impact, the major theme identified by participants was the introduction of net zero legitimising the continued use of biomass to achieve emission reductions in 'difficult to decarbonise' sectors, such as aviation, and heavy industry such as steel and cement manufacturing. These sectors have relied on the use of fossil fuels for decades, and the potential for biomass to replace those fuels as a 'drop-in' for coal or liquid fuels has been catalysed by the requirement for net zero by 2050. Participant responses demonstrate that where some sectors or organisations might once have considered themselves a part of the 20% of emissions still allowed in 2050, net zero has focused the minds of the 20% towards managing carbon – either through the intentional displacement of fossil-based carbon for reductions, or via technologies which have the potential to remove carbon from the atmosphere. The 'net' in 'net zero' has legitimised approaches which seek to remove carbon from the atmosphere, generating negative emissions, and participant responses indicated this has emboldened

Drax by legitimising its business model for BECCS deployment. It has also increased the focus on the role of carbon in bioenergy projects, drawing focus away from the environmental and social co-benefits that biomass use can deliver, with policy participants the only respondents to mention co-benefits in relation to net zero. Even still, the mention of co-benefits by policy respondents was to frame the carbon-associated benefits of biomass use as non-carbon, tangible benefits, such as increased biodiversity or job creation in rural economies.

The primary pathway for this based on participant responses is BECCS, identified by the IPCC (IPCC 2023) and the UK's own CCC (CCC 2024) as a key enabler of net zero. Participant responses focused overwhelmingly on BECCS as crucial to continued biomass use, with some indicating it was no longer legitimate to use biomass without carbon capture and storage (CCS). The UK government recently announced £22bn of investment for CCS (Burnell 2024), showing support for the CCS element and a commitment to funding the infrastructure required at scale. Focus on the negative emission potential of the investment in relation to national carbon emission reduction targets and achieving net zero supports insights from participants who observe that investment in large-scale projects with demonstratable national impact is much easier to 'sell' to the public by policymakers. One policy participant outlined how some policymakers will be drawn to focus on policies such as those on BECCS, as they are "exciting, shiny new pipes" (Case ID 08) as opposed to associated policies on land-use or agriculture. Considering how previous UK governments have leveraged techno-scientific solutions for biomass to avoid tensions between environmental policy objectives and objectives for economic development (Levidow and Raman 2020), anticipating technological advancements in large-scale BECCS projects reduces the need for government to trade off one objective against the other.

But in doing so, has the 'net' in 'net zero' created the conditions for BECCS to become, as one participant put it, a "moral hazard" (Case ID 21)? Several participants indicated that continued biomass use in the UK hinges on the ability to capture carbon and generate negative emissions, but the perception of some participants is that the reliance on this within industry is seemingly greater than the volumes of carbon removal outlined by the CCC. This is driven by previous policy decisions, such as the UNFCCC rating of biomass as carbon neutral at the point of combustion, legitimising the use of biomass for negative emissions within the political economy. Given the urgency with which we need to respond to the developing impacts of the climate emergency, policy relying too heavily on BECCS for future removals when the technology is not yet proven to work at the scale envisaged, does risk slowing climate mitigation activities in other sectors that could reduce emissions now. In a similar argument, NGO responses focused heavily on the potential impact that focusing both policy and finance on other sources of renewable energy (such as investment in solar and wind power), as opposed to subsidising biomass would have had, arguing that the impact on carbon emission reduction

would have been greater if investing in different renewable energy technologies. This demonstrates the moral hazard that participants expressed, that if BECCS is relied upon for policy relief now and carbon removals in the future, what decisions are policymakers not taking with respect to other sources of renewable energy supply or societal change?

In fact, in any scenario, the CCC's assessment of the UK's carbon budget demonstrates that carbon removals are now a requirement to achieve net zero because existing reduction measures are too slow, and even with large-scale BECCS deployment, further reductions are required. However, under their 'Headwinds' scenario, which assumes both societal behaviour change and innovation are difficult to come by, the reliance on CCS increases towards 2050, and achieving net zero costs more than scenarios where societal engagement is high, leading to greater behavioural change (CCC 2020). The converse is also true, whereby the CCC's 'Tailwinds' scenario demonstrates how with both rapid societal change and advanced technological innovation in areas like CCS, the UK could achieve net zero by 2042; albeit at a higher cost (CCC 2020).The argument for negative emissions seems clear, but for any policy framework to support future biomass use sustainably, it must reconsider the reliance on BECCS and its associated carbon removal potential to ensure it does not become an expensive tool for policy relief. Framing BECCS in policy discourse is particularly important, as arguments made by participants demonstrate a false dichotomy between the carbon removal potential of BECCS, and the carbon reduction potential of other renewable technologies and societal approaches, when in fact the CCC outline a combination of both will increase the UK's potential to reach net zero by 2050.

The introduction of the 'net' in 'net zero' has also introduced the concept of carbon debt into the discussion, and the temporal aspect of balancing carbon emissions and commitments to remove carbon from the atmosphere. With fossil fuels, carbon is taken from the geosphere after being locked away for millions of years, whereas biomass can act as the vector for carbon transitioning between the atmosphere and geosphere, in a much shorter timeframe. At the point of biomass combustion, carbon dioxide is released into the atmosphere, and new biomass growth sequesters carbon from the atmosphere into the geosphere via photosynthesis. However, if carbon emissions are not balanced with removals, this can accumulate a carbon debt, exasperated by the quality and rate of carbon sequestration. This makes biomass unique as a source of renewable energy with negative emission potential, but in the context of urgency around climate action, the timescales of carbon emissions and removals associated with biomass highlight the importance of sustainability in its production and use. The situation would be much different if the target was 'zero' carbon emissions by 2050. Future policy frameworks will need to consider the carbon debt associated with biomass use, especially as 2050 gets

closer, as the potential for carbon removal to return benefits within the 2050 timeframe and contribute to net zero will differ between BECCS systems.

Policy should treat carbon removals using biomass as complimentary to carbon reductions in other sectors and wider society, considering the potential for biomass to return carbon removals within the increasingly limited time before the 2050 net zero goal.

5.4. Biomass trade-offs and tricky decisions on the path to net zero.

Participant responses showed that the major potential benefits of increased biomass use are tied to economic opportunities for job creation, economic growth within industry, and financial benefits for rural stakeholders more likely to be involved in the production of domestic biomass feedstocks, such as farmers, landowners, and foresters. Similarly to responses on drivers of influential policies, industry participants focused most heavily on economic opportunities. In contrast, policy participants focused more heavily on the ecosystem services that could be delivered, echoing one participant's earlier claim that "policy makers would like to have an agricultural industry which is economically viable and environmentally sustainable" (Case ID 16). These potential benefits are built on the premise that the UK will look to increase domestic supplies of biomass towards 2050, reducing the reliance on imports and, therefore, reducing the impact of price rises on the UK from the global market for biomass due to geopolitical shocks. This again demonstrates the differing perspectives of policy and industry, despite similar objectives that work towards increasing the national supply of domestic biomass, as opposed to imports.

Knowledge and expertise around the use of bioenergy was seen as a key opportunity for the UK to export across the world, attracting international investors, and contributing towards the UK's geopolitical power. This is driven by a view that the UK can position itself as a global leader in bioenergy and BECCS from the opportunity to aid countries with a high biomass potential in their transition away from fossil fuels despite the UK's potential domestic biomass supply being comparably low globally, due to land constraints. La Rovere (2020) suggests that countries with lower levels of accessible domestic biomass resources, such as the UK, are well positioned to support developing countries with a high biomass potential through financing and technology support. This would support the principle of 'common but differentiated responsibility' (CBDR) introduced under the UNFCCC, which acknowledges the historical contributions to climate change that developed nations such as the UK have made and leverages their privileged position of increased economic capacity to aid other countries with their efforts to tackle climate change. There is also a geographical element to factor in,

as one participant identified, the UK's carbon capture and storage potential in the North Sea positions it as a potential "global demonstrator" for CCS. As the UK shifts towards increased domestic biomass production, there is an opportunity to internationalise the knowledge and expertise within the UK biomass and bioenergy field. Given the transboundary nature of climate change and carbon emissions, future biomass policy frameworks should consider this shift, and seek to maximise the positive impact that the UK's international biomass activities can have on the UN's Sustainable Development Goals (SDGs), following the principle of CBDR.

Policy should encourage and leverage UK expertise and knowledge within biomass and bioenergy to contribute towards the UN SDGs, such as leading the way with sustainability standards and practices.

Despite the focus on the future increase in the domestic supply of biomass, the global impact of the UK's biomass practices is important to consider if, as results in Table 13 show, the UK might demonstrate global leadership through its expertise in the future. Contributing to global climate change mitigation efforts by leading on domestic policy that supports the sustainable use of biomass, development of feedstocks and technologies, and particularly the negative emission potential of BECCS, the UK could position itself as a global leader as it did so in 2019, when it became the first major economy to pass a legally binding net zero emissions target (BBC 2019). However, as responses to Q3b in Table 16 show there is a concern amongst the biomass sector that the benefits of the current system are not equitably shared, with the major beneficiaries being dominant and established forces in the energy system in receipt of financial subsidies, as discussed in the next section. To act as a global role model, future policy frameworks for UK biomass will have to demonstrate equitable and transparent biomass practices that minimise the wider systemic impacts of both domestic and international biomass supply-chains, addressing concerns around environmental degradation and adverse impacts on vulnerable communities. This would enable the UK to contribute global leadership within the framework of the UN SDGs, particularly on SDGs 7 (Affordable and Clean Energy), 12 (Responsible Consumption and Production), 13 (Climate Action) and 15 (Life on Land), encouraging the sustainable sourcing, transportation, and consumption of biomass feedstocks. Of course, early adopters are likely to face higher upfront investment costs to innovate and deliver new technologies, methodologies, and approaches, in exchange for being global leaders.

Results also show that the benefits outlined above are contrasted with significant trade-offs, particularly financial costs, such as the high subsidies required by industry for economic viability at scale and the variable global market for biomass feedstocks. Policy and industry focused heavily on

this, but again from differing perspectives. Policy participants were particularly concerned at the level of subsidy required to achieve BECCS at the scale required to remove sufficient carbon dioxide from the atmosphere, in line with existing carbon budget projections. This is a continuation of the reliance on BECCS and the assumption that technological advancements will prevail in the future, as policy considers the financial support required and lobbied for by industry. The technology-centric approach to policy is also highlighted in responses on air quality, which gained consensus across all three stakeholder groups. However, participants claimed innovation in combustion technology would deliver better air quality over time. Industry participants were quick to communicate the investment and capital expenditure to build the infrastructure required for BECCS, and to ensure adherence to future regulatory requirements for biomass. More specifically, industrial participants involved in the production of biomass feedstocks were concerned with the upfront cost of establishing purpose-grown crops or short rotation forestry. Given that the policies associated with the establishment of purpose-grown energy crops (Project Arable Biomass Renewable Energy and the Energy Crops Scheme) were not highlighted as influential in the deployment of bioenergy over the past 20 years, and linked to perceived policy failure that generated negative perceptions of bioenergy crops, participant concerns around the burden of cost on farmers are significant. Similarly to the benefits, the costs outlined were associated with an increase in domestic production of biomass, and a focus on BECCS as the primary, or only, future for biomass. If this is the case, then this places increased importance on the biomass producers, and therefore, future policy frameworks will need to overcome scepticism amongst farmers and properly support them if placing additional responsibility on them via new domestic biomass supply chains.

Policy should redistribute support towards biomass producers, to encourage farmers and foresters to develop and sustain new biomass supply-chains.

In contrast, NGO concern was focused heavily on the land use aspect of increasing domestic biomass supply. Where the UK has imported wood pellets from abroad previously, a focus on growing more non-food crops on UK farmland has brought in discussions about the use of land, and the 'food vs. fuel' debate. In the context of the wider land system, achieving net zero will lead to a change in how we utilise land, particularly as the UK is land constrained. Current land-use and landscape values, being the attributes of landscapes that people find important, will have to be challenged and deconstructed in order to enable the transition to clean energy (Calvert, Greer *et al.* 2019). This is demonstrated in responses, which also framed the use of land for growing energy crops against the use of land for other renewable sources, such as solar. This is likely to become more complex given the UK government's

decision to lift the ban on onshore wind farm development in 2024, introducing another competitor in land-based decision-making, but hopefully clarified in the upcoming Land Use Framework being developed by Defra. However, whilst different renewable energy sources have different geographies and, therefore, differ on the issue of land use, it is marginal people and land that are most likely to be impacted by a top-down approach to land management (McCarthy and Thatcher 2019). These trade-offs highlight the need for policy frameworks that address both environmental and economic impacts of biomass use, whilst going beyond just mitigating the negative impacts of biomass use by anticipating future technological advancements, navigating, and integrating with wider systems of land use, energy, and agriculture.

Policymakers should integrate biomass policy design with wider systems of land use, energy, and agriculture.

5.5. Beneficiaries of biomass.

Responses to Q3b highlighted in Table 16 show that participants clearly think those in receipt of government subsidies involved in bioenergy to be the greatest beneficiaries, pointing to the enabling role that biomass had in allowing energy incumbents to retain their existing financial assets previously tied to coal use. Some participants opted to single out Drax and the government subsidy it receives for its operations, whereas others preferred to suggest Drax without mentioning it, instead using terms like 'large bioenergy producer', 'big power plant that receives large government subsidies', or 'big player'. The relationship between Drax and the government was one which was highlighted across multiple interviews, with participants providing insights on the power dynamics at play, implying the sheer scale of Drax and its operations had made the relationship dependent and too big to fail. Drax needs subsidy to continue its operations, and the government needs dispatchable low-carbon energy generation that delivers greenhouse gas reductions, and serves societal expectations of national energy provision. The decision to switch Drax from coal to biomass was, argues one participant, not intended to be the start of a long-term bioenergy strategy in the UK, due to the scale of the plant and the volume of feedstock required as they stated "If it hadn't been for the entire process, you would not have started your bioenergy strategy in the UK with Drax, it's just so big the scale of that plant, and I don't know if you've ever visited it, but the scale of the plant is so enormous that there was never going to be a UK feedstock procurement route available to it." (Case ID 22).

Overall, Drax wields high levels of both political and economic power within the biomass sector, not just over government, but also within the biomass sector over feedstocks and growers. Results in Table 16 also show this may well be set to continue, as net zero has legitimised Drax's future business case

predicated on continued government subsidy to support their development of BECCS. The political economy has delivered huge financial benefits to Drax and its shareholders and, in exchange, contributed to the phase-out of coal in the UK. The relationship with Drax and reliance on its capabilities in the future is something that must be considered if biomass policy is to redistribute benefits across the sector. Negative feedback loops have developed to a point where the perception is that continued biomass use is supporting private interests over public benefits, presenting a challenge to policymakers who wish to generate political support for biomass policy decisions. This is evident in the Public Dialogue on 'the role of biomass in achieving net zero' which outlined a public perception that the Biomass Strategy "could be dominated by the profit motives of the energy sector as opposed to achieving net zero" (DESNZ 2023), demonstrating public uncertainty over the future of biomass.

Whilst energy incumbents like Drax are perceived to be current and future winners in biomass policy, in the context of a perceived shift towards increasing domestic biomass production, responses to Q3b also a slight shift in benefits towards stakeholders involved in establishing biomass production, such as agriculture, landowners, and foresters. This is primarily built around the assumption that government policy will seek to financially incentivise farmers and landowners to grow biomass for future demand, enabling the agricultural sector to diversify income streams and create rural jobs, benefitting rural economies. This would represent a decentralisation of benefits currently concentrated into large single asset projects towards many smaller agricultural projects and demonstrates the uneven process of destabilising existing power dynamics involved in the transition to clean energy. This has been contextualised in part by discourses of self-reliance and energy security, which (Morris 2013) asserts are linked to bottom-up, grassroots narratives. This differs from the top-down approach to biomass policy to date. Despite this, the policy focus on the future role of biomass in delivering negative emissions to achieve net zero seemingly favours large-scale projects, such as existing assets being primed for carbon capture or decarbonising aviation through SAF. Decentralisation and centralisation of power and resources "can occur on many intersecting levels" (Ferrall, Heinemann *et al.* 2021). Policy enables biomass use; therefore, a future policy framework for biomass should carefully consider how the centralisation of power through government support will impact stakeholders differently and evaluate how this will impact the sustainability of biomass use in the context of net zero.

Policymakers should consider the impact of centralisation and decentralisation of support on stakeholders and the subsequent sustainability impacts of biomass use.

Systemic reliance on supporting large-scale projects, underpinned by business models favouring large-scale stakeholders, undermines the potential for biomass use to contribute to a diversification of the energy system and associated benefits. This could, as one participant noted, lead to the same issue of centralisation in the energy system, and the reliance on a few large-scale supply-chains. In contrast to the eco-modernist approaches of past UK governments to bioenergy (Levidow and Raman 2020), a diversified energy system that is supported by localised, place-based approaches to biomass, would represent an eco-localist approach. Markets for renewable energy in the UK to date, however, are driven by national policies that still favour the centralisation of biomass resources. As Harnmeijer, Toke *et al.* (2018) identify, this can lead to a top-down approach that is prescriptive in its engagement with local people and can enable private interests to undermine the autonomy of local communities in decision-making processes. As results demonstrate, the continued use of biomass to support the UK's net zero target has the potential to redistribute benefits towards rural economies, and combining this with localised biomass systems would align more closely with the principles of a circular bioeconomy. This alternative approach would, therefore, connect local rural communities more closely to the benefits of biomass use, open more opportunities to develop positive feedback loops associated with biomass, and have the potential to generate greater political support for its use.

Localising benefits also represent an opportunity to better integrate the use of bioenergy within the wider UK bioeconomy and go beyond the linear economic model that drives the extraction, conversion, and utilisation of biomass towards a more circular approach to the bioeconomy. Beyond transport fuels and energy, various bio-based sectors exist to produce bioproducts, such as chemicals or construction materials. However, who benefits from a more circular approach will depend on the overall goal and how biomass systems and the bioeconomy are optimised to achieve certain objectives. For example, the introduction of net zero has brought about an increased focus on the role of carbon and carbon budgets in biomass decision-making. Therefore, the primary goal to fulfil through the utilisation of biomass is carbon reduction or removal. This is evident in the UK's carbon budgets, which prioritise the potential for biomass to deliver negative emissions through BECCS, as well as the strategic allocation of bioenergy in "difficult-to-decarbonise" sectors such as aviation and heavy industry. This is also reflected in the UK's Biomass Strategy (DESNZ 2023), which identifies the limited supply of sustainable biomass to be used in hard to decarbonise sectors and to generate carbon removals, bringing into question where the biomass supply will come from. It did not, however, set out a cross-sectoral prioritisation for biomass or outline which sectors would be entitled to benefit from biomass in the future, leaving many sectors competing to benefit from using biomass in their own pathways to net zero. This siloed, sectoral focus may detract from an opportunity to develop a coherent set of cross-

sectoral policies that maximise the integration of bioenergy with the wider bioeconomy, which a new cross-sectoral framework on biomass sustainability could facilitate (Taylor, Sparks *et al.* 2024).

Instead, much of the policy focus beyond BECCS focuses on another technology that is being primed to deliver carbon reductions at scale, SAF. Responses to Q3b demonstrate that participants believe the primary future beneficiaries of biomass to be current incumbents, both from an energy perspective and an airline perspective. Much of this is driven by the desire to maintain the existing status quo within the aviation sector, despite an expectation that the sector is projected to be the largest emitter of carbon dioxide by 2050, relying on removals to offset unavoidable emissions (Environmental Audit Committee 2023). Participants pinpointed the purchasing power of airlines to source and secure biomass feedstocks on the global and domestic markets, along with a societal desire to not lose the capacity to fly abroad, as key drivers for this. The importance placed on SAF is highlighted by the UK government's 'Jet Zero' Strategy (DfT 2022), which was criticised by NGOs for lacking any acknowledgement of demand reduction, instead aiming to support continued growth in the aviation sector. Whilst proponents of SAF believe the strategy encourages innovation and delivers an ambitious target for the private sector to aspire to, it relies on optimistic projections for SAF scalability and on carbon offsetting. As one industry participant noted, this strategy differs from the RTFO, which successfully increased the mandate for biofuels in road transport fuel over time and tightened sustainability criteria which gave suppliers time to refine their processes. However, the RTFO raised costs for suppliers, which were ultimately passed onto citizens in fuel prices, which is a localised cost to road users in exchange for emissions reductions that will deliver incremental benefits on an international level. This demonstrates how structural power within fossil-fuelled industries resists change, and much like the co-firing of biomass in coal-fired power plants, the potential for biomass to act as a 'drop-in' via fuel blends drives incumbents within the transport sector to prioritise biomass. This aids their transition from liquid fossil fuels in a way that minimises the cost of change to them, and policies enable them to pass that cost onto citizens.

5.6. Public perception and biomass 'behind the scenes'.

A major theme which emerged from the results considering the public benefits of utilising biomass to achieve net zero was the notion that biomass and its associated benefits are behind the scenes. Responses outlined how the small but significant role biomass plays in the future net zero energy system, combined with the complexity of bioenergy systems and carbon cycles, mean that biomass utilisation is disconnected from benefits discernible to the public. This is demonstrated by one participant who noted "For the most part, the vast majority, if you think about your friends and family, as long as the lights turn on and they can afford their bills, they're fine. That's great. If it's decarbonized even better, great." (Case ID 13). If the future of biomass is large-scale BECCS projects, delivering

carbon removals on a national scale at the local level, it is unlikely that society will recognise a difference. The concept of 'net' in net zero introduces the idea of carbon balances, and so carbon removals also offset societal behaviours, such as consuming meat and flying abroad, that are associated with higher carbon emissions. Therefore, BECCS allows for some maintenance of the status quo, but responses indicate that this might not be tangible or quantifiable at the local level. Therefore, the benefits to the public are behind the scenes. Backhouse and Lorenzen (2021) assert that a focus on carbon in bioeconomy strategies detracts from the opportunity to deliver social and environmental benefits. The behind the scenes benefits of carbon removals are getting focus, but these are less tangible than environmental and social benefits; the types of public benefits identified by participants, such as job creation, reducing cost to the taxpayer with respect to achieving net zero, and protecting and restoring natural ecosystems. Despite only two participants identifying society as a current beneficiary of biomass, responses to this question highlighted the potential for biomass to contribute social benefits, but demonstrate that focus on carbon detracts from delivering the type of tangible public benefit that is likely to mobilise political support for increasing biomass use.

The lack of tangible and demonstratable benefits of biomass was evident in participant responses when alluding to the public perception of biomass, which is viewed as a significant barrier to continued biomass utilisation. This impacts the entire biomass sector across all levels and is catalysed by several factors. First, participants identified the portrayal of biomass in the media as an example of a negative feedback loop in which the continued scrutiny of Drax and its global biomass operations dominates. As one participant noted, Drax and biomass are synonymous with each other in the media, and the scale of Drax and government subsidy it receives opens it up to public and media scrutiny, which harms the biomass sector. Secondly, whilst the similarity to coal as a dispatchable source of power is a significant benefit for biomass within a renewable energy system, the association with coal still undermines its public legitimacy. In contrast to policy and industry participants, NGOs used the word 'unabated', often associated with the use of fossil fuels, to describe the UK's approach to 'unabated biomass' use. This is understandable given many environmental NGOs have a less favourable perception of biomass and is done with the intent to influence policy away from supporting it further. However, even within industry responses, there was an indication that 'combustion', again associated with fossil fuels and biomass but not other sources of energy, has become less favourable due to impacts on air quality and associated emissions. One participant even went as far as to say they were considering rebranding their entire business to remove any association with 'burning'. Finally, participants consider the complexity of biomass and bioenergy systems to be a key barrier to public engagement, in comparison to competing arguments for increased tree-planting, which are simplified as a measure to tackle climate change. One popular narrative in climate change discourse is the use of

nature-based solutions (NbS), including the rewilding or reforesting of land, but participant responses indicate that this narrative works against arguments for the increased use of biomass despite obvious connections with the natural environment. Clearly, there is a challenge within public policy discourse around the communication of biomass, which will continue to be a challenge for future policy. However, consideration of the dominant narratives within the public discourse discussed above could help policymakers to adequately address concerns about the continued use of biomass. This could be done through the use of tools such as a Narrative Policy Framework (Crow and Jones 2018), which could enable the development of clear and concise narratives that overcome the controversy surrounding biomass and ensure that policy is guided by robust scientific debate.

Policy should set aside resources to support engagement with beneficiaries and stakeholders to address dominant narratives of public concern.

5.7. Discussion summary.

This chapter has discussed the themes and topics that emerged because of the semi-structured interview process with experts from across the United Kingdom's biomass and bioenergy sector, which sought to address the following primary research questions aimed at filling the gap in the existing literature:

1. **How has policy impacted the sustainable use of bioenergy to achieve carbon emission reductions in the UK since 2000?**
2. **How does the UK's political economic situation determine who benefits from, and who pays for, the deployment of sustainable bioenergy systems, to achieve net zero by 2050?**

The discussion addressed Q1 and highlighted how greenhouse gas reduction targets and economic drivers combined to incentivise the deployment of bioenergy through government policy, and as a result, contributed to the phase-out of fossil fuels but not without creating the conditions for negative behaviour and negative perceptions to grow. The challenge for policy is made more complex by tensions present in the policymaking environment, the industry, and the competing definitions of 'long-term' policy, undermined by the siloed nature of policymaking on biomass. The discussion also explored insights into Q2, putting this in the context of net zero, which has caused certain sectors to focus their future energy needs on biomass, where the introduction of the 'net' has legitimised approaches that generate negative emissions. This has focused debate on the potential for biomass to contribute to net zero around the carbon dioxide removal potential, with policy and industry focus moving to BECCS as a top priority, arguing that carbon removals are a indirect societal benefit. There

is an assumption that in the future, the UK will seek to reduce the reliance on the import of biomass by looking to scale up the production of domestic biomass feedstocks. However, this will have to overcome long-standing scepticism of non-food crops within the agricultural sector to succeed. If successful, this could see a shift in the distribution of benefits associated with biomass, favouring stakeholders associated with the production of biomass feedstocks, which has implications for environmental and social benefits in rural areas. Public perception and the distribution of biomass benefits have a key role to play in the social legitimacy of continued biomass use because if policymakers are hoping to mobilise political support for future biomass projects, they need to ensure the benefits of biomass are not hidden from the public 'behind the scenes' through a continued focus on carbon.

Whilst this discussion has provided an in-depth focus on the key themes that emerged from the interview data through the analysis of correlation, it does not show causation. Results demonstrated how participants could not link distinct policies to specific impacts, but rather that the collective influence of many identifiable drivers resulted in a set of identifiable policy outcomes. Inferences made through the lens of political economy identified the potential policy influence, recognised, and highlighted the complex interdependencies and power dynamics, and put them into the context of economic, political, and social factors. Political economy has enabled the analysis of variables within the complex political and economic systems functioning within and around the UK biomass sector, revealing systemic relationships, as opposed to specific causes and effects. The themes in this discussion are distilled in Table 22 below, and developed in the next chapter, which puts forward an alternative framework for biomass policy in the UK that seeks to maximise sustainability benefits, in line with the UK's net zero target.

Table 22 – A table summarising the discussion theme and deficiency in the political economy identified, and the consequent consideration for future policy.

Discussion theme and deficiency identified	Consideration for the future
Policy mechanisms didn't protect consumers and taxpayers from price volatility or from exploitation of public funds by developers.	Future policy mechanisms for biomass should consider price volatility and put in place measures to protect consumers, through clauses that enable the clawback of public funds.
Public concern that profitability will be placed before the need to tackle climate change and energy bills due to failure of policy to mobilise political support.	Future biomass policy should incentivise beneficiaries to develop positive feedback loops within the system they operate, distributing and communicating benefits more widely.
Powerful incumbents can leverage technology to exert power over knowledge and infrastructure, leading to technology lock-in.	Address existing power dynamics to ensure policy is driven by societal need as opposed to industry desires.
Siloed policymaking environment leads to disjointed policy responses.	Ensuring policymaking in practice reflects the interlinkages between biomass, the environment, climate, nature, and people, by shifting towards greater inter-departmental collaboration.
Net zero has increased the focus on biomass to deliver negative emissions but the UK risks over-reliance on a technology not yet proven at scale, to the detriment of wider societal carbon reduction activities.	Policy should treat carbon removals using biomass as complimentary to carbon reductions in other sectors and wider society, considering the potential for biomass to return carbon removals within the increasingly limited time before the 2050 net zero goal.
The UK has historically contributed greater amounts of carbon emissions causing climate change, and therefore under the UN CBDR principle has a responsibility to leverage benefits accrued by fossil fuelled development to help other nations.	Leverage the UK expertise and knowledge within biomass and bioenergy to contribute towards the UN SDGs, such as leading the way with sustainability standards and practices.
Negative perceptions of purpose grown energy crops amongst farming communities due to perceived policy failures in the past are discouraging engagement with national efforts to increase domestic biomass supply.	Redistribute support towards biomass producers, to encourage farmers and foresters to develop and sustain new biomass supply-chains.
Biomass policy overlaps several policy areas and an increased focus on domestic biomass supplies is set to increase focus on the interaction between these policy areas, which is undermined by siloed policymaking.	Integrate biomass policy design with wider systems of land use, energy, and agriculture.
Current mix of centralised support for large-scale biomass operations will need to shift to support smaller-scale, domestic biomass supply-chains located in sometimes disparate, rural communities.	Consider the impact of centralisation and decentralisation of support on stakeholders and the subsequent sustainability impacts of biomass use.
Past policies have failed to mobilise public support for continued biomass use and communicate the benefits of utilising biomass to the public.	Policy should set aside resources to support engagement with beneficiaries and stakeholders to address dominant narratives of public concern.

6. An alternative framework for biomass policy

The discussion in the previous chapter highlighted several key considerations for future biomass policy frameworks summarised in Table 22, to reorientate the political economy of biomass use in the UK towards supporting redistributive policy that delivers greater benefit to people and the planet, in the context of net zero. Biomass policy to date has supported the UK in beginning to decouple society from fossil fuels, particularly coal, whilst maintaining a focus on the existing status quo and economic growth. This has been enabled by policies such as international carbon accounting frameworks, the conversion of coal power plants to biomass, and large financial subsidies. However, this approach has failed to mobilise significant political support for continued biomass use by reinforcing positive feedback loops. Instead, it has generated inequalities within the biomass sector, undermining its social legitimacy. This is the result of leveraging biomass to support the same linear economic principles that led to the exploitation of fossil fuels in exchange for continued economic growth and privatisation.

The introduction of net zero into the political agenda has reinforced the focus on carbon in biomass and legitimised approaches which seek to remove carbon from the atmosphere, such as BECCS. Despite the CCC's advice that massive-scale carbon reductions and removals are necessary to achieve net zero by 2050, the reliance on technological advancements in BECCS to deliver negative emissions in the future has allowed for policy relief in other areas, such as driving behavioural change in society. This is unique to biomass as it is a source of renewable energy that acts as a vector between atmospheric and geological stores of carbon, placing increased importance on the timeliness of policy in the context of urgent climate action, ensuring biomass can be grown and utilised before it is too late for its use to have a significant impact. But this must be done with caution, as a focus on carbon detracts from the potential for biomass to contribute towards environmental and social objectives, generating positive feedback loops with a wider range of stakeholders and mobilising increased political support. This is particularly important considering the direction of travel set out by government in the revised UK Biomass Strategy, which outlines a desire to increase the domestic supply of biomass, meaning an increase in the number of localised, domestic biomass supply-chains in the future.

This presents an opportunity to move away from the technology-focused model for policy towards a bioregional approach, promoting the sustainable management of resources, such as biomass, within natural ecological boundaries. This also raises questions about who should be responsible for the management of biomass systems intrinsically linked to nature and the atmosphere, whilst integrating biomass into energy systems, all of which can be viewed as public goods. Reflecting on this, Ostrom (1990) demonstrates through extensive case studies that communities can self-organise and sustainably manage common resources without succumbing to the "tragedy of the commons", and

without the need for the privatisation of, and access to resources, or through the top-down governance of resources by a centralised authority. Instead, Ostrom (1990) proposes a rearrangement of the commons (including common pool resources such as forests, fisheries, and water systems) which advocates for collective decision-making by the resource users, and proportional costs and benefits ensuring those who contribute the most effort receive a proportional return. However, considering biomass as a larger common pool resource, Ostrom's approach introduces complexity to biomass policy design yet unseen at scale, challenging established structural power that currently determines who has the right to benefit from biomass and in which way. So far, the political economy in the UK has favoured the use of biomass on a large scale to decarbonise electricity supply through importing biomass from abroad, externalising the ecological impacts of extracting biomass from natural systems. Given the deficiencies in the political economy discussed in the previous chapter, Ostrom's proposals for the sustainable management of natural resources challenge the false dichotomy presented between privatisation and government control, putting forward an alternative framework for policy and governance that prioritises acting locally whilst thinking globally.

This chapter puts forward an alternative framework for biomass policy (visualised in Figure 11 below in this section) that seeks to redistribute the benefits of biomass more equitably, challenging some of the deficiencies highlighted in the political economy, in line with the principles of a fair and just transition to net zero. For this to occur, several elements within the enabling environment for biomass policymaking require reform to stimulate such a policy mix:

1. **Increased cross-sectoral collaboration via a systems-thinking approach to policy.**
   Current policy remits are siloing interrelated policy areas on biomass, such as land use, energy, agriculture, forestry, environmental protection, and transport. Despite governmental policy measures such as net zero providing overarching objectives, departmental contributions to these are split into effort shares. With an increased focus on domestic biomass production and supply, future collaboration between Defra and DESNZ will be critical to ensure that biomass supply is matching demand, and that demand is not going to exceed ecological limits designed to protect environmental systems from degradation. A continual feedback loop between departments will enable the consideration of the complex trade-offs associated with the optimisation of biomass systems towards policy objectives, maximising the potential for biomass to contribute towards net zero without breaching environmental protection.
2. **Alignment of the role of biomass amongst cross-departmental strategies and frameworks.**
   Alongside the revised Biomass Strategy, alignment of the role of biomass in achieving net zero amongst other government frameworks is key to providing assurances to industry in the absence of long-term commitments. Strategies such as the Land Use Policy Framework being

developed by Defra will have major implications for future domestic supply of biomass. The development of a cross-sectoral framework for biomass sustainability, as committed in the revised UK Biomass Strategy, has the potential to bring together stakeholders from across the bio-based sector and facilitate further alignment of departmental thinking on biomass from multiple perspectives.

3. **Reallocation of support towards distributed circular systems away from large-scale linear systems by addressing the mix of centralised and decentralised support.**

   Global supply-chains supporting the linear usage of biomass for low-carbon electricity have suited the political economy, particularly as this business model falls primarily falls within the remit of a singular government department, enabling the defossilisation of electricity production. However, the scale of investment in large-scale power assets, historically running on coal, concentrates finance and government support for biomass into incumbent energy companies. Subsidies have made this economically viable and profitable for energy incumbents; however, increasing domestic biomass supplies will require financial support to be distributed across wider networks of localised stakeholders involved in cultivating biomass feedstocks. Distributing financial support amongst larger networks of stakeholders that are more closely connected to local communities can potentially connect larger sections of the public to the benefits of increasing biomass use. It also has the potential to reduce the reliance on global imports, improving energy security and energy system resilience in the face of geopolitical shocks. Centralisation and decentralisation can occur at varying levels, and addressing this mix by increasing the proportion of support for decentralised biomass systems will mean government support is no longer concentrated in the hands of a few large-scale stakeholders.

4. **Prioritising biomass system outcomes beyond a singular focus to ensure distributive policy by design.**

   Optimising policy to incentivise the development of biomass systems that serve a singular objective, such as maximising carbon emission reductions or removals, detracts from the potential for biomass systems to deliver system-wide benefits. Instead, approaching policy in a way which values biomass use that delivers benefits to the wider network of systems it integrates with, will encourage greater circularity of resource use, and potentially develop greater positive feedback loops that mobilise political support. An understanding of the trade-offs associated with this approach is key, as in exchange for giving up some progress towards a primary policy objective such as carbon removals, there may be greater potential for

environmental or social benefits. However, this will be context and location-specific; therefore, which outcomes are prioritised will depend on the existing systems and practices the biomass system is integrating with. For example, in a flood prone region, biomass feedstocks which have a high ability to slow water flow, catch flood debris, and withstand periods of high-water levels could be a priority for farmers and landowners. In contrast, in heavily agricultural regions, the establishment of biodiversity positive biomass feedstocks might help to counteract the negative impact on local wildlife of vast monocultures, and therefore be a priority for that region. Instead of applying a homogenous national policy that sets prioritised outcomes, the prioritisation of outcomes must be localised, and decision-making should be enabled by flexible policy incentives that empower local stakeholders to contribute towards environmental protection. This avoids the potential for centralised, top-down approaches to biomass rulemaking imposing regimes on local communities and more likely generates political support.

Whilst the changes to the enabling environment for biomass policy above would address some of the major deficiencies in the current political economy, implementing them would present its own challenges. The changes presented would challenge the status quo, and structural power inherent in capitalist economies would resist change that might lead to a reduction in profits or detract from a focus on economic growth. However, when it comes to the complex ecological systems supporting the production and harvest of biomass feedstocks, the solution cannot be to pursue growth whilst anticipating technofixes that will mitigate the negative impacts on the environment. The scale of the challenge that climate change presents must be met with a proportionate scale of change if we are to decouple humanity from endless fossil-fuelled growth, based on harmful extractive economic principles. Those same extractive economic principles must then not continue to be applied to biomass and its inherent links to our natural world. Otherwise, biomass will be exploited and profited from at the expense of the planet. Instead, policy mechanisms should seek to support redistributive measures that deliver the benefits of biomass to a broader set of diverse stakeholders, more connected to local communities and the public:

1. **Reward biomass systems that deliver multi-dimensional benefits whilst protecting citizens.** Supported by the harmonisation of approaches to sustainability via a new cross-sectoral framework, policy mechanisms should be assessed on their ability to generate multi-dimensional benefits, beyond a single policy aim. Taking a holistic approach to analysing and understanding the existing systems that biomass use will overlap and integrate with, as well as how biomass will change and interact with those systems, will enable this. Instead of rewarding energy producers with long-term contracts under the CfD scheme, which protects

them from price fluctuation whilst delivering low-carbon electricity, a new model for performance-based subsidies could reward projects based on progress against social and ecological criteria. Within this model, public money could be directed towards public good, with benefits such as flood protection, biodiversity gain, and economic contribution to local communities given incentives alongside carbon reductions or removals. If performance indicators are not met, reallocation mechanisms could divert funds away from poorly performing projects and towards the next round of funding for new entrants, avoiding the exploitation of publicly funded subsidies.

2. **Develop stringent sustainability criteria in line with the latest scientific evidence, reviewed periodically.**

   Monitoring, reporting, and verification (MRV) are crucial to determining where biomass has delivered impact against sustainability criteria. Given the continued development of both scientific evidence on biomass and public perceptions of biomass, approaches to MRV and the sustainability criteria need to be scientifically robust and reviewed periodically to develop trust and transparency in processes. This will also ensure they are not creating negative system impacts or enabling negative behaviours based on outdated evidence or assumptions. For the UK to realise its potential as the global leader in biomass, approaches must be underpinned by stringent sustainability criteria that set a standard for other countries to follow, minimising the potential cross-border impacts of global biomass supply chains. Utilising existing frameworks such as the UN SDGs would aid in the development and communication of the UK's international activities related to biomass and demonstrate the UK's commitment to tackling global challenges by leveraging UK biomass expertise.

3. **Allocate resources to engaging with beneficiaries and stakeholders, as well as addressing public concern.**

   Greater focus should be given to the engagement of stakeholders to ensure beneficiaries recognise the benefits on offer, making them more likely to mobilise in support of biomass use, bringing biomass out from behind the scenes. Localising benefits may aid in this, but centralised government intervention may encourage a top-down approach to policymaking, minimising the autonomy of local actors to engage with biomass systems. Therefore, a bottom-up approach, which focuses on fostering community engagement with biomass systems and developing public understanding of them, would have the greatest impact. This could include supporting local governments with how to incorporate local biomass systems into initiatives such as Local Area Energy Plans (LAEPs) (ESC 2024), connecting localised benefits with national and global net zero efforts. Whilst connecting local communities to the

benefits of biomass will aid this, the inherent links between biomass and its extraction from the environment open biomass use up to environmental scrutiny. Therefore, resources should be set aside within policy to identify and address common narratives of concern within public discourse to develop effective communication and public dialogues in response. This is as important to the success of the policy as the policy detail itself. Therefore, government resources should be allocated towards engaging with industry, the public, NGOs, and academia to ensure open and transparent engagement on biomass deployment, benefits, and associated impacts.

4. **Encourage domestic biomass feedstocks by supporting farmers and foresters together, over the long-term.**

   Increasing the supply of domestic biomass will increase the burden on farmers, foresters, and their land, but reduce the UK's reliance on global biomass supply-chains. If policymakers wish for an agricultural sector that is economically viable and environmentally sustainable, then farmers and foresters need policy that incentivises the enhancement of ecosystems, whilst considering public concern about vast monocultures devoid of biodiversity. Policies need to incentivise farmers and foresters to diversify their practices with biomass feedstocks, by integrating their growth alongside other pressures on land, such as food and conservation efforts, boosting their economic security in the process. Grants could be made available to farmers, like the England Woodland Creation Offer (Forestry Commission 2021), which incentivises tree planting, to cover some of the initial upfront cost involved in the establishment of new biomass crops. A performance-based contract mechanism could then support farmers long-term, on the basis that they are fulfilling environmental and social criteria in exchange for subsidies that reward sustainable practices. This should focus on activities that provide long-term ecological regeneration, such as improving soil health, increasing biodiversity, and providing flood mitigation. However, this will depend on the ecology of the crop being planted. This will ensure that those benefitting from the extraction of biomass are proportionately responsible for the sustainable management of it and the impacts of establishment, cultivation, and harvest on ecological systems.

5. **Reduce the reliance on centralised BECCS to provide negative emissions.**

   In all scenarios, the UK needs both carbon removals and reductions to achieve net zero. However, the current political economy is leveraging the former as policy relief against the latter. It is clear that BECCS will play a role in the future, but the risk of reliance on technology that has not yet been proven at scale detracts from the need to provide low-carbon solutions now. Instead, negative emission technologies such as BECCS should be addressed by policy as

supplementary to wider decarbonisation efforts, as opposed to maintaining the status quo for incumbent businesses in hard-to-abate sectors. Centralising power through the consolidation of subsidies and incentives for BECCS will not generate long-term political support and social legitimacy, as public concerns about the profit motives of the energy sector are difficult to overcome. Policy should avoid locking the economy into path dependencies on BECCS by limiting subsidies to carefully scaled deployment alongside carbon emission reductions. The complexities of BECCS and the concept of net zero are abstract, intangible, and disconnected from society. Therefore, a more localised approach will help local communities to engage with BECCS and appreciate the trade-offs associated with its utilisation. To do this, BECCS policy should incentivise multidimensional outcomes which encourage focus beyond a singular objective of maximising the carbon removed, which might come at the expense of distributing benefits more widely across the systems impacted.

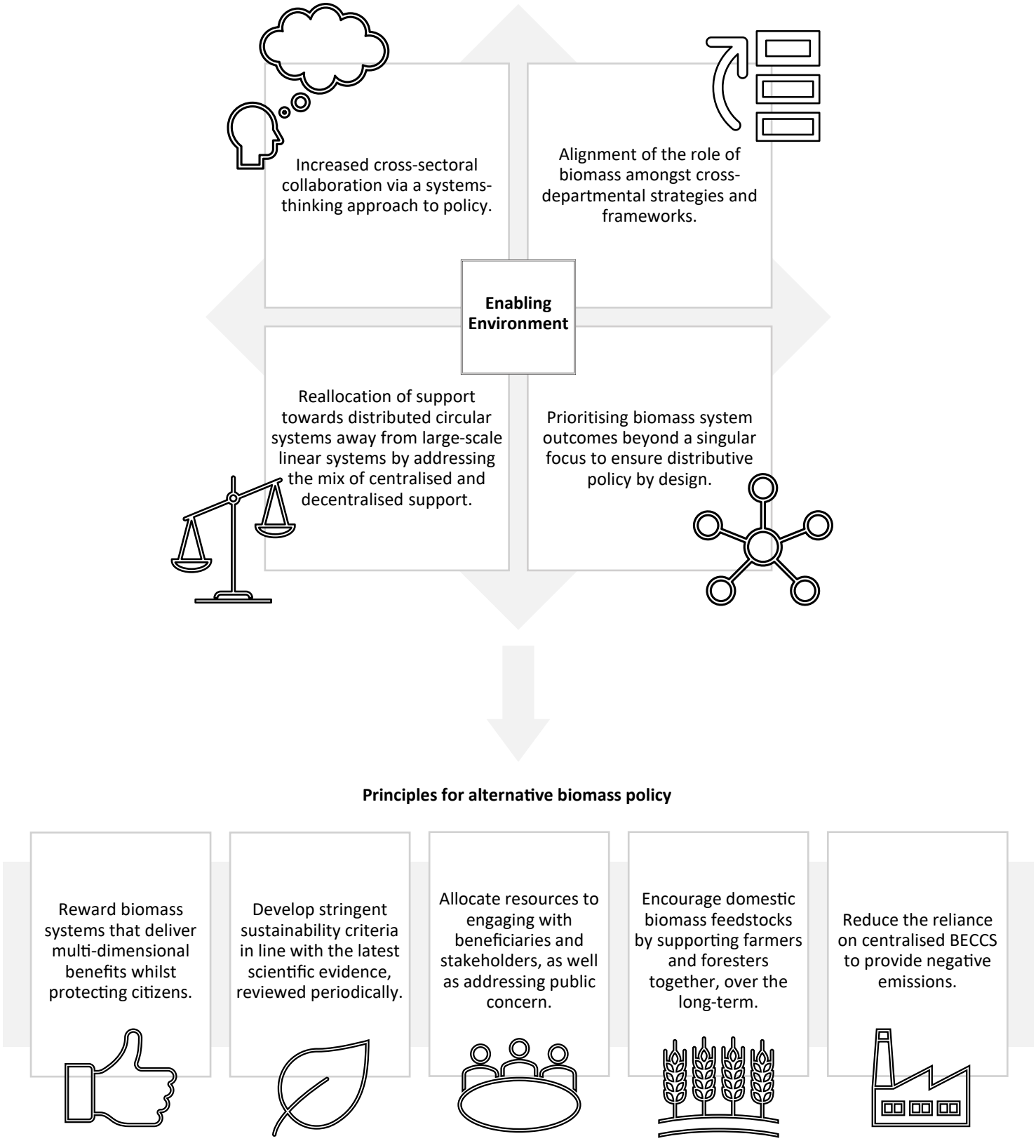

Figure 11 - A diagram outlining the changes to the enabling environment and subsequent biomass policy principles that make up the alternative framework for biomass policy design.

7. Conclusion

This research aims to address the gap identified in the literature by understanding how the political economy of renewable energy transitions impacts their success in displacing fossil fuel use, considers the implications for policy that seeks to use biomass to achieve net zero, and puts forward an alternative policy framework for biomass that maximises sustainability in line with net zero targets. This was motivated by a need to bridge a gap in understanding of the non-technical factors influencing biomass policy design within the context of the UK's transition to net zero. Whilst technological developments have made biomass technologies viable, the political and economic factors shaping their adoption have been given less focus within research. To address the gap identified in current knowledge, three primary research questions were formulated:

1. **How does the political economy of energy transitions impact their success in replacing fossil fuels and reducing carbon emissions?**
2. **How has policy impacted the sustainable use of bioenergy to achieve carbon emission reductions in the UK since 2000?**
3. **How does the UK's political economic situation determine who benefits from, and who pays for, the deployment of sustainable bioenergy systems, to achieve net zero by 2050?**

These primary research questions influenced the design of a study that takes a political economy approach to biomass use in the UK in the context of net zero. The systematic literature review addressed the first research question, demonstrating a gap in the literature around the political economy of biomass use, and highlighting the non-technical factors that impact the success of renewable energy transitions. This literature review then formed the basis for addressing the second and third research questions, through the design of a qualitative study involving semi-structured interviews with 26 experts from across policy, industry, and non-governmental organisations engaged in the UK biomass sector. A robust thematic analysis of the insights gathered enabled the identification of key policies influencing bioenergy deployment, drivers, and impacts, providing a lens with which to view the impact of political economy on biomass policy design in the UK:

1. **Policy drivers and impacts:** Historical policies have primarily supported large-scale biomass projects through technology-agnostic mechanisms, favouring centralised energy models which phase out fossil fuels in exchange for financial subsidies, driven by a desire to maintain focus on economic factors whilst delivering greenhouse gas reductions. The introduction of net zero has focused minds on the carbon element of biomass, and the potential to generate negative emissions through BECCS, but this has also reinforced path dependencies and risks of technology lock-in.

2. **Deficiencies in the political economy:** Insights highlighted deficiencies in integrating environmental justice and local community considerations into biomass policy. Public debates around biomass sustainability remain polarised, often shaped by industrial and NGO narratives rather than transparent, evidence-based discourse. A lack of joined-up thinking on biomass within policy and industry was identified, as well as a lack of long-term policy to support farmers and foresters; a problem which the 'net' in net zero amplifies through the concept of carbon debt and timeliness of carbon sequestration.

3. **Trade-offs and beneficiaries:** The distribution of costs and benefits associated with biomass deployment is uneven. Industrial actors and centralised systems are most likely to benefit, whereas a future ambition to increase domestic supplies of biomass will increase the burden on stakeholders more closely connected to distributed rural communities, involved in biomass feedstock cultivation. This presents a challenge to policy which has historically been focused on technology, as this has suited the political economy. The future move towards growing more biomass domestically places more responsibility in the hands of Defra, as opposed to DESNZ, therefore overcoming siloes in policymaking will be key to the development of sustainable biomass supply-chains domestically.

4. **Biomass behind the scenes:** Policies have failed to generate positive feedback loops that mobilise political support for future biomass use, instead fuelling public concern that the energy sector could exploit the use of biomass in return for profits. The benefits of biomass use on a national scale are identified as behind the scenes, intangible to the public, such as carbon emission reductions mitigating climate change, or carbon removals allowing for some maintenance of the status quo in the face of achieving societal change needed to achieve net zero. These are not as direct and obvious as local benefits, such as job creation, environmental protection, or reducing the cost of net zero to citizens.

In addition to addressing the primary research questions outlined above, the research also provided insight into the themes and topics which emerged from the literature review, relating to the political economy of renewable energy transitions and the relationship between biomass and net zero. Figure 5 summarised the primary themes of the existing literature on the political economy of energy transitions related to biomass, and the research has provided insight into the below:

1. **The why - The existence of a social contract between government and the people:** The increased need to act on climate change has heightened the profile of environmental and social factors within the social contract for the provision of energy. However, with the public benefits of biomass being primarily perceived as behind the scenes, links between

environmental benefits and biomass are difficult to demonstrate at scale to the public whereas negative impacts have been captured in the media. The environmental and social aspects of biomass and the role it plays in supporting the social contract aren't mobilising political support, and there is a subsequent lack of broad public acceptance for its use. Continued financial support leveraging taxpayer money to subsidise large-scale energy generation from biomass risks adding fire to the flames, as although the generation of negative emissions provides indirect public benefits, the result remains the same; that private financial interests appear to take precedence over tangible public benefits.

2. **The what - Which technologies should be supported and how can policy support them:** The introduction of net zero has intensified the focus on biomass to achieve negative emissions, which manifests as a preference for large-scale drop-in technologies that utilise existing infrastructure whilst minimising potentially disruptive systemic impacts. Despite this approach achieving carbon emission reductions and removals, it also creates path dependencies where future policy decisions become constrained by past investments and established incumbent interests. The greater focus on biomass as a method for carbon removal whilst also producing energy or fuel is evident in the importance placed on BECCS and SAF, which present opportunity for progress against net zero targets without demanding wider societal behavioural shifts, allowing for policy relief.
3. **The how – The approach to take to displace fossil fuels and encourage support:** The use of large-scale biomass operations to reduce the use of coal has suited the political economy but has also concentrated power in the hands of a few larger stakeholders. Government interventions are fragmented by the siloed nature of policymaking, missing opportunity for a holistic approach to biomass policy that integrates themes such as land use, environmental objectives, and energy. Top-down interventions have overlooked the opportunity for local-level engagement with biomass that would help to foster broader public and political support for its continued use.

Beyond the broader questions on the why, the what, and the how, Figure 8 captured the specific themes which arose from the existing literature around bioenergy and net zero, and the research has built on this:

1. **Public perspectives and social legitimacy:** Public support is lacking for biomass policy, and negative perceptions are eroding trust in the sustainability of biomass practices, amplified by increased public concern for the environment. This is challenging the social legitimacy of continued biomass use, under the current policy mix. This perception will continue to develop under the current political economy, preferring to support existing power structures, unless

policy intervention shifts to demonstrate greater support for environmental and social objectives (which are higher up the political agenda) over the profit motives of the incumbent energy sector.

2. **Biomass flexibility and strategic deployment:** Priority is being given to dispatchable sources of power in 'difficult-to-decarbonise', however the suitability of a biomass feedstock is not only a technical consideration, as the potential for biomass to deliver multi-dimensional benefits shouldn't be overlooked. Policy is optimised to deliver carbon reductions and future removals at scale, as opposed to holistic resource efficiency and sustainability. However, in the context of ambitions to scale the domestic supply of biomass feedstocks, this requires policy to go beyond strategically deploying biomass at a national scale by considering the impact of new, decentralised biomass supply-chains, where challenges and opportunities will differ depending on the geographical region they are situated within the UK.
3. **Net zero and carbon balances:** The potential for biomass to produce negative emissions and remove carbon dioxide from the atmosphere sets it apart from other sources of renewable energy. This has enabled government to rely on BECCS for policy relief, enabled by international carbon accounting mechanisms, and will continue under the current political economy which enables greenhouse gas reductions whilst maintaining focus on economic growth. This demonstrates the redistribution of benefits through net zero isn't a given but will require deliberate policy intervention that challenges the status quo to deliver benefits to a wider set of stakeholders.

Given the deficiencies identified and themes explored this research proposed an alternative policy framework for biomass, summarised in Figure 11, that prioritises sustainability through several themes:

1. **Decentralisation:** Supporting decentralised biomass projects to redistribute benefits and enhance local stakeholder engagement with biomass systems.

2. **Integrated policy design:** Developing cross-sectoral policies that align energy, land-use, and ecological objectives, reducing siloed decision-making and promoting multidimensional policy outcomes over a singular policy focus.

3. **Stakeholder engagement:** Establishing mechanisms for meaningful stakeholder participation in policy design, ensuring benefits are properly communicated, and involving wider sets of stakeholders in the rollout of policies.

4. **Prioritising people and planet:** Creating financial incentives that prioritise social and environmental benefits over private profits, ensuring public money is for public good.

By adopting an interdisciplinary approach via political economy, this research contributes towards understanding the non-technical barriers to biomass policy development in the UK. It addresses the identified gap by contextualising biomass use within the UK's unique political economy and proposes an alternative policy framework which brings biomass policy back to earth. This demonstrates the importance of interdisciplinary approaches on the pathway to achieving net zero, whilst addressing the climate, ecological, and energy emergencies, particularly when considering biomass and its inherent links to our natural world.

8. Considerations for future work

This chapter reflects on the research and considers how it could be implemented and expanded in the future. Given the proposed framework for policy, the stakeholders most likely to benefit from the insights presented are those involved in policy related to biomass. The nature of biomass policy means that it spans multiple policy remits. Therefore, the proposed framework could be applicable across various government and non-governmental departments. Furthermore, the findings within the literature review could be applied to other sources of renewable energy and are particularly relevant for technologies that are established energy sources now facing challenges in increasing their adoption. Whilst this research focused on the UK context, the approach and methodology could be applied to other countries to understand how political and economic institutions influence the design of biomass abroad, opening opportunities for comparative case studies between countries, economies, and politics.

Whilst this research used energy as a lens with which to view the political economy of biomass, future work on the political and economic impacts of using biomass to deliver bioproducts, such as chemicals, would provide a more comprehensive view of the UK's political bioeconomy. This would capture developing narratives around the next stage of decoupling society from fossilised hydrocarbons, where the challenge is less about decarbonisation and more about defossilisation, through the development of bio-based sectors that produce non-fossil-based versions of everyday products. Despite biomass and bioenergy being synonymous with one another in the media, bioenergy is just one part of the wider bioeconomy and is often one of the lowest value outcomes for biomass compared to the synthesis of chemicals. To cover chemicals in this research would have required a larger set of interviews to be conducted, which presented a challenge to complete with limited time, hence the focus on bioenergy as a section of the wider bioeconomy. Taking a similar methodological approach to bioproducts in the UK would complement the findings of this study and provide a more holistic view of the UK's political bioeconomy.

Another consideration for future research that builds on this study is the impact of the revised Biomass Strategy (DESNZ 2023), published in August 2023, just a month before the interview process took place. At the time, participants did not make mention of the influence of the revised strategy in their responses, most likely due to the short time interval between its publication and the interviews. Despite some criticism, the strategy was well received as a signal of the direction of travel from government for industry but was subject to an investigation by the National Audit Office as to the value for money which biomass represents. This found that government departments will need to work together to prioritise limited biomass supplies and that more assurances were needed regarding the sustainability of biomass supply (NAO 2024). It also highlighted the need to annually review the

potential for BECCS to deliver negative emissions in line with net zero, giving government enough time to react if reality falls short of projections (NAO 2024). Given these findings, building on this research with insights into the impact of the Biomass Strategy and the future of government support for biomass would be justified.

References

Backhouse, M. and K. Lorenzen (2021). "Knowledge Production and Land Relations in the Bioeconomy. A Case Study on the Brazilian Sugar-Bioenergy Sector." SUSTAINABILITY **13**(8).

Baker, L. and B. K. Sovacool (2017). "The political economy of technological capabilities and global production networks in South Africa's wind and solar photovoltaic (PV) industries." POLITICAL GEOGRAPHY **60**: 1-12.

BBC (2019). "UK Parliament declares climate change emergency."

BEIS (2022). Digest of UK Energy Statistics 2021. UK, BEIS.

Bergius, M. and J. T. Buseth (2019). "Towards a green modernization development discourse: the new green revolution in Africa." JOURNAL OF POLITICAL ECOLOGY **26**: 57-83.

Bhamidipati, P. L. and U. E. Hansen (2021). "Unpacking local agency in China-Africa relations: Frictional encounters and development outcomes of solar power in Kenya." GEOFORUM **119**: 206-217.

Booth, A., D. Papaioannou and A. Sutton (2012). Systematic Approaches to a Successful Literature Review.

Braun, V. and V. Clarke (2006). "Using thematic analysis in psychology." Qualitative Research in Psychology **3**(2): 77-101.

Bryant, R. L. (1998). "Power, knowledge and political ecology in the third world: a review." **22**(1): 79-94.

Burnell, S. (2024). "Nearly £22bn pledged for carbon capture projects."

Calvert, K., K. Greer and M. Maddison-MacFadyen (2019). "Theorizing energy landscapes for energy transition management: Insights from a socioecological history of energy transitions in Bermuda." GEOFORUM **102**: 191-201.

Carrington, D. (2022). Revealed: oil sector's 'staggering' $3bn-a-day profits for last 50 years. The Guardian.

CCC (2020). "The Sixth Carbon Budget: The UK's path to Net Zero."

CCC (2022). Progress in reducing emissions - 2022 Report to Parliament. Climate Change Committee, Climate Change Committee.

CCC (2024). "2024 Progress Report to Parliament."

Cetkovic, S. and A. Buzogany (2016). "Varieties of capitalism and clean energy transitions in the European Union: When renewable energy hits different economic logics." CLIMATE POLICY **16**(5): 642-657.

Commission, F. (2021). "England Woodland Creation Offer."

Committee, E. A. (2023). "Net zero and the UK aviation sector."

Crow, D. and M. Jones (2018). "Narratives as tools for influencing policy change." Policy & Politics **46**.

Crowley (2024). "Drax: UK power station still burning rare forest wood."

Crowley, J. R., Tim (2022). Drax: UK power station owner cuts down primary forests in Canada. BBC. BBC, BBC.

DESNZ (2023). "Biomass Strategy 2023."

DESNZ (2023). "Role of biomass in achieving net zero: public dialogue."

DfT (2022). "Jet Zero strategy: delivering net zero aviation by 2050."

Duvenage, I., R. Taplin and L. Stringer (2012). "Bioenergy project appraisal in sub-Saharan Africa: Sustainability barriers and opportunities in Zambia." NATURAL RESOURCES FORUM **36**(3): 167-180.

Edmondson, D. L., F. Kern and K. S. Rogge (2019). "The co-evolution of policy mixes and socio-technical systems: Towards a conceptual framework of policy mix feedback in sustainability transitions." RESEARCH POLICY **48**(10).

ESC (2024). "Local Area Energy Plans."

Fathoni, H. S., R. Boer and Sulistiyanti (2021). "Battle over the sun: Resistance, tension, and divergence in enabling rooftop solar adoption in Indonesia." GLOBAL ENVIRONMENTAL CHANGE-HUMAN AND POLICY DIMENSIONS **71**.

Ferrall, I., G. Heinemann, C. von Hirschhausen and D. M. Kammen (2021). "The Role of Political Economy in Energy Access: Public and Private Off-Grid Electrification in Tanzania." ENERGIES **14**(11).

FitzGibbon, J. and K. O. Mensah (2012). "Climate Change as a Wicked Problem:An Evaluation of the Institutional Context for Rural Water Management in Ghana." **2**(2): 2158244012448487.
Galdas, P. (2017). "Revisiting Bias in Qualitative Research:Reflections on Its Relationship With Funding and Impact." **16**(1): 1609406917748992.
Garrido, S., T. Sequeira and M. Santos (2020). "Renewable Energy and Sustainability from the Supply Side: A Critical Review and Analysis." APPLIED SCIENCES-BASEL **10**(17).
Geels, F. W. (2002). "Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study." Research Policy **31**(8): 1257-1274.
GOV.UK (2008). "Climate Change Act 2008."
GOV.UK (2024). "Great British Energy founding statement."
Guterres, A. (2018). Secretary-General's remarks on Climate Change. Online, United Nations.
Harnmeijer, J., D. Toke and B. Slee (2018). "Community renewables in the UK - a clash of cultures?" International Journal of Technology Intelligence and Planning **12**(1): 99-120.
Harrison, T. (2021). "UK biomass emits more CO2 than coal." Insights Retrieved 07/10/2022, 2022, from https://ember-climate.org/insights/research/uk-biomass-emits-more-co2-than-coal/.
Hess, T. M., J. Sumberg, T. Biggs, M. Georgescu, D. Haro-Monteagudo, G. Jewitt, M. Ozdogan, M. Marshall, P. Thenkabail, A. Daccache, F. Marin and J. W. Knox (2016). "A sweet deal? Sugarcane, water and agricultural transformation in Sub-Saharan Africa." GLOBAL ENVIRONMENTAL CHANGE-HUMAN AND POLICY DIMENSIONS **39**: 181-194.
Hielscher, S., G. Seyfang and A. Smith (2011). Community innovation for sustainable energy. Working Paper - Centre for Social and Economic Research on the Global Environment**:** 1-22.
IPCC (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability (Summary for Policymakers). In Press.
IPCC (2022). Climate Change 2022: Mitigation of Climate Change. Climate Change 2022, Intergovernmental Panel on Climate Change.
IPCC (2023). Climate Change 2022 - Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, Cambridge University Press.
Jasanoff, S. and H. R. Simmet (2021). "Renewing the future: Excluded imaginaries in the global energy transition." ENERGY RESEARCH & SOCIAL SCIENCE **80**.
Johnstone, P. and A. Stirling (2020). "Comparing nuclear trajectories in Germany and the United Kingdom: From regimes to democracies in sociotechnical transitions and discontinuities." ENERGY RESEARCH & SOCIAL SCIENCE **59**.
King, N. (2004). Essential Guide to Qualitative Methods in Organizational Research. London, SAGE Publications Ltd.
Krausmann, F., K.-H. Erb, S. Gingrich, H. Haberl, A. Bondeau, V. Gaube, C. Lauk, C. Plutzar and T. D. Searchinger (2013). "Global human appropriation of net primary production doubled in the 20th century." **110**(25): 10324-10329.
La Rovere, E. L. (2020). "The potential contribution of emerging economies to stop dangerous climate change. The case of Brazil." WILEY INTERDISCIPLINARY REVIEWS-CLIMATE CHANGE **11**(1).
Lakhanpal, S. (2019). "Contesting renewable energy in the global south: A case-study of local opposition to a wind power project in the Western Ghats of India." ENVIRONMENTAL DEVELOPMENT **30**: 51-60.
Levidow, L. and S. Raman (2020). "Sociotechnical imaginaries of low-carbon waste-energy futures: UK techno-market fixes displacing public accountability." SOCIAL STUDIES OF SCIENCE **50**(4): 609-641.
Lockie, S. (2015). "What is environmental sociology?" Environmental Sociology **1**(3): 139-142.
Mackieson, P., A. Shlonsky and M. Connolly (2019). "Increasing rigor and reducing bias in qualitative research: A document analysis of parliamentary debates using applied thematic analysis." **18**(6): 965-980.
McCarthy, J. and J. Thatcher (2019). "Visualizing new political ecologies: A critical data studies analysis of the World Bank's renewable energy resource mapping initiative." GEOFORUM **102**: 242-254.

Morris, J. (2013). "The Evolving Localism (and Neoliberalism) of Urban Renewable Energy Projects." Culture, Agriculture, Food and Environment **35**(1): 16-29.
Muller, F. and S. Claar (2021). "Auctioning a 'just energy transition'? South Africa's renewable energy procurement programme and its implications for transition strategies." REVIEW OF AFRICAN POLITICAL ECONOMY **48**(169): 333-351.
Muller, F., S. Claar, M. Neumann and C. Elsner (2020). "Is green a Pan-African colour? Mapping African renewable energy policies and transitions in 34 countries." ENERGY RESEARCH & SOCIAL SCIENCE **68**.
NAO (2024). "The government's support for biomass."
Nunan, F. (2015). Understanding Poverty and the Environment: Analytical Frameworks and Approaches. London, UK, Routledge.
Office, N. A. (2014). "Report - Value for money: Early contracts for renewable electricity."
Olmos-Vega, F. M., R. E. Stalmeijer, L. Varpio and R. Kahlke (2023). "A practical guide to reflexivity in qualitative research: AMEE Guide No. 149." Medical Teacher **45**(3): 241-251.
Osiolo, H. H., A. Pueyo and J. Gachanja (2017). "The Political Economy of Investment in Renewable Electricity in Kenya." IDS BULLETIN-INSTITUTE OF DEVELOPMENT STUDIES **48**(5-6): 119-140.
Ostrom, E. (1990). Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge, Cambridge University Press.
Palit, D., B. K. Sovacool, C. Cooper, D. Zoppo, J. Eidsness, M. Crafton, K. Johnson and S. Clarke (2013). "The trials and tribulations of the Village Energy Security Programme (VESP) in India." ENERGY POLICY **57**: 407-417.
Perkins, J. H. (2019). Energy Transitions: Linking Energy and Climate Change. Climate Change Management**:** 87-106.
Pilgrim, S. and M. Harvey (2010). "Battles over biofuels in Europe: NGOs and the politics of markets." Sociological Research Online **15**(3): 45-60.
Purkus, A. (2016). Concepts and Instruments for a Rational Bioenergy Policy: A New Institutional Economics Approach. Switzerland, Springer International Publishing.
Purkus, A., M. Röder, E. Gawel, D. Thrän and P. Thornley (2015). "Handling uncertainty in bioenergy policy design – A case study analysis of UK and German bioelectricity policy instruments." Biomass and Bioenergy **79**: 64-79.
Robbins, P. (2012). "Political ecology : a critical introduction."
Röder, M., K. Chong and P. Thornley (2022). "The future of residue-based bioenergy for industrial use in Sub-Saharan Africa." Biomass and Bioenergy **159**: 106385.
Röder, M., C. Jamieson and P. Thornley (2020). "(Stop) burning for biogas. Enabling positive sustainability trade-offs with business models for biogas from rice straw." Biomass and Bioenergy **138**: 105598.
Röder, M., A. Mohr and Y. Liu (2020). "Sustainable bioenergy solutions to enable development in low- and middle-income countries beyond technology and energy access." Biomass and Bioenergy **143**: 105876.
Schwerhoff, G. and M. Sy (2019). "Developing Africa's energy mix." CLIMATE POLICY **19**(1): 108-124.
Sergi, B., M. Babcock, N. J. Williams, J. Thornburg, A. Loew and R. E. Ciez (2018). "Institutional influence on power sector investments: A case study of on- and off-grid energy in Kenya and Tanzania." ENERGY RESEARCH & SOCIAL SCIENCE **41**: 59-70.
Singh, P. and N. Singh (2019). "Political economy of bioenergy transitions in developing countries: A case study of Punjab, India." WORLD DEVELOPMENT **124**.
Sismondo, S. (2004). An introduction to science and technology studies, Blackwell.
Sovacool, B. K. (2012). "The political economy of energy poverty: A review of key challenges." ENERGY FOR SUSTAINABLE DEVELOPMENT **16**(3): 272-282.
Sovacool, B. K. (2018). "Success and failure in the political economy of solar electrification: Lessons from World Bank Solar Home System (SHS) projects in Sri Lanka and Indonesia." ENERGY POLICY **123**: 482-493.

Spivey, H. (2020). "Governing the Fix: Energy Regimes, Accumulation Dynamics, and Land Use Changes in Japan's Solar Photovoltaic Boom." ANNALS OF THE AMERICAN ASSOCIATION OF GEOGRAPHERS **110**(6): 1690-1708.
Survation (2022). RenewableUK Topical Poll. Survation. Survation.
Taylor, D. (2019). The Impact of Environmentalists on Climate Change Discourse and Policy in the United Kingdom, University of Birmingham.
Taylor, D. (2023). Utilising the Literature Analysis Tool (LAT) in conjunction with a systematic literature review process, Aston University.
Taylor, D., J. Sparks, K. Chong and M. Röder (2024). "Determining the Benefits of Biomass: Who Wins, and Who Loses?" **14**(10): 2350.
Temper, L., S. Avila, D. Del Bene, J. Gobby, N. Kosoy, P. Le Billon, J. Martinez-Alier, P. Perkins, B. Roy, A. Scheidel and M. Walter (2020). "Movements shaping climate futures: A systematic mapping of protests against fossil fuel and low-carbon energy projects." ENVIRONMENTAL RESEARCH LETTERS **15**(12).
Treasury, H. (2013). Drax Biomass backed by UK Guarantee. UK, HM Treasury.
Turner, J. (2021). "What can we learn from the role of coal in the Industrial Revolution?" Retrieved 07/10/2022, 2022, from https://www.economicsobservatory.com/what-can-we-learn-from-the-role-of-coal-in-the-industrial-revolution.
van der Horst, D. and J. Evans (2010). "Carbon Claims and Energy Landscapes: Exploring the Political Ecology of Biomass." LANDSCAPE RESEARCH **35**(2): 173-193.
van Rooijen, L. W. (2014). "Pioneering in Marginal Fields: Jatropha for Carbon Credits and Restoring Degraded Land in Eastern Indonesia." SUSTAINABILITY **6**(4): 2223-2247.
Wang, W. H., V. Moreno-Casas and J. H. de Soto (2021). "A Free-Market Environmentalist Transition toward Renewable Energy: The Cases of Germany, Denmark, and the United Kingdom." ENERGIES **14**(15).

Appendices

Appendix 1 – Approved invitation to interview email used by the researcher.

Request to participate in a research interview

Dear XXX,

I am writing to ask if you will be willing to **take part in an expert interview** I am conducting as part of my PhD research into biomass and bioenergy in the United Kingdom. My research is looking at **the design of policy that impacts biomass** and how that aims to **achieve net zero**. This study involves engaging multiple stakeholders from governmental policy, industrial, and non-governmental backgrounds, and **I would be grateful for your expert insight**. During my time working with the Supergen Bioenergy Hub, I identified your organisation as a key stakeholder in the UK biomass sector, and wider energy policy arena.

The interview will take approximately 50-60 minutes of your time, and will be conducted **online and remotely**, via Microsoft Teams, at a time that is convenient to you. You will be asked open ended questions on **the impact of policy on biomass** use, the introduction of **net zero**, and the opportunities and barriers to **using biomass to achieve net zero** in the future. Participation is **entirely voluntary**, and **all data I collect will be anonymised** prior to analysis and in any material, I publish as a result of this research, such as my PhD thesis, journal articles, or conference presentations.

If you are interested in participating, please review the attached Participant Information Sheet (PIS) and Consent Form and **get in touch by emailing me at** [redacted]@aston.ac.uk. I am happy to answer any questions you might have about this study and organise a convenient timeslot for interview.

I hope to hear from you soon.

Best Regards,

Dan

Dan Taylor (he/him)
PhD Researcher
Energy & Bioproducts Research Institute (EBRI)
Birmingham, B4 7ET, UK
+44 [redacted]
aston.ac.uk

REC ID EPS21024, Version 2, 26 July 2023

Appendix 2 – Approved social media copy for recruiting interviewees.

Social media call for participants (Example copy)

LinkedIn

📣 Do you have expertise in biomass and bioenergy in the UK? I need your help!

🕵 I'm seeking interview participants as part of my PhD research into how policy design impacts the sustainable use of biomass. The interview will be conducted online and remotely, taking just 50-60 minutes of your time.

⁉ Interested? Be a part of this exciting study about how we can design policy to use biomass sustainably in achieving net zero. Message me here on LinkedIn for more information and to arrange an interview!

REC ID EPS21024, Ver 2, 26 July 2023

Twitter

📣 Do you have expertise in biomass and bioenergy in the UK?

🕵 I'm seeking interview participants as part of my PhD research into how policy design impacts the sustainable use of biomass!

⁉ Interested? DM me and I'll be in touch with more info!

REC ID EPS21024, Ver 2, 26 July 2023

REC ID EPS21024 Version 2, 26 July 2023

Appendix 3 – Approved Participant Information Sheet (PIS).

Aston University BIRMINGHAM UK | EBRI Energy & Bioproducts Research Institute | Supergen Bioenergy

Participant Information Sheet

The political economy of using biomass to achieve net zero in the UK

Invitation

We would like to invite you to take part in a research study forming part of Dan Taylor's PhD project titled "The political economy of using biomass to achieve net zero in the UK".

Before you decide if you would like to participate, take time to read the following information carefully and, if you wish, discuss it with others such as your family, friends, or colleagues.

Please ask a member of the research team, whose contact details can be found at the end of this information sheet, if there is anything that is not clear or if you would like more information before you make your decision.

What is the purpose of the study?

The purpose of this research is to understand how our political and economic situation in the United Kingdom impacts our ability to make policy that encourages the sustainable use of biomass to achieve our net zero targets. This involves stakeholder engagement with experts from across the biomass sector, including policy makers, industry, and non-governmental organisations, in the form of one-hour expert interviews. These interviews will explore how policy design has impacted biomass use in the past, the impact of net zero on biomass use, and the challenges of using biomass to achieve net zero. The outcome of this research will be to produce a framework which encourages the design of policy that promotes sustainable biomass use to achieve net zero, and tackle the climate, ecological, and energy crises. The insights provided by the interviews will be crucial in determining the optimal conditions for policy to maximise the benefits of utilising biomass resources to achieve net zero, as well as promoting wider environmental, social, and economic benefits.

Why have I been invited?

You are being invited to take part in this study because of your area of expertise, be that policymaking, the industrial sector, or experience at a non-governmental organisation, around the topics of biomass and bioenergy, energy policy, or the transition to net zero. Given the broad political economy approach of this study, specific technical knowledge of topics such as biomass conversion or the bioeconomy are not required to participate.

What will happen to me if I take part?

If you decide to participate in the study, you will need to inform the researcher of your wish to do so. The researcher will then be in contact via email to arrange a date and time for interview at your convenience, and to send you a Participant Consent Form. The Participant

REC ID EPS21024 Version 2, 26 July 2023

Consent form outlines your rights as a potential participant and clearly communicates which parts/activities of the study you consent to. Upon the completion of this form (returned via email), and agreement of a date and time for interview, the interview will be confirmed.

The interview will take place over Microsoft Teams, arranged by the researcher, for approximately 50-60 minutes. During this time, the researcher will ask you open ended questions about biomass policy, the impact of net zero on biomass usage, and the barriers to using biomass to achieve net zero. Your responses will be recorded and anonymized for the purposes of this study. Following the interview, you may request a summary of the findings once they are available.

You are free to withdraw from the study at any time, without giving a reason, and your legal rights will not be affected. You will have seven days from the date of the interview to request withdrawal of your data from the study.

Do I have to take part?

No. It is up to you to decide whether you wish to take part.

If you do decide to participate, you will be asked to provide informed consent.

You can halt your participation in the research at any time by terminating the Microsoft Teams call and any data collected up to that point will not be used. You are free to refrain from answering any questions you do not wish to respond to.

If you wish to withdraw your data after participation, then you have up to seven days to do so by contacting the researcher or the research team via email. After this point, your data will be anonymised, and it will not be possible to withdraw it.

Will my taking part in this study be kept confidential?

Yes. A code will be attached to all the data you provide to maintain anonymity. Analysis of your data will be undertaken using coded data.

If we need to collect personal data (such as a name and contact details) we will only use this for the purposes outlined in this participant information sheet e.g. to contact you to arrange an interview.

The data we collect will be stored electronically on a secure encrypted mobile device, password protected computer server or secure cloud storage device.

To ensure the quality of the research Aston University may need to access your data to check that the data has been recorded accurately e.g. for the purposes of audit. If this is required, your data will be treated as confidential by the individuals accessing your data.

How will the conversation during the interview be recorded and the information I provide managed?

With your permission the interview will be recorded (video and audio) and live transcription functionality will be switched on.

Due to Microsoft Teams functionality, video and audio are recorded together during a Teams call, unless video feeds are switched off. It is your right to turn off your video feed if you do not wish video to be recorded, and the researcher will remind you of this

prior to beginning the recording.

The live transcription document generated by Microsoft Teams will be verified and amended, with the help of the video and audio recordings, by a member of the research team/transcriber approved by Aston University. This process will involve removing any information which could be used to identify individuals e.g. names, locations etc.

Video and audio recordings will be destroyed as soon as the transcripts have been checked for accuracy.

We will ensure that anything you have told us that is included in the reporting of the study will be anonymous.

You of course are free not to answer any questions that are asked, without giving a reason.

What are the possible benefits of taking part?

Participating in the interview will give you the opportunity to be a part of a unique study into how policy impacts biomass use in the United Kingdom, and contribute to a new policy framework aimed at ensuring sustainable biomass use to achieve net zero.

What are the possible risks and burdens of taking part?

The study has been designed to minimise all possible risks and burdens involved with taking part. Attending online, remotely, removes the need and risk of travel to attend in person, and enables you to choose a safe and comfortable location and time in which to conduct the interview. The interview will require approximately 50-60 minutes of your time. Given the assurances of anonymity, and secure handling and destruction of data once results are anonymised, we feel there is minimal risk to you participating in the study.

What will happen to the results of the study?

The results of this study may be published in scientific journals and/or presented at conferences. The results will be used to inform the completion of Dan Taylor's PhD project, taking a political economy approach to the use of biomass to achieve net zero in the UK. If the results of the study are published, your identity will remain anonymous.

A lay summary of the results of the study can be forwarded to you when the study has been completed. Should you wish to receive a copy, please provide your email address on the Consent Form or contact a member of the research team.

Expenses and payments

There will be no expenses or payments provided in return for taking part in an interview.

Who is funding the research?

The study is being funded by Aston University.

Who is organising this study and how is my data being used?

Aston University is organising this study and acting as data controller for the study.

Research data will be used only for the purposes of the study or related uses identified in this Information Sheet or Appendix A.

Who has reviewed the study?

This study was given a favorable ethical opinion by the College of Engineering and Physical Sciences Research Ethics Committee.

What if I have a concern about my participation in the study?

If you have any concerns about your participation in this study, please speak to the research team and they will do their best to answer your questions. Contact details can be found at the end of this information sheet.

If the research team are unable to address your concerns or you wish to make a complaint about how the study is being conducted you should contact the Aston University Research Integrity Office at research_governance@aston.ac.uk or via the University switchboard on +44 (0)121 204 3000.

Research Team

PhD Researcher
Name: Dan Taylor
Email: [redacted]@aston.ac.uk
Contact Telephone Number [redacted]

Supervisor
Name: Mirjam Röder
Email: m.roeder@aston.ac.uk
Contact Telephone Number: 0121 204 3643

Supervisor
Name: Katie Chong
Email: k.chong1@aston.ac.uk
Contact Telephone Number: 0121 204 4088

Thank you for taking time to read this information sheet. If you have any questions regarding the study, please don't hesitate to ask one of the research team.

Appendix A: Transparency statement

Aston University takes its obligations under data and privacy law seriously and complies with the Data Protection Act 2018 ("DPA") and the General Data Protection Regulation (EU) 2016/679 as retained in UK law by the Data Protection, Privacy and Electronic Communications (Amendments etc) (EU Exit) Regulations 2019 ("the UK GDPR").

Aston University is the sponsor for this study based in the United Kingdom. We will be using information from you in order to undertake this study. Aston University will process your personal data in order to register you as a participant and to manage your participation in the study. It will process your personal data on the grounds that it is necessary for the performance of a task carried out in the public interest (GDPR Article 6(1)(e). Aston University may process special categories of data about you which includes details about your health. Aston University will process this data on the grounds that it is necessary for statistical or research purposes (GDPR Article 9(2)(j)). Aston University will keep identifiable information about you for 6 years after the study has finished.

Your rights to access, change or move your information are limited, as we need to manage your information in specific ways in order for the research to be reliable and accurate. If you withdraw from the study, we will keep the information about you that we have already obtained. To safeguard your rights, we will use the minimum personally identifiable information possible.

You can find out more about how we use your information at https://www.aston.ac.uk/about/statutes-ordinances-regulations/publication-scheme/policies-regulations/data-protection or by contacting our Data Protection Officer at dp_officer@aston.ac.uk.

If you wish to raise a complaint on how we have handled your personal data, you can contact our Data Protection Officer who will investigate the matter. If you are not satisfied with our response or believe we are processing your personal data in a way that is not lawful you can complain to the Information Commissioner's Office (ICO).

REC ID EPS21024 Version 2, 26 July 2023

Appendix 4 – Approved Consent Form.

The political economy of using biomass to achieve net zero in the UK

Consent Form

Name of Chief Investigator: Dan Taylor

		Please initial boxes
1.	I confirm that I have read and understand the Participant Information Sheet (REC ID EPS21024 Version 2, 26 July 2023) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
2.	I understand that my participation is voluntary and that I am free to withdraw at any time during the study, without giving a reason and without my legal rights being affected.	
3.	I understand that this study is anonymous and that I am able to withdraw my data up to seven days after taking part in an interview, by contacting the researcher or research team. After seven days, my data will be anonymised, and it will not be able to be withdrawn.	
4.	I agree to my interview being audio recorded and to anonymised direct quotes from me being used in publications resulting from the study.	
5.	I agree to my interview being video recorded.	
6.	I agree to my anonymised data being used by research teams for future research.	
7.	I agree to my personal data being processed for the purposes of inviting me to participate in future research projects. I understand that I may opt out of receiving these invitations at any time.	
8.	I agree to take part in this study.	

Name of participant:	
Date:	

Name of person receiving consent:	
Date:	

If you wish to receive a lay summary of the research project upon its completion, please provide an email address to which the summary can be sent.
Email address:

REC ID EPS21024 Version 2, 26 July 2023

Appendix 5 – The Interview Question Form.

Interview Question Form

(Q1a) What policies drove the most significant deployment of bioenergy that led to carbon emission reductions in the UK over the past 20 years?

- **(Q1b)** What were the drivers for those policies at the time?
- **(Q1c)** What was the impact of those policies and when was the impact felt?

(Q2a) What impact has the introduction of net zero had on the deployment of bioenergy in the UK?

- **(Q2b)** How has the UK's net zero legislation impacted bioenergy deployment?

(Q3a) What is using biomass to achieve net zero going to cost the UK leading up to 2050, and how will it benefit the UK?

- **(Q3b)** Who currently benefits the most from biomass use in the UK, and who will benefit from using biomass to achieve net zero by 2050?
- **(Q3c)** How do the public benefit from the UK using biomass to achieve net zero?

Appendix 6 – A table displaying the codes, child codes, and themes associated with each code.

Code	**Child code**	**Themes included**
(Q1a) Policies	(ARBRE) Arable Biomass Renewable Energy	Participant response including project ARBRE.
	(CfD) Contracts for Difference	Participant response including CfD.
	(CHPQA) Combined heat and power quality assurance scheme	Participant response including CHPQA.
	(FITs) Feed In Tariffs	Participant response including FITs.
	(RHI) Renewable Heat Incentive	Participant response including RHI.
	(RO) Renewables Obligation	Participant response including RO.
	(RTFO) Renewable Transport Fuel Obligation	Participant response including RTFO.
	Bioenergy Strategy (2000s)	Participant response including the Bioenergy Strategy (2000s).
	Clean Growth Strategy	Participant response including the Clean Growth Strategy.
	Climate Change Act	Participant response including the Climate Change Act of 2008.
	Converting Power Plants	Participant response including the conversion of coal power plants to use, or co-fire with, biomass.
	Energy Crops Scheme	Participant response including the ESC.
	European Policy	Participant response including EU policies such as the Renewable Energy Directive or the EU Emissions Trading Scheme.
	Funding Energy Research	Participant response focusing on the funding of energy research in the UK.
	Smart Export Guarantee	Participant response including the Smart Export Guarantee.
	Waste Management Policy	Participant response focusing on waste management policy in the UK pertaining to landfill, recycling, and incineration processes.

(Q1b) Drivers	Biomass Perception	Participant responses indicating that the developing perception of biomass as a low-carbon or carbon neutral option drove policy design.
	Carbon Accounting	Participant responses indicating that the rating of biomass as carbon neutral under the United Nations Framework Convention on Climate Change enabled policy design.
	Diversify Energy Resources	Participant responses indicating that biomass can help diversify sources of energy in the UK, improving energy system resilience, different from national energy security.
	Economic	Participant responses indicating that economic factors such as opportunities for job creation, retaining existing financial assets (power stations, and opportunity for economic growth.
	Energy Security	Participant responses indicating that biomass can deliver despatchable power when needed, in the face of increased geopolitical tensions impacting international supplies of energy, such as imported gas.
	Environmental	Participant responses indicating desire to use biomass to deliver environmental benefits such as increasing biodiversity, protecting ecosystems, or boosting ecosystem services.
	GHG Reduction	Participant responses indicating desire to incentivise decarbonisation in respect of existing carbon budgets and wider climate change mitigation activities.
	Increase Domestic Production	Participant responses indicating desire to increase the production of biomass feedstocks on UK soils.
	Industry Engagement	Participant responses that indicated that direct industry lobbying and engagement with policymakers influenced policy design.
	Non-Biomass Policy Focus	Participant responses that indicated the drivers for policy design were not biomass focused but did impact on biomass use.
	Social	Participant responses that focused on desire to deliver social benefits such as reducing energy bills, minimising tax burdens, or improving local economies.
(Q1c) Impact	Fossil phase out	Participant responses that focused on fossil fuels being displaced by biomass use.
	Negative Behaviours	Participant responses that mentioned behaviours because of biomass use that the participants deemed negative, such as exploitation of biomass subsidies, environmental impacts of sourcing biomass, and participant defined 'bad actors' who exploited biomass policies to gain financial benefit.
	Stimulate New Domestic Supply	Participant responses focused on the cultivation of new supplies of biomass feedstocks grown in the UK.

(Q2a) Net zero	(Q2a) General	Generalised participant responses on the impact of net zero on the whole, coded for sentiment.
	(Q2a) Impacts	Participant responses that focused on specific themes related to the impact of net zero.
	BECCS	Participant responses that linked net zero to bioenergy with carbon capture and storage.
	Carbon focus	Participant responses that indicated net zero had focused on the carbon element of biomass, and the potential to impact carbon dioxide levels in the atmosphere.
	Co-benefits focus	Participant responses that linked net zero to the potential for co-benefits from biomass use, coupling the potential for low-carbon or carbon neutral energy with opportunities for social, environmental, or economic benefits.
	Domestic focus	Participant responses that linked the introduction of net zero to a focus on the production of biomass in the UK.
	Hydrogen	Participant responses that indicated net zero increased focus on the potential to use biomass for hydrogen production.
	Rethinking policy	Participant responses that indicated a shift in policy thinking once net zero was introduced, moving away from 80% emissions reduction to net zero, and the implications for existing policy mechanisms.
	SAF	Participant responses that linked net zero to the use of biomass to produce sustainable aviation fuels.
	The future role of biomass	Participant responses that indicated a shift in views on the future role of biomass use following the introduction of net zero.
(Q2b) Legislation	Policy certainty	Participant responses that praised the introduction of net zero into legislation as providing policy certainty for industry and society to get behind.
	No impact	Participant responses that explicitly stated net zero didn't make an impact.

(Q3a) Trade-offs	Benefits	Participant responses pertaining to a benefit of using biomass, as perceived by the participant.
	Economic opportunities	Participant responses focusing on the potential for economic growth in rural economies, job creation in biomass supply-chains, and economic growth in industry.
	UK global leadership	Participant responses indicating the leadership potential of the UK in the biomass and bioenergy field, contributing to geopolitical power and the export of knowledge across the world.
	Ecosystem services	Participant responses focusing on potential ecosystem benefits of using biomass feedstocks grown in the UK, such as environmental benefits including water retention in soils, increased soil health, and boosting biodiversity.
	Resource efficiency	Participant responses focusing on the utilisation of waste biomass feedstocks from existing processes to create heat and or products, linked to the principles of a circular economy.
	Complementary energy	Participant responses that pointed to the role of biomass as a source of despatchable power in the context of intermittent energy supply from renewable sources such as wind and solar.
	Energy security	Participant responses indicating that biomass can deliver despatchable power when needed, in the face of increased geopolitical tensions impacting international supplies of energy, such as imported gas.
	Cost saving	Participant responses indicating that biomass use in the energy system would decrease the cost of the transition to net zero.
	Essential for net zero	Participant responses outlining how biomass is essential to achieving net zero, in the context of the potential for negative emissions, highlighting reports by the UK Climate Change Committee who outline how removals are necessary to achieve net zero by 2050.
	Negative emissions	Participant responses indicating the potential for negative emissions as a benefit of using biomass.
	Reduce fossil fuel use	Participant responses that indicate the potential for biomass to displace current fossil fuel use in certain contexts, such as replacing coal with biomass in our energy system.
	Reduce energy bills	Participant responses indicating that biomass in the energy system would lead to a reduction in energy bills for citizens.
	Costs	Participant responses pertaining to a cost of using biomass, as perceived by the participant.
	Financial	Participant responses that indicated upfront investment costs associated with establishing new biomass supply-chains, including the variability in the cost of globally traded biomass feedstocks in the context of increasing global demand.
	Land use	Participant responses that focused on the UK's land capacity in the context of ambitions to increase domestic biomass supply, traded off against other types of land use.

	Air quality	Participant responses capturing concerns over the particulate matter emitted during the processing, transportation, and conversion of biomass, as well as the need for technology that mitigates this risk.
	Reliance on imports	Participant responses that indicated a reliance on imported biomass puts the UK at risk of global price fluctuation and geopolitics.
	Environmental degradation	Participant responses that focused on the potential for biomass sourcing to cause environmental degradation, such as damage to forests or intensive farming of purpose grown energy crops.
	Social	Participant responses that focused on the potential for biomass sourcing to cause issues for local communities near biomass supply-chains, such as negative impacts on the local economy or health.
	Distracting from alternatives	Participant responses that indicated the financial subsidies provided by the UK government to support biomass deployment could have been used on more readily available renewable energy technologies such as solar and wind.
	New infrastructure	Participant responses that indicated the need for new infrastructure and the challenges associated with developing and building this infrastructure to utilise biomass in the future.
	Technical challenge	Participant responses that focused on the technical challenges that different biomass conversion technologies are facing when trying to scale to a commercial level.
	Training needs	Participant responses that highlighted a skills gap in the current UK workforce in relation to utilising biomass.

(Q3b) Current Beneficiaries	Agriculture	Participant responses that indicated the agricultural sector benefit from biomass use.
	Bioenergy Subsidy Receipt	Participant responses that indicated that those in receipt of financial subsidies currently benefit from biomass use.
	Biomass Producers	Participant responses that indicated those currently producing biomass feedstocks benefit from biomass use.
	Drax	Participant responses that explicitly stated Drax were a beneficiary of biomass.
	Energy Sector	Participant responses that indicate the energy sector benefit from biomass due to its despatchable energy potential supporting the grid.
	Forestry	Participant responses that state the forestry sector to be benefitting from biomass use.
	Government	Participant responses that stated the UK government benefit from biomass use, due to biomass allowing for policy relief via the reduction of greenhouse gas emissions in the energy sector, whilst powering the nation.
	Landowners	Participant responses that highlighted landowners as beneficiaries of biomass.
	Society	Participant responses that pointed to the wider societal benefit of using biomass, such as reliable energy and reducing fossil fuel usage leading to climate change mitigation.
	Waste Processors	Participant responses that indicated waste processors, such as landfill management and recycling companies, benefit from biomass use.
(Q3b) Future Beneficiaries	Agriculture	Participant responses that indicated the agricultural sector will benefit from biomass use, due to increased ambition for domestic biomass production, diversifying income streams and government subsidy potential.
	Biomass Transportation	Participant responses that indicated intermediary transport companies in biomass supply-chains will benefit from future biomass use.
	Current Energy Incumbents	Participant responses that indicated current energy companies would benefit from future biomass use, due to continued financial subsidy, ability to procure global biomass stock, and capacity to capitalise on the potential of negative emission technologies.
	Foresters	Participant responses that indicated the forestry sector would benefit from future biomass use.
	Landowners	Participant responses that highlighted landowners as beneficiaries of future biomass use.
	Non-power sectors	Participant responses that highlighted the non-power products of biomass conversion, such as chemicals, which could benefit in the future.
	Private Engineering	Participant responses that focused on the potential for private consultancy firms with expertise in biomass conversion to find more work from future biomass use.

(Q3c) Public Benefits	Direct	Participant responses indicating a direct benefit to the public of using biomass.
	Air quality	Participant responses linking biomass use to an increase in air quality.
	Behind the scenes	Participants indicated that the public would directly benefit from biomass use that delivers negative emissions as this will allow for some maintenance of the status quo, directly impacting people's lives by enabling them to continue life as they live it now, as without carbon removals more reductions from societal behaviours such as flying and eating meat will be needed.
	Cost saving to net zero	Participant responses focused on the role of bioenergy with carbon capture and storage in the lowest cost predictions for achieving net zero in a financial sense.
	Job creation	Participants indicated that increasing domestic biomass production will create jobs in communities linked to biomass supply-chains, opening more opportunities for income generation.
	Moral benefit	Participant responses focused on the role of biomass in supporting the nation to achieve net zero and mitigate climate change, and the positive feeling of achievement this will bring the public.
	More nature	Participant responses highlighted the potential for increased domestic biomass production to support more areas for natural space.
	Rural economy	Participant responses discussed the potential for biomass production to support rural economies linked to the agricultural sector.
	Rural heating	Participant responses highlighted the role of biomass to support off-grid communities in rural locations in providing a source of heat.
	Utilising waste	Participant responses focused on the potential to utilise waste biomass,
	Valuable by-product	Participant responses highlighted the valuable by-products, such as non-fossilised sources of hydrocarbons, available because of biomass use and the continued use of hydrocarbons in everyday products that the public use.
	Indirect	Participant responses indicating an indirect benefit to the public of using biomass.
	Climate change mitigation	Participant responses linking the use of biomass to greenhouse gas reduction, therefore mitigating the impact of climate change, and the associated but indirect benefits that the public will feel as a result as well as a sense of national achievement.
	Ecosystem Services	Participant responses linking the use of biomass to delivering indirect but beneficial ecosystem services, such as increased biodiversity, reduced impact of flooding, or increased soil nutrient content benefitting farming and food production.