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ADVANCED REVIEW

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Designing biomass policy: The political economy of renewable energy for net zero

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Abstract

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. As well as technical processes, renewable energy transitions are processes of social, environmental, and economic change which have the potential to challenge the status quo. This status quo determines who benefits from energy, where wealth is created, and the level of inequality between stakeholders within our energy systems. The politicization of energy transitions motivates stakeholders to engage in the policymaking process to ensure any trade-offs associated with policy changes benefit them. Bioenergy is unique amongst renewable energy sources as it is inherently linked to biomass extraction from our natural environment and because biomass is the only source of renewable carbon. However, this further politicizes its use and is a source of controversy in public debate. Polarized perspectives in the public debate on biomass policy allow stakeholders to assert themselves as experts on the topic and to make authoritative claims that further their interests to influence policy development. Therefore, political and economic drivers shape and influence the sustainability and success of proposed policies. Despite this, there is little research into the nontechnical factors influencing the design of sustainable biomass policy for net zero. This research highlights how political economy impacts the success of renewable energy technologies in replacing fossil fuels and the implications for using bioenergy.

This article is categorized under:

- Sustainable Energy > Bioenergy
- Policy and Economics > Energy Transitions
- Climate and Environment > Net Zero Planning and Decarbonization

KEYWORDS

biomass, net zero, policy, political economy, renewable energy

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1 | INTRODUCTION

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-fossilized sources of energy. However, this transition threatens the interests of powerful oil and gas companies, who have benefitted from the fossil-fueled status quo for decades. Furthermore, the emergence of political targets, such as new laws for achieving net zero emissions, has further politicized 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 nontechnical 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, organizations such as the Intergovernmental Panel on Climate Change (IPCC) and the United Kingdom's 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, made more complex by the challenges of a politicized energy transition. This complexity is fueled by polarized public debate around bioenergy that is exploited by various actors (such as energy producers or nongovernmental organizations [NGO]), 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 legitimized 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. While not a "silver bullet" solution to decarbonization, the flexibility of bioenergy and its potential to displace fossil fuel use across multiple sectors makes it a viable part of the United Kingdom's plans to achieve net zero. However, the United Kingdom'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 decarbonizing our energy systems, but processes of nontechnical 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 United Kingdom 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. While there is broad literature on the technological challenges of utilizing biomass feedstocks to achieve different aims and displace fossil fuel usage, there is little research into the nontechnical factors influencing the design of biomass policy to contribute toward our transition to net zero. This research aims to understand how the political economy of renewable energy transitions impacts their success in displacing fossil fuel use for the transition to net zero and considers the implications for policy that seeks to use biomass to achieve net zero. To do this, the methodology and process for formulating the research questions, literature search, analysis, and write-up is presented. This is followed by an examination of the political economy and ecology of renewable energy, and observations of the trade-offs challenging the utilization of bioenergy to reach net-zero. Finally, the political economy of bioenergy, the influence of net-zero goals, and their intersection with the broader UK bioenergy policy landscape is discussed.

2 | METHODOLOGY

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 nontechnical 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 politicized energy transition. An overview of the literature review methodology, a detailed description of how a

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literature analysis tool (LAT) 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 politicized 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 United Kingdom. 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 nontechnical barriers to sustainable bioenergy deployment in the United Kingdom, seeking to maximize benefits for people and the planet while being sensitive to existing political and economic factors.

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 around how the literature review is carried out, minimizes the risk of error influencing results, and enables reproduction of the results by others (Booth et al., 2012). A systematic approach also lent itself to the use of a 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). 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 while minimizing the potential for missing relevant research. Leveraging the LAT has maximized the benefits of taking a systematic approach, minimized the risk of error in a literature search, and reduced the time required to analyze the relevance of selected papers (Taylor, 2023).

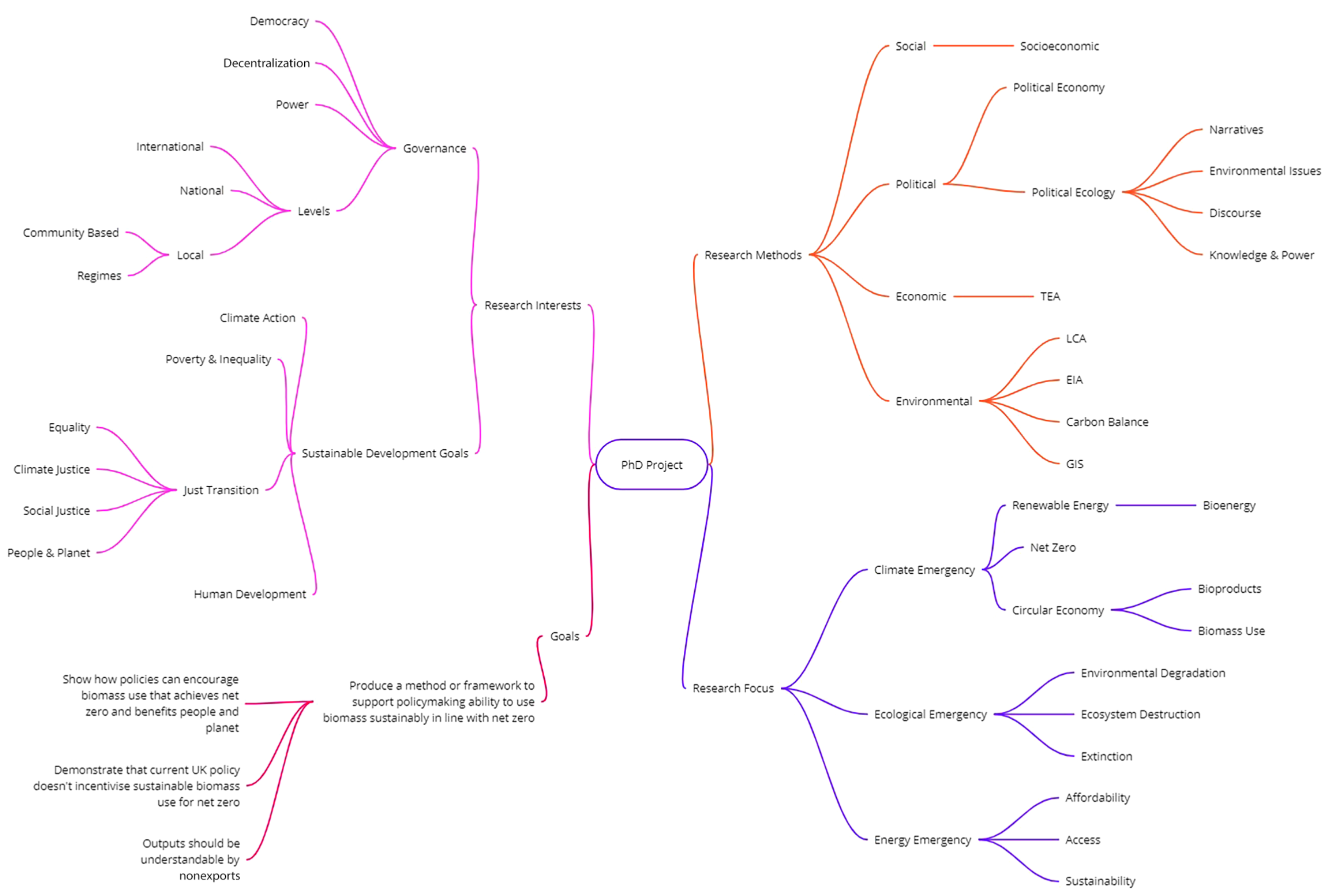

FIGURE 1 A mind map of research focus, interests, methods, and goals to summarize and triangulate the aim of the research and guide the words searched for in the literature, to determine relevancy to the research.

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The systematic approach included 10 steps, as shown in Figure 2; 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.

Analysis of the collated searches revealed a significant increase in papers published focusing on political economy, renewable energy and biomass and bioenergy from 2010 onwards. This coincides with the beginning of co-firing of

FIGURE 2 Systematic literature review steps, adapted from Booth et al. (2012).

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biomass (in this case, compressed wood pellets) and coal on a large scale began in the United Kingdom, in addition to major European Union (of which the United Kingdom 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.

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 utilizing the LAT to examine the extracted search results in Microsoft Excel, quick removal of duplicate results by comparing the digital object identifiers was achieved.

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 prioritize time and focus on the most relevant papers, enabling quick identification of the research gap and achieving the aims of this systematic literature review.

3 | THE POLITICS OF RENEWABLE ENERGY TRANSITIONS

3.1 | Politicizing energy transitions

Described as "the defining issue of our time" by the United Nations Secretary-General in 2018 (Guterres, 2018), climate change is an inherently "wicked problem" (FitzGibbon & Mensah, 2012) that impacts every aspect of life on Earth. The IPCC demonstrates this in its Sixth Assessment Report, which "recognizes the interdependence of climate, ecosystems, biodiversity and human societies" (IPCC, 2022a) 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 "silver bullet" exists for halting the climate and ecological crises. They will require societal, political, and economic system changes to be addressed 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 utilized for energy and products, emitting carbon dioxide into our atmosphere. Not only has the use of coal, oil, and gas fueled a rise in global temperatures, but it has also fueled a rise in global inequality. Many countries worldwide owe their recent historical economic development to the exploitation of fossil fuels, such as the United Kingdom'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 toward de-fossilization. This is made more complex by the state of the fossil fuel market, which has been capitalized on by a handful of multinational corporations, centralizing 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 decarbonization 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 & Sy, 2019). Changes to these energy systems will create sustainability benefits, trade-offs, winners, and losers. This has led to the increased politicization 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.

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3.2 | Political economy and ecology

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 generalized 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 United Kingdom. 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 & 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 mobilizing 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 et al. (2019) identify that sustainable policy for energy transitions will focus on creating incentives that generate political support, providing positive feedback and further mobilizing additional supporters through time. It is not enough to deploy a sustainable energy solution; mobilizing support will ensure the longevity of any benefits accrued from the transition. Despite this, Garrido et al. (2020) find that while research in developed nations has shifted toward 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.

Alternatively, building on political economy, the field of political ecology brings together environmental change and the forces of politics and economics. Whilst there is not an agreed definition of political ecology within existing literature (Robbins, 2012) asserts that our political and economic ideologies frame and politicize ecological systems. It is difficult to accurately define political ecology due to its broad scope and how environmental knowledge is continuously impacted by existing power structures, such as established institutions, elected authorities or management groups (Nunan, 2015). Despite this, there are similarities and themes within the literature from which a core set of principles can be presented (Taylor, 2019); identifying how powerful actors can institutionalize their understanding of an issue, exploring power relations and how they impact the human-environment relationship, acknowledging the way power structures impact knowledge about the environment (Nunan, 2015), and aiming to achieve sustainability through social equality (Bryant, 1998). Biomass is uniquely placed within the renewable energy transition to benefit from a political ecology analysis due to the overlap with natural ecosystems, our environment, and the human appropriation of biomass to produce energy and products. This links the politicization of climate change and renewable energy, including the competing interests of the many actors involved in the energy transition, to the ecological systems from which biomass is sourced.

3.3 | The political economy of renewable energy

Leading policymakers and government actors leverage green modernization narratives to further their goal of protecting the triple bottom line of people, profit, and the planet. The prioritization 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 & 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, decentralization 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, utilizing eco-modernization strategies to ensure they deliver environmental and social benefits. Since eco-modernization is built upon the premise that environmentalist policies will benefit the economy and lead to growth, renewable energy projects must develop within the

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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 favor market-based solutions (Muller et al., 2020). This is more complex when policies are enacted nationally at a central level without consideration for local contexts. In contrast, localized interventions promote opportunities for co-designed socioeconomic programs alongside energy technology transfer (Muller & 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 programs 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 et al. (2018) support this, adding that the success of niche renewable energy projects relies on an environment that promotes innovation, where the decentralization 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 centralization and decentralization of power to take place at many different levels within public or private models of ownership (Ferrall et al., 2021).

Although decentralization 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 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 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 centralized 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 decentralization 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 et al., 2021). Conversely, centralized decision-making at a national government level in the United Kingdom has stifled technological and policy experiments that could potentially lead to renewable energy success (Cetkovic & Buzogany, 2016).

Temper et al. (2020) further develop this perspective to highlight that decarbonization within any economy is not a standalone process but interwoven with social issues that market-based approaches cannot deal with alone. Localized community-based approaches seek to mobilize 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 politicization of the energy transition, where stakeholders compete to maximize the benefits of the energy transition for their own gain, meaning policymakers are left to decide who "wins" and who "loses."

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Fathoni et al. (2021) also pinpoint existing power asymmetries within energy systems that favor incumbent energy producers, highlighting that decentralizing these systems will challenge the incumbents' power and dependency on fossil fuel fuel-based systems that maintain the status quo. Fathoni et al. (2021) argue that focusing on a variety of small-scale actors will bring in diverse perspectives, challenging the marginalization 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 decentralized 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 et al., 2018).

Although civic participation in renewable energy deployment is key to project success, mobilizing 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 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 decarbonizing 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 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, criticizing 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 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 et al., 2017). Adding international dimensions further complicates this, as while globalization 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 & Sovacool, 2017).

3.4 | Discussion

Several key themes stand out within the literature on the political economy of renewable energy transitions. 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 United Kingdom, 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 politicization of the energy transition has occurred, as policymakers must now decide how to implement policy that achieves the United Kingdom's net zero ambitions, while 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

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de-fossilizing our economy (Figure 3). 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 privatization and centralization 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 marginalized communities can argue for social and environmental benefits, calling for change from the economic status quo.

4 | USING BIOENERGY TO ACHIEVE NET ZERO

4.1 | The political economy of bioenergy systems

Biomass is unique in its position as a renewable energy source, as the only source of non-fossilized carbon; however, its use for energy is controversial and the focus of negative media attention (Crowley & Tim., 2022). Other renewable energy sources, such as solar and wind, are often idealized 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

	Social Contract (Why?)	**Energy Decarbonization** (What?)	**Approach** (How?)
Main Points	*Policymakers are responsible for the delivery of a secure supply of energy on a national scale at an affordable rate.* *In return, policymakers receive political support from the public.* *Competes with the powerful vested interests of energy incumbents in capitalist economies*	*Variety of renewable energy options available, each with different benefits and trade-offs.* *Challenge to policymakers is to implement decarbonization 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.* *Decentralized, 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?* *Decentralization versus centralization of political, economic, and social power?*

FIGURE 3 A table demonstrating the key themes and questions which arise from the existing literature on renewable energy transitions and political economy.

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nature, ecological systems, and our land. While 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 United Kingdom, this image works against developing, cultivating, and using biomass feedstocks like energy crops (van der Horst & 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, 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 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 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 optimization. Both Hess et al. (2016) and Sovacool (2012) demonstrate the complexity of achieving success in bioenergy deployment and emphasize the need for context-specific, multidisciplinary analysis (such as political economy) to highlight nontechnical 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 et al., 2013; Röder et al., 2022; Röder, Jamieson, & Thornley, 2020; Röder, Mohr, & Liu, 2020).

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 mobilize 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 fueled energy systems (Hielscher et al., 2011). Given that existing economic approaches to energy provision in the United Kingdom 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 A. Purkus (2016).

A. 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 (Alexandra Purkus et al., 2015). However, as outlined by Hielscher et al. (2011), the threat of change motivates existing power structures, such as incumbent energy producers, to seek to minimize 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 monopolized 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 utilizing what they can to maintain financial power. While it might seem that biomass availability leads to an easier transition away from fossil fuels, a different approach is required to minimize any negative impacts and ensure a just transition that achieves social and environmental objectives (La Rovere, 2020).

4.2 | 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

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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 fossilized 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.

Although 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 commoditizes 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 (Backhouse & Lorenzen, 2021; Röder et al., 2022; van Rooijen, 2014). 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 et al., 2012).

Public perspectives are something which environmental 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 & 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 United Kingdom, this is demonstrated by public polling, which shows that the public know the least about biomass compared to other renewable energy sources (Survation, 2022).

4.3 | 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 United Kingdom's 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 decarbonizing the United Kingdom, including the role of biomass in achieving the United Kingdom's net zero target. As well as highlighting the need for specific policy and action on utilizing biomass for energy, the CCC also demonstrate how comprehensive policy development across areas such as land, waste management, and industrial decarbonization need to include coordinated biomass elements (CCC, 2022). However, this needs to be established in the United Kingdom's "Biomass Strategy," developed by the Department for Business, Energy, and Industrial Strategy (BEIS) and was due for release toward the end of 2022 (BEIS, 2021).

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 legitimized 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-decarbonize 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, 2022b). The government's ambitions in the United Kingdom 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 United Kingdom'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 & 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 United Nations call for (Guterres, 2018). These top-down initiatives are based on

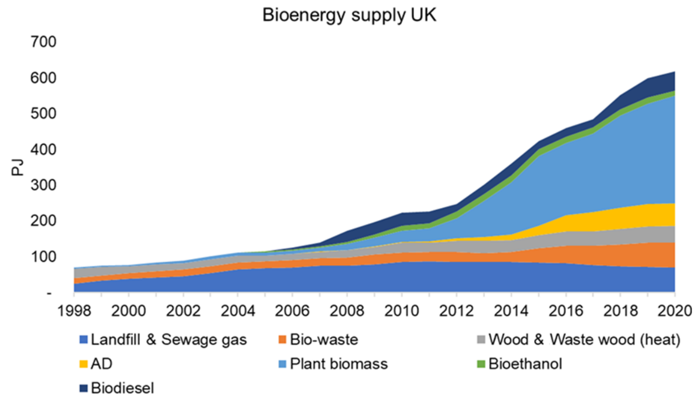

FIGURE 4 A graph detailing the mix of bioenergy supply in the United Kingdom, adapted from the Digest of UK Energy Statistics (DUKES) (BEIS, 2022).

Year	Policy Event	Source Level
1990	Nonfossil Fuel Obligation	UK
1992	Rio Earth Summit	Global
1997	Kyoto Protocol Adoption	Global
2002	EU Directive on Biofuels for Transport	EU
	Renewable Obligation Certificates	UK
2005	EU Emission Trading Scheme	EU
	Kyoto Protocol Action	Global
	EU Biomass Action Plan	EU
	Clean Development Mechanisms	EU
	EU Biofuels Strategy	EU
2008	Climate Change Act	UK
	Renewable Transport Fuel Obligation	UK
2009	EU Quality Standards for Fuels & Biofuels	EU
	EU Renewable Energy Directive Update	EU
2010	Feed-in-tariffs	UK
2011	Renewable Heat Incentive	UK
2012	UK Biomass Strategy	UK
2013	Contracts for Difference	UK
	IPCC Fifth Assessment Report	Global
2015	Paris Agreement	Global
2016	EU 2030 Climate & Energy Framework	EU
2018	UK Declaration of Climate and Ecological Emergency	UK
	UK legislation for net zero by 2050	UK
	EU Renewable Energy Directive II	EU
	Renewable Energy Guarantee of Origin	UK
2019	Climate Change Act Amendment	UK
2020	Brexit	UK
2021	Green Gas Support Scheme	UK

FIGURE 5 A table showing policy developments relevant to bioenergy at international and national levels since 1990.

individual consumer action, such as incentivizing recycling schemes, active travel options such as bus and train travel, and changing diets. Energy market interventions such as the Renewable Transport Fuel Obligation, Renewable Heat Incentive, and the Contracts for Difference scheme place emphasis on financial incentives to generate market competition and push innovation as the solution. This is significant for biomass use in the United Kingdom, 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 United Kingdom's energy mix.

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	Public Perspectives	Biomass Flexibility	Net Zero and Carbon Balances
Main Points	*Public debates being exploited by self-interested actors, who assert their authority in the debate to influence knowledge of and decisions around biomass use* *Differing perspectives and framing can undermine public trust in biomass use* *Extractive image of biomass can work against it's deployment in energy contexts (van der Horst & 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 prioritize 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 6 A table demonstrating the key themes and questions which arise from the political economy of using biomass to achieve net zero in the United Kingdom.

The largest contributor to the generation of electricity from biomass in the United Kingdom 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 10 years, with 2 out of 6 units awaiting conversion. With a total capacity of almost 4 gigawatts, Drax power station is the largest power station in the United Kingdom; however, its business model relies on two inputs subject to intense media scrutiny (Crowley & Tim., 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 United Kingdom. The second is relying on government subsidies to guarantee their

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BOX 1 Determining who benefits from biomass

Our political and economic institutions determine policies that influence the distribution of wealth, benefits, and inequalities associated with biomass extraction from our natural environment. This includes who the biomass is extracted by, where value is applied to/extracted from biomass along the supply chain, and who benefits. Biomass has the potential to contribute toward alleviating climate, ecological, and energy emergencies, sometimes achieving a "win–win–win" in tackling all three emergencies at once, but the current political economy will determine the success of this. The same political economy has been extracting fossil fuels, amassing wealth within a few multinational corporations, and driving rising carbon emissions for decades; what does this mean for biomass?

financial operations in exchange for converting their facilities from coal to biomass (GOV.UK, 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 fulfill (Figures 4–6 and Box 1).

5 | CONCLUSION

The transition from fossil fuels to renewable energy requires significant change within our political, social, and economic systems; the politicization of our energy systems further complicates that. Existing research into the nontechnical aspects of renewable energy transitions highlights the challenges facing decision-makers in trying to further this transition. First, the existence of a social contract between elected governments and local communities, challenging policymakers to provide secure and affordable energy on a national scale, which can conflict with the interests of powerful private actors, for example, incumbent fossil-fueled energy producers. Second, the choice of which technologies to support to achieve energy decarbonization, while navigating the competing priorities of the electorate and private interests and how these technologies impact the centralization or decentralization of power (in both a sociopolitical and energy production sense). Finally, the approach policymakers use to incentivize 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.

Reducing our reliance on fossil fuels and transitioning to net zero energy systems goes beyond the challenge of decarbonizing our technology and includes nontechnical, economic, social, and environmental factors. The politicization 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 nontechnical 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 nontechnical 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 maximize 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. Therefore, the success of using biomass sustainably to contribute toward solving the climate, ecological, and energy crises will depend on the impact of our political economy on this finite natural resource, warranting further study(Sidebar title).

AUTHOR CONTRIBUTIONS

Daniel Taylor: Data curation (lead); formal analysis (lead); methodology (lead); project administration (lead); visualization (lead); writing – original draft (lead). **Katie Chong:** Supervision (equal); writing – review and editing (equal). **Mirjam Röder:** Supervision (equal); writing – review and editing (equal).

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