Indicators of a Sustainable Energy Transition: Application of the UK's Net Zero Growth Plan

Liyna Marguerie De Rotrou

Campus Fryslan, University of Groningen

Capstone Bachelor Thesis

Raul Cordero Carrasco

June 5, 2024

Abstract

Extreme climate events are increasing in frequency and severity worldwide, affecting everyone to varying degrees. Mitigating carbon emissions is more important than ever and governments around the world have responded to this challenge by adopting net-zero targets and formulating net-zero action plans. An energy transition from fossil-fuel dependency to renewable energy is essential to achieve net-zero targets by 2050. However, this transition must be sustainable by encompassing economic, social, environmental, governmental and technical aspects. In this research, an evaluation of the sustainability of the UK's Net Zero Growth Plan was conducted using a rapid literature review to identify and define indicators of a sustainable energy transition. Key findings show that the policy plan is competent regarding the areas of job creation and education, but cannot be considered as a comprehensive energy transition policy framework as it focuses predominantly on economic and governmental aspects, disregarding social, environmental and technical aspects such as acceptability and user-friendliness.

Introduction

In recent years, the urgency of addressing climate change adaptation has become increasingly apparent as the effects of global warming continue to escalate. The international community, recognising the need for action, has committed to ambitious targets. The Paris Agreement marked a significant milestone in global efforts to address climate change in 2015, with participating countries committing to "reducing total greenhouse gas (GHG) emissions to maintain a temperature increase of no more than 1.5°C above pre-industrial levels" (*The Paris Agreement*, n.d.-b). Primarily, the agreement's goals aim to reduce carbon emissions to 43% by 2030 (*The Paris Agreement*, n.d.-a) and achieve net-zero emissions by 2050. Net-zero refers to the concept of reducing CO_2 emissions and maintaining them as close to zero as possible. Now, this endeavour is not only integral to the attainment of the UN's Sustainable Development Goals (SDGs), but also represents the most efficient way to mitigate the adverse impacts of climate change we are currently facing. Achieving net-zero therefore requires an energy transition from a dependent fossil fuel-based energy system to one with varied renewable energy technologies and sustainable management of these systems. This will curb emissions while meeting societal energy demands. However, despite these commitments, the rate of transition and transformation remains inadequate, evidenced by the intensification of climate-related catastrophes (Carrington, 2024; Farmer, 2024; Poynting & Stallard, 2024), underscoring the urgent need for faster action. Long et al. (2022) recognise that systemic change is needed with "major shifts in policies, generation and consumption patterns of energy." Nonetheless, the inherent complexity of different national energy systems, as highlighted by KC et al. (2022), complicates efforts toward achieving carbon neutrality, often resulting in the formulation of ambiguous policies surrounding the energy transition.

The formulation and implementation of effective net-zero policies pose significant challenges. Environmental policies often lack clear criteria for defining success, leading to inconsistency and inefficiency in pursuing net-zero targets. Furthermore, current indicators used to gauge progress towards these objectives are often ambiguous, and designed based on

intuition rather than rigorous methodical foundation (Hasund, 2005). Moreover, prevailing environmental governance structures continue to adhere to an economic-centric paradigm, prioritising economic growth. Ultimately, it is imperative to recognise that reducing emissions is the fastest way to mitigate the adverse effects of climate change, many of which we are already experiencing. Governments signatories to the Paris Agreement must further develop their strategies for effectuating an energy transition (United Nations Secretary-General, 2023).

Creating strong net-zero policies that enforce sustainable change is highly relevant to current affairs amid more frequent climate impacts with increased global temperatures and extreme climate events. For instance, activists and scientists from the climate movement are amplifying calls to action for governments to adopt more robust measures to secure the planet's future. From a policy perspective, one way to increase the transition of energy systems requires the development of comprehensive, multi-disciplinary indicators to guide policymakers in environmental governance. By integrating essential aspects of sustainability into climate policy formulation, policymakers can steer governments towards improving their current energy transition strategies and realising net-zero objectives by 2050.

The purpose of this research is to assess the UK's net-zero policy framework, the *Net Zero Growth Plan*, by using a set of indicators defined according to current literature. This framework is the most recent net-zero policy framework published by the UK government in March 2023 (Department of Energy Security and Net Zero, 2023), following suit from the *Net Zero Strategy: Build Back Greener*. The Net Zero Growth Plan is part of a larger campaign called '*Powering Up Britain*' and works alongside an energy security action plan. The study aims to explore the literature on energy transitions and identify indicators under the dimensions of sustainability. This set of indicators covers key aspects of the energy transition and can, in turn, be used to evaluate other net-zero policy frameworks or as a checklist during their formulation. Improved policy design frameworks will help governments and industries meet their net-zero commitments and facilitate more transparent and accurate reporting of environmental progress.

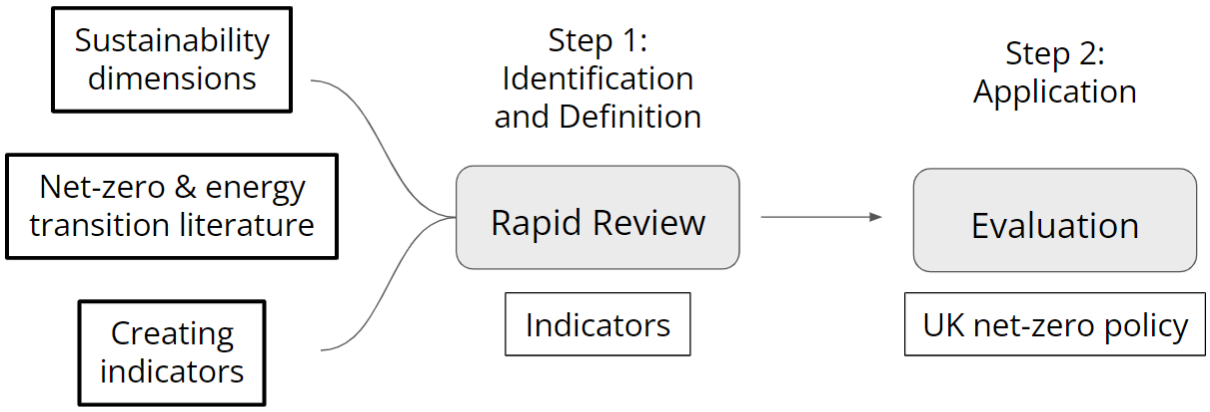
To address this and to contribute further to the sustainability dimensions framework, the following research questions will be explored and answered: *What aspects should be considered in the formulation of net-zero policy frameworks?* And, *has the UK's net-zero policy framework been formulated accordingly?* Ultimately, this study seeks to contribute to the global efforts to mitigate climate change through the use of sustainable energy transition policies and ensure a sustainable future.

This study will apply the identified indicators to the UK's policy framework because the UK is recognised as a global leader in energy transition innovation. Additionally, as my home country, I have a deeper understanding of its political climate, historical context, and demographic differences across its regions, which allows for a more nuanced analysis of the framework's implications. Moreover, there has not yet been an evaluation of the UK's net-zero policy document using sustainability dimensions.

This study employed a rapid literature review (RLR) of energy transition literature to accumulate indicators of a sustainable energy transition. The research then focused on the application of these indicators to evaluate the sustainability of energy transition policies in the context of the UK's net-zero policy framework (see Figure 1). By analysing existing policy frameworks and literature, this study aims to identify gaps and opportunities for enhancing policy effectiveness and achieving net-zero objectives.

Figure 1

Visualisation of the outline of this study.



Literature Review

Background concepts

This section underpins the theoretical foundations of the net-zero and energy transition concepts. Firstly, the works of Franhauser et al. (2021) and Khan (2023) are explored to underpin the origins of 'net-zero' and how it intrinsically links to sustainable development. Secondly, the works of Falcone et al. (2019) and Rosenow et al. (2017) are used to examine the current research on energy transition theory.

According to Frankhauser et al. (2019), the concept of net-zero can be understood by three key categories: the urgency of 'zero', the integrity of 'net' and the consistency with sustainable development objectives. The urgency of achieving 'zero' focuses on the imperative to rapidly reduce carbon emissions, aiming to keep them as close to zero as possible

worldwide. This stems from recent IPCC reports warning of the Earth's trajectory towards a temperature increase of 1.5°C, now 2°C, within the current century due to human activities. The attainment of net-zero global anthropogenic CO_2 emissions is deemed crucial to mitigate this trend (Masson-Delmotte et al., 2019). Consequently, prioritising efficient reduction strategies becomes imperative. The integrity of 'net' underlines the intricate dynamics of natural systems, emphasising the need for careful consideration when implementing carbon reduction measures (Frankhauser et al., 2019). Concerns arise regarding potential disruptions to biological processes that could alter the functioning of carbon sinks. Such disruptions not only impact the Earth's ecosystems but also pose significant long-term risks for future generations, making these solutions unsustainable. The third category encompasses socio-economic factors crucial for effective regulatory processes. This includes recognizing the timescale required for policy implementation, which must extend beyond a decade (Frankhauser et al., 2019) for successful outcomes. These categories collectively illustrate the transformative efforts necessary to achieve net-zero.

Moreover, Khan (2023) emphasises the nexus between carbon neutrality and sustainable development, suggesting that carbon neutrality initiatives should align with broader socio-economic and environmental goals. Technological solutions such as carbon capture, renewable energy technologies, and sustainable transportation (Khan, 2023) play a vital role in achieving carbon neutrality targets. Additionally, financial mechanisms such as green finance funds and carbon markets offer avenues to mobilise investments in low-carbon technologies and projects whilst promoting engagement in carbon neutrality incentives. By integrating these approaches, societies can effectively transition towards a feasible and desirable zero-carbon world (Frankhauser et al., 2019; Khan, 2023).

As mentioned above, the net-zero concept refers to the reduction of energy emissions. Therefore, an energy transition is needed from one that is fossil-fuel dependent and finite, to another that can offer energy security and carbon-free emissions. Both Falcone et al. (2019)

and Rosenow et al. (2017) state that implementing a mix of policy instruments is the only way to achieve a successful transition.

In understanding the theoretical underpinnings of energy transitions, scholars like Falcone et al. (2019) underline the significance of employing a diverse mix of policy instruments. They emphasise that using a combination of regulatory, economic and social instruments, integrating various elements of policy frameworks, is paramount for facilitating successful energy transitions. Their research highlights the importance of considering feasibility, effectiveness, and socio-economic implications when implementing instruments and designing policies aimed at driving the transition towards sustainable energy systems. By adopting a methodological framework encompassing these key elements, policymakers can better assess the suitability of different approaches and tailor policies to specific contexts.

Similarly, Rosenow et al. (2017) advocate for the use of a mix of policy instruments to support energy transition efforts, especially in energy efficiency. They argue that comprehensive and well-targeted policies are essential for achieving successful transitions. This is because by addressing the complexities and nuances of energy systems through a variety of policy interventions, governments and stakeholders can overcome barriers and capitalise on opportunities for sustainable energy development. This highlights the importance of adopting a holistic approach that considers the interplay between different policy instruments and their impacts on socio-economic and environmental dynamics.

Moreover, the Energy Transitions Commission (ETC) provides a broader perspective on the feasibility of energy transitions at a global scale. As a coalition of leaders from diverse sectors of the energy landscape (Energy Transitions Commission, 2024), the ETC believes that transitioning to a zero-emissions future is both technically and economically possible. They assert that solutions for reducing greenhouse gas emissions (GHGs) are already known or identifiable by scientists worldwide. Despite acknowledging the challenges, such as the cost of transitioning to a zero-emissions economy, which they estimate to be less than 0.5% of the

world's GDP (Energy Transitions Commission, 2024), the ETC remains optimistic about the potential for achieving ambitious climate goals. However, further examination is needed to explore whether a true zero-emissions economy is achievable given the complexities involved in transitioning entire energy systems and concerns keeping the carbon dioxide levels in balance.

Theoretical Concepts

The following section is about the theoretical framework behind the sustainable indicators of an energy transition. The works of Ilskog (2008), and Purvis et al. (2018) are used to briefly describe what sustainability dimensions mean and explain why this is the underpinning literature for the theoretical framework of this study.

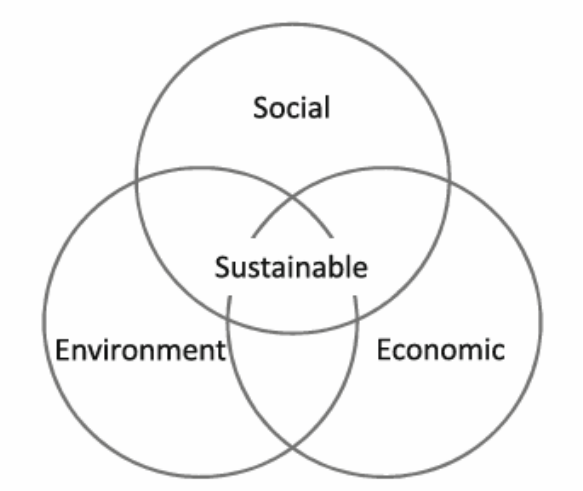
Purvis et al. (2018) propose that the concept of sustainability is based on three interconnected pillars: social, economic and environmental dimensions (see Figure 2). Their paper begins with an introduction to sustainability, emphasising its critical role in addressing global environmental challenges and advocating for a broader comprehension beyond conventional definitions (Purvis et al., 2018). Through a conceptual literature analysis, the authors explore the historical roots and conceptual origins of these sustainability pillars, aiming to make clear their evolution and interconnectedness over time. They underscore the unification and interdependence of these pillars, arguing for an integrated approach that considers synergies and trade-offs between them (Purvis et al., 2018). This shows the complexity of conflicting goals and overlapping dimensions within sustainability, suggesting the need for additional dimensions to address these challenges effectively.

According to Purvis et al. (2018), one predominant description of sustainability across the literature involves the three pillars (social, economic and environmental) as factors or goals. They relay the origin and push for this defining feature as part of the UN's formulation of the SDGs explicitly embedding the three pillars. However, the emergence

of the three-pillar paradigm lacks a strong theoretical foundation, primarily stemming from specific origins of sustainability as a concept. This highlights the importance of further theoretical development and integration to address the complexities inherent in sustainability discourse effectively.

Figure 2

A Venn diagram showing the most common representation of the three pillars (Purvis et al., 2018).



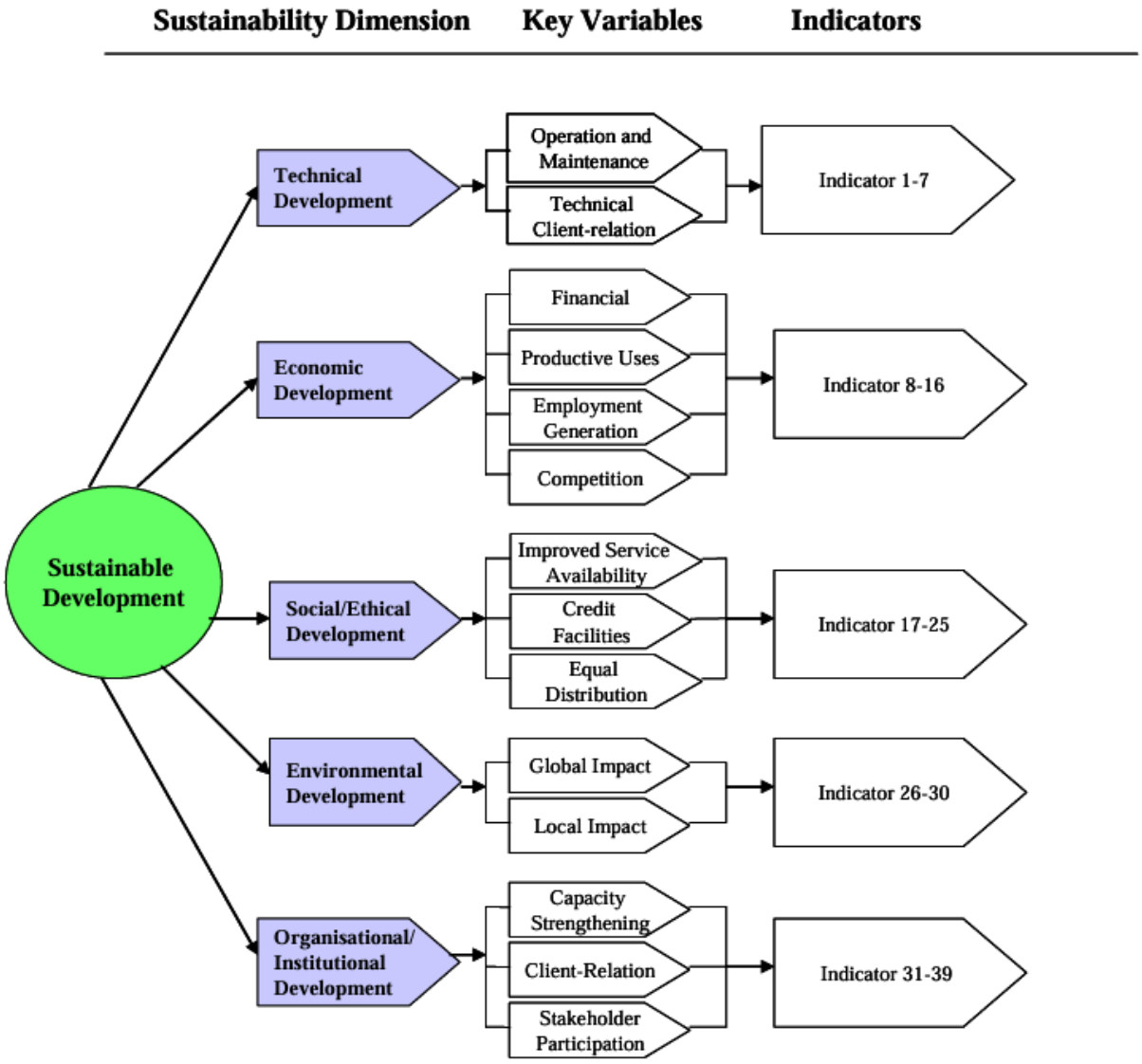
Ilskog (2008) presents a comprehensive framework encompassing five key dimensions of sustainability (see Figure 3). They involve the three pillars mentioned above (Purvis et al., 2018) and have two additional dimensions. They are: economic, social, environmental, technical and organisational. Her working paper on field workers and rural electrification projects outlines sustainability indicators aligned with these dimensions, drawing parallels with the UN sustainable development framework and Purvis et al. (2018)'s sustainability framework. By integrating these dimensions into an assessment of rural electrification projects, Ilskog provides valuable guidance and tools for evaluating project effectiveness and sustainability. Moreover, these indicators aim to enhance living standards in rural areas by promoting economic

development and improving overall quality of life, something which energy transitions should seek to achieve (Ilskog, 2008).

In discussing the dimensions of sustainability, Ilskog (2008) points out the significance of technical, economic, social-ethical, environmental and organisational factors in project sustainability. Notably, she emphasises the importance of the technical dimension in directly influencing project sustainability, highlighting the necessity of maintaining fuel supplies, spare parts, and operational personnel (Ilskog, 2008). Moreover, Ilskog (2008) defines economic sustainability in terms of revenue sufficiency and affordability for users, underscoring the need for a sustainable market for energy services. She also addresses organisational sustainability, emphasising aspects such as project management, client satisfaction, and gender representation in decision-making. However, it is noted that the limited importance placed on environmental sustainability, particularly in projects already implemented, suggests a potential area for reevaluation and alignment with broader environmental regulations such as the Paris Agreement. Additionally, Ilskog (2008) incorporates social and ethical considerations into the sustainability framework, encompassing factors such as access to electricity, development of health institutions, and educational levels in the project area, thereby reflecting a holistic approach to sustainability assessment.

Figure 3

The sustainability dimensions framework developed by Ilskog (2008) taken from her working paper.



Methodology

Net-zero policies must be formulated clearly, addressing key aspects of sustainability, in order to achieve zero emissions. In accordance with the UN's SDGs, this study applied similar sustainability dimensions to that of Ilskog (2008) to identify and define what makes a sustainable energy transition. Additionally, the works of Hasund (2005) and Ilskog (2008) have inspired the decision to formulate indicators of a sustainable energy transition. These two scholars are leading in the methodology for creating indicators and show that by providing guidance before the policy formulation process, policymakers are better informed and are thus able to propose comprehensive policies that address multiple aspects (Hasund, 2005; Ilskog, 2008). Due to time constraints I have not conducted interviews with experts but have instead applied a two-step procedure whereby a RLR of the relevant literature was carried out to identify and define indicators of sustainable energy transitions that can achieve net-zero, and an application of these indicators was used to evaluate and examine the current UK net-zero policy framework.

As part of the first step, identifying the indicators needed for a sustainable energy transition policy strategy, a RLR was conducted on energy transition literature from the last decade. To make the search reliable and systematic, the following elements were used as guiding points. These included, using peer reviewed articles from 2015 onwards, published in English and found on the databases SmartCat. That date was chosen in accordance with the date of the Paris Agreement. The following keywords were searched for in titles and abstracts: 'energy transition' AND 'energy' AND 'environment' AND 'criteria' AND 'policy'. No grey literature was included. A RLR was best suited for this study due to time constraints as it allowed for cuts and flexibility (Sutton et al., 2019) in the searching process by using "simplified approaches" (Smela et al., 2023) to the finding of literature. Selecting peer-reviewed articles increased the validity of the search as indicators identified from these papers are from 'experts'.

However the search was not limited to one discipline, meaning a mix of studies were included increasing the diversity of possible results. However, conducting a RLR, does not eliminate bias, as there might still be bias in the findings and analysis (Bourton et al., 2023). For instance, by using specific predetermined keywords. Though these were based on the theoretical foundations of this study. Another critique of the application of this method, is that by answering a complex policy-related question, this method doesn't test theories or explain the complexities of such studies (Wilson et al., 2021). Given more time, different methods would be employed to allow for more diverse results, a larger body of evidence and create indicators based on diverse criteria. Once the indicators were identified from the RLR (see Results section), they were categorised into similar sustainability dimensions to those proposed by Ilskog (2008) and Purvis et al. (2018), contributing to the reliability of this study. The categorised indicators identified from the literature will inform energy transition and net-zero policymakers on what to include during the beginning of the policy formulation process.

In the second step, the defined indicators were applied to evaluate just how sustainable the UK's *Net Zero Growth Plan* is, by identifying whether the policies are on track for a sustainable energy transition.

Results

RLR Results

The RLR gave an output of 94 articles after using advanced search criteria. Due to time constraints the first 11 articles were included (see Table 1). Varying topics were found, with social perception of renewable energy (RE) technologies, evaluations of energy transitions and assessments of different technical solutions such as offshore wind projects being the most prominent. Similar keywords to that of the literature study conducted in Vanegas-Cantarero et al. (2022)'s paper were found. This means the RLR was successful by producing similar results

that are inline with other literature reviews. Despite the low number of articles, a wide variety of regions were studied making the results comprehensive of differences between the global south and the global north. Overall, the literature expressed the recognition that change is needed in the energy sector to achieve low carbon emission targets, regarding both production and consumption patterns (KC et al., 2022; Long et al., 2022).

The analysis of the articles involved some level of bias due to the subjective nature of identifying either explicit or implicit indicators. From this body of work, 16 indicators of a sustainable energy transition were identified and then defined (see Tables 2-6). They were further categorised into five dimensions of sustainability. These are economic, social, environmental, governmental and technical, similar to that of Ilskog (2008) and Long et al., (2022).

Table 1

List of RLR results and identified indicators

Author/Reference	Title	Objective of study	Case Study or Area	Indicators
Long et al. (2022)	Enhancing sustainable development via low carbon energy transition approaches	Explores various low-carbon energy transition approaches that promote sustainable development.	Malaysia	Combined approaches, Job creation
Govindan (2023)	Pathways to low carbon energy transition through multi criteria assessment of offshore wind energy barriers	Identifies the barriers of achieving low-carbon energy transition of offshore wind projects.	India	Education, Committed institutions, Energy security
Rajagopal	Implications of the	Examines the implications	India	Energy security, Improving

(2023)	energy transition for government revenues, energy imports and employment: The case of electric vehicles in India	of introducing electric vehicles.		health
KC et al. (2022)	Public Perception on the Sustainable Energy Transition in Rural Finland: A Multi-criteria Approach	Examines the public perception regarding the sustainable energy transition.	Finland	Education, Job creation, Affordability, Improving health, Acceptability, Energy efficiency, Alternative energy sources
Sandin et al. (2019)	Transition governance for energy efficiency - insights from a systematic review of Swedish policy evaluation practices	Analyses transition governance strategies and policy evaluation practices for energy efficiency.	Sweden	Evaluation methods, Local participation, Acceptability
Yürek et al. (2023)	Socio-political evaluation of renewable energy resources under uncertain environment	Examines the socio-political implications of renewable energy sources in uncertain conditions.	Turkey	Evaluation methods, Job creation, Improving health, Efficient land use, Affordability, Transparency, Education, Acceptability, Alternative energy sources
Vanegas-Cantarero et al. (2022)	Beyond LCOE: A multi-criteria evaluation framework for offshore renewable energy projects	Develops a multi-criteria evaluation framework for offshore renewable energy projects.	Scotland, Portugal	Evaluation methods, Combined approaches, Alternative energy sources, Acceptability, Job creation, Affordability

Rodríguez-Segura et al. (2023)	Social acceptance of renewable energy development in southern Spain: Exploring tendencies, locations, criteria and situations	Examines the social acceptance of renewable energy projects.	Spain	Acceptability, Location acceptability, Alternative energy sources, Efficient land use, Local participation, Committed institutions, Affordability, Energy security
Aryanpur et al. (2019)	An overview of energy planning in Iran and transition pathways towards sustainable electricity supply sector	Develops a framework outlining the transition pathways to achieve a sustainable energy supply sector.	Iran	Combined approaches, Energy security, Job creation, Committed institutions, Evaluation methods
Ferrari et al. (2019)	Assessment of tools for urban energy planning	Examines the effectiveness and suitability of tools for urban energy planning.	Italy	Evaluation methods, User friendliness, Energy efficiency, Location acceptability
Spandagos et al. (2023)	Energy poverty prediction and effective targeting for just transitions with machine learning	Analyses the use of machine learning techniques to predict energy poverty and effective targeting interventions for just transitions	EU member states	Evaluation methods, Affordability, Transparency

Indicator Results and UK Net Zero Growth Plan Evaluation

Table 2

Economic dimension

Indicator	Definition	Inclusion in UK policy

Job creation	Implementing new energy technologies to increase job opportunities.	Yes
Energy security	Finding solutions to balance energy supply and demand.	Yes
Affordability	Reducing energy prices via operating costs or consumer benefits.	No

The UK's net-zero policy framework has included job creation as the most significant indicator, evidenced by several weighty investments and projections. A £20 billion investment in *Carbon Capture, Utilisation and Storage* (CCUS) has been marked for private investment and job creation demonstrating a commitment to capacity building with a skilled workforce (Department of Energy Security and Net Zero, 2023). Since the end of 2020, 80,000 green jobs have been created, and there is a clear plan to support 12,000 additional jobs by 2030 in energy production, transport and energy storage sectors. Furthermore, by 2035, about 240,000 jobs are expected to be created through a £10 billion investment in heating system measures, contributing to the Gross Value Added (GVA). Additionally, the aviation fuel industry is projected to create 65,000 jobs by 2050. However, this last point remains contentious within the framework, raising questions about its alignment with net-zero goals. Overall, the policy framework acknowledges the need for existing occupations to evolve over the next 30 years, emphasising job creation as integral to the energy transition.

The framework has included energy security as an indicator, as evidenced by some key initiatives and strategies. The plan highlights the optimisation of electric vehicles (EVs) to address rising energy demand and employs climate compatibility checkpoints to compare the GHG footprints of imports versus domestic energy production (Department of Energy Security and Net Zero, 2023). The report projects a potential 60% increase in electricity demand by the

middle of the next decade, underscoring the need for robust energy planning. Additionally, the scaling up of engineered Greenhouse Gas Removals (GGRs) is intended to boost energy exports. The government is actively working to balance energy supply and demand by expanding renewable energy technologies in the energy mix. However, the framework acknowledges the need for more varied suggestions to enhance energy security further.

The framework has not adequately included affordability as an indicator, as demonstrated by several points. Although there are ambitions to double hydrogen production, this goal is consistently noted as being “subject to affordability and value for money,” indicating a conditional commitment rather than a firm plan. The framework mentions cost savings across the electricity system, by delivering double hydrogen production, but it remains unclear if these savings will translate to lower energy costs for consumers. While the phrase “community benefits for network infrastructure” is used, it is ambiguous whether this implies lower energy costs. In the housing sector, social housing programs and capital support schemes aim to maximise investment by leveraging co-funding from local authorities and housing associations. The ‘Help to Heat’ schemes and the Social Housing Decarbonisation Scheme, with a £6.6 billion investment, focus on improving energy efficiency and attracting private investment, targeting low-income households and the least energy-efficient homes. However, these measures primarily benefit investors rather than directly addressing affordability for residents. The framework also includes ambitious plans to support innovation and deployment of low-carbon technologies to reduce costs for households and businesses, yet the benefits to consumers are not explicitly detailed. Despite these efforts, the framework fails to address the broader issue on reducing energy costs for consumers.

Table 3

Social Dimension

Indicator	Definition	Inclusion in UK policy

Improving health	Reducing negative effects on public health.	No
Education	Improve knowledge of RE technologies.	Yes
Acceptability	Improving the socio-political factors affecting communities' views on RE technologies.	No

The framework has not sufficiently included the indicator of improving health, as shown by a few observations. There are references to increasing health benefits by improving environmental conditions such as biodiversity and air and water quality. However, these are an inherent part of the energy transition goals and thus it is a vague statement. The Health and Safety Executive addresses public health factors and promotes sustainable solutions, such as replacing iron mains with plastic pipes to reduce CO_2 emissions. The transport sector's goals, which aim to have a healthier population, and new projects exploring healthier food farming options in peatlands, also imply health benefits. However, the framework lacks a clear, comprehensive statement of reducing negative public health impacts. This omission highlights a gap in explicitly connecting environmental actions to direct health improvements for the public.

The framework has included education as the second-most significant factor, as evidenced by several initiatives aimed at preparing the workforce for a green economy. The Green Jobs Delivery Group has an education sector to ensure the workforce is ready for future energy demands. The Department of Education (DfE) has launched the *Sustainability and Climate Change Strategy*, aiming to "equip learners of all ages with the necessary knowledge and skills" (Department of Energy Security and Net Zero, 2023). Additionally, the Department of Energy Security and Net Zero has allocated £5 million for training 10,000 individuals in low-carbon heating and £15 million for 16,000 more through the Home Decarbonisation Skills

Training Fund. Furthermore, there has been a rise of apprenticeships in sustainable energy practices, such as low-carbon heating technicians and sustainability business specialists, to meet employer demands. From summer 2023, “industries need to conduct research on workforce demand and skills gaps within the power and network sectors” (Department of Energy Security and Net Zero, 2023), which will enhance progress transparency and ensure a prepared workforce. In England, the DfE is investing an additional £3.8 billion in skills by 2024-25, including funding for green skills programs like apprenticeships, T levels and Bootcamps.

Another initiative is the increase in public awareness campaigns, such as the ‘It All Adds Up’ campaign. The aim is to inform consumers about “low- and no-cost actions” and encourage the adoption of renewable energy technologies, such as heat pumps, despite the high upfront costs.

The framework has not adequately included the indicator of acceptability, despite recognising its importance. According to the RLR, acceptability encompasses the socio-political factors that affect how the public perceive RE technologies and net-zero projects. These factors include economic benefits for consumers (Rodriguez-Segura et al., 2023; Spandagos et al., 2023), energy demands are being met (Rodriguez-Segura et al., 2023), what type of RE technology the project is (KC et al., 2022; Rodriguez-Segura et al., 2023; Yurek et al., 2023), and whether local participation is occurring. Nearly all articles discussed factors relating the acceptability of RE technologies from the wider population. While the framework’s principles aim “to minimise the burden on the public and build public acceptability for major changes” (Department of Energy Security and Net Zero, 2023), there is a lack of specific policies addressing these goals. It fails to mention plans to assess the location of renewable energy technologies or provide clearly stated ways for consumers to receive economic benefits. While there is some mention of local government involvement, the lack of detailed strategies to enhance understanding of public opinion and economic incentives undermines the integrity of the framework’s proposals. Therefore, without concrete measures to address the socio-political factors, the framework’s effectiveness in gaining public support remains limited.

Table 4

Environmental dimension

Indicator	Definition	Inclusion in UK policy
Efficient land use	Applying a multi-purpose approach to RE technologies' placement.	No
Location acceptability	Increasing acceptability of RE technologies by selecting the most suitable location.	No
Alternative energy sources	Increasing the implementation of RE technologies in our daily lives.	Yes

The framework has not adequately included anything regarding efficient land use or location acceptability, as evidenced by several shortcomings. While nature-based solutions have been proposed by the *Independent Review of Net Zero*, and the *National Environment Investment Readiness Fund* is exploring 86 projects in England, these initiatives primarily focus on restoring nature rather than optimising land use for RE projects. The commitment to secure £500 million per year in private finance by 2027, increasing to £1 billion per year by 20230, is a positive step for environmental restoration. However, the framework lacks a clear strategy regarding the placement and integration of RE projects within the landscape. This omission indicates a significant gap in planning for efficient land use, which is essential for balancing renewable energy development with environmental conservation and other land-use needs. Furthermore, there is no mention of how the government will or is making a decision on suitable locations for the RE projects, which should be made in collaboration with the local population. Without addressing where RE projects should be strategically located, the framework issues an opportunity to ensure that land is used effectively and sustainably in the transition to net-zero.

The framework has included the indicator of alternative energy sources, as evidenced by several key initiatives and commitments. The framework acknowledges the temporary role of fossil fuels until “credible” clean energy alternatives are fully integrated, despite the misleading implication that such alternatives are not yet viable. Notably, the inclusion of alternative fuels for vessels highlights a previously underemphasized area in the literature. The *Energy Security* framework outlines a diversified energy mix, emphasising the expansion of wind, solar, nuclear, and hydrogen technologies as zero-emission solutions. The framework includes new nuclear power projects and the continuation of the offshore wind sector, alongside the establishment of a new solar taskforce and delivery roadmap. Certification capabilities for onshore solar and wind plants further demonstrate the commitment to alternative energy sources. Significant progress has been made in transitioning from coal to renewable energy technologies, although there is a possibility of carbon offsetting or trading being part of these improvements. The reduction in net GHG emissions from power—from 85% in 1990 to 12% in 2021—illustrates the impact of these efforts. The frequent mentions of wind (55), solar (17), nuclear (44), and hydrogen (124) throughout the policy plan underscore the emphasis on these technologies. Additionally, the "Offshore Wind Environmental Improvement Package" (Department of Energy Security and Net Zero, 2023) signifies a comprehensive approach to enhancing offshore wind infrastructure and its environmental impact.

Table 5

Governmental Dimension

Indicator name	Definition	Inclusion in UK policy
Combined approaches	Implementing a mix of approaches to maximise the benefits.	Yes
Committed institutions	Collaboration between stakeholders, governmental departments and experts.	No
Transparency	Openly publishing policies in a precise and clear manner.	Yes
Local participation	Including residents and citizens in decision-making processes and evaluations of policies.	No
Evaluation methods	Creating comprehensive and sound frameworks to improve decision making outcomes.	Yes

The framework has included combined approaches, as shown by many key statements and initiatives within the framework. The government emphasises the importance of an integrated approach to maximise co-benefits of the transition, acknowledging the interconnected nature of climate action. Additionally, the commitment to a multilateral approach underscores the recognition that addressing climate change requires collaboration on a global scale. Embedding a systems-driven approach to complex policy problems further demonstrates the intention to consider multiple factors and stakeholders in decision-making processes.

The establishment of “shorter statutory deadlines and a fast-track route” (Department of Energy Security and Net Zero, 2023) reflects a strategic and outcomes-based approach to environmental requirements, allowing for more flexible and extensive policy implementation.

Moreover, the creation of the Domestic and Economic Affairs (Energy, Climate, and Net Zero) Cabinet committee ensures a coordinated approach across government departments, facilitating cohesive efforts in achieving net-zero goals. Overall, the framework demonstrates a commitment to utilising a mix of approaches to address the complexities of transitioning to a sustainable, net-zero future.

The framework has not adequately included indication of committed institutions, as evidenced by several observations. Despite the creation of various task forces aimed at addressing energy efficiency, reducing energy demand, and increasing energy supply, there is a lack of explicit commitment to strengthening institutional frameworks to drive meaningful action. The continuation of stating their progress with the UNFCCC commitment and the allocation of funds “£11.6 billion on ICF in 2021/22-2025/26” (Department of Energy Security and Net Zero, 2023) to the International Climate Finance (ICF) demonstrate a commitment to international collaboration, yet there is little clarity on how this commitment will translate into enhanced institutional cooperation or engagement with experts from diverse fields. Although the framework emphasises a “multilateral approach and international leadership” (Department of Energy Security and Net Zero, 2023), there is a notable absence of specific mechanisms for collaboration with experts and stakeholders, such as meetings or collaborated reports with scientists and local communities, which are essential for informed decision-making and effective implementation of net-zero strategies. While there is clear improvement of internal government organisation there is nowhere anything about collaborating (more) with experts.

The policy framework has included the implications of transparency, as evidenced by several initiatives aimed at increasing public access to data and holding the government accountable. Publicly available data from “net-zero and environmental schemes” (Department of Energy Security and Net Zero, 2023) provide insights into supporting green jobs and their economic impact, fostering transparency in decision-making processes. Moreover, the *Independent Review of Net Zero* and the *Committee on Climate Change's Progress Report to*

Parliament serve as mechanisms to keep the government accountable and enhance public reporting. In response to recommendations for increased transparency, the government plans to share more information about internal reporting tools and processes, as well as the frequency of emissions data sharing, demonstrating a commitment to openness. While certain policies' approaches may not always be clear, the framework acknowledges the need for improvement and outlines steps to address this issue, such as providing clearer outlines and sharing more information on how net-zero is being delivered within government. Overall, the policy framework demonstrates a commitment to enhancing transparency through increased public reporting and improved communication of government actions and processes.

The policy framework has not adequately included local participation, as demonstrated by several observations. While there are references to “public and business engagement to reduce energy consumption”, as well as “public dialogues on net-zero issues to inform policy development” (Department of Energy Security and Net Zero, 2023), there is a notable absence of specific mechanisms to include local communities in decision-making processes or evaluations. While the framework acknowledges the importance of providing “local authorities with flexibility to respond to the views of their communities in onshore wind projects” (Department of Energy Security and Net Zero, 2023), there is a lack of mention of how the local population will be involved in shaping policies and initiatives related to net-zero. Although there is a section on public empowerment and engagement, it primarily focuses on outreach rather than meaningful inclusion in decision-making processes. For instance, the framework could have outlined plans to take a qualitative approach to understanding the barriers to local participation and actively involve communities in co-creating solutions. Without explicit strategies for local participation, the framework may miss opportunities to harness the knowledge and perspectives of local communities in achieving net-zero goals.

The UK's net-zero policy framework has included various evaluation methods, as shown by the development and implementation of differing frameworks aimed at improving

decision-making outcomes. Initiatives such as market and private investment frameworks are expected to “accelerate the delivery of objectives” (Department of Energy Security and Net Zero, 2023), indicating a commitment to evaluating the effectiveness of financial decision-making processes. Additionally, the introduction of “guiding frameworks” (Department of Energy Security and Net Zero, 2023) to facilitate public engagement and the establishment of the *Energy & Climate Behavioural Science Framework* and the *2030 Strategic Framework for International Climate and Nature Action* demonstrate a systematic approach to evaluating and enhancing strategies related to net-zero. The integration of outcomes from COP26 and COP27, as well as the *Kunming-Montreal Global Biodiversity Framework*, further underscores a comprehensive evaluation approach. Departments are also required to adhere to sustainability frameworks, including the *Nature Markets Framework* and the *Green Finance Policy Framework*, indicating a commitment to evaluating sustainability efforts across various sectors. While the extent of the comprehensiveness and effectiveness of these frameworks requires further examination, the existence of evaluation mechanisms is evident through independent reviews and reports from entities like the *Independent Review of Net Zero* and the *Committee on Climate Change's Progress Report*.

Table 6

Technical Dimension

Indicator name	Definition	Inclusion in UK policy
Energy efficiency	Improving reporting methods and system supply	No
User friendliness	Creating inclusive user interfaces	No

The policy framework has not adequately included the indicator of energy efficiency as defined in Table 6. While there is a commitment to investing £6 billion between 2025-28 to “reduce the UK's final energy consumption from buildings and industry by 15% by 2030 relative

to 2021 levels" (Department of Energy Security and Net Zero, 2023), there is a lack of specific measures addressing energy efficiency reporting and monitoring. While the framework mentions monitoring, reporting, and verification (MRV) methods for the UK *Emissions Trading Scheme* and GHGs from farms, and has improved food waste reporting for large food businesses highlights a commitment to environmental sustainability, but energy efficiency reporting methods are conspicuously absent. Despite mentions of increasing supply system efficiency, there is a notable lack of recognition or emphasis on improving reporting methods for energy efficiency, which is crucial for tracking progress and identifying areas for improvement in achieving net-zero goals. Therefore, the framework falls short in adequately addressing the indicator of energy efficiency.

The framework has not included the indicator of user-friendliness. All indicators have two or more articles emphasising their importance apart from user-friendliness in the technical dimension. This highlights user-friendliness as a significant result. Although there was a "digital discovery" in 2022 to explore the "need for new content on net-zero" and the potential for a comprehensive platform on the official government website (Department of Energy Security and Net Zero, 2023), there is limited follow-through on how these tools will be made inclusive. While the framework includes an 'online advice tool' to assist consumers in "improving home energy performance" (Department of Energy Security and Net Zero, 2023), it lacks specific measures to enhance the accessibility and usability of these tools. Despite initiatives to enhance user interface and provide online resources, the framework overlooks the need to ensure equitable access to these tools, particularly for vulnerable or marginalised communities who may face barriers to accessing digital resources. Therefore, the framework falls short in addressing the indicator of user-friendliness which is essential to engage the public for the energy transition.

Discussion

Economic dimension

The transition towards RE sources presents various economic opportunities at different scales, from local communities to global markets. At the local level, the adoption of RE technologies can stimulate job creation, particularly in sectors like solar and wind energy installation, maintenance, and manufacturing. This overlap between job creation and the social dimension is crucial as it not only addresses unemployment but also fosters community resilience and economic empowerment. Moreover, investing in RE infrastructure can be cost-effective and profitable, as stated by Vanegas-Cantarero et al. (2022) that emerging offshore RE (ORE) technologies compete favourably with fossil fuel-based generation. This finding suggests that market acceptance and investor interest in ORE technologies are growing, signalling a promising shift towards sustainable energy investments.

However, it's essential to critically examine the economic implications of the energy transition. For instance, the widespread adoption of EVs could lead to a significant decrease in government revenue due to reduced tax imports, as highlighted by Rajagopal (2023)'s research. This underscores a risk that governments need to take in order to reduce emissions. Additionally, investment in the aviation sector to create jobs is highly questionable but not surprising. It shows that the UK wants to continue their agenda to mobilise the economic growth benefits of the energy transition but keep their profitable aviation sector running. This contradicts the targets of reducing carbon emissions and therefore makes the UK net-zero policy redundant.

Furthermore, the transition of the energy sector towards a “green economy” inherently involves a profound transformation of the entire economic landscape. This shift not only means a reconfiguration of energy production and consumption patterns but also influences the broader socio economic framework of the policy plan. However, the paradigm used in the framework is one that will slow the transition rate. “Everyone must work together to achieve

net-zero to gain the economic benefits and ensure the environment is in a state for future generations" (Department of Energy Security and Net Zero, 2023). This statement clearly shows the priorities of the UK government highlighting a major problem that needs to be addressed by political scientists. This problem is that economic gain from an initiative that focuses on the betterment of the earth and mankind doesn't make sense. Although there are economic benefits of the energy transition, this sentence reeks of neverending capitalistic growth pursued since the 70s with Margaret Thatcher.

Social dimension

The focus on education and job creation is admirable because they are integrated in the whole process. Regarding the increase in green orientated apprenticeships, in which "industries must conduct research on the workforce demand and skills gaps within power sectors" (Department of Energy Security and Net Zero, 2023), this is great for transparency of the progress the government are doing regarding education and keeping up with targets by ensuring there is a workforce prepared for the future. However, in all the initiatives, for education-related and others, only England is mentioned. It should be stated what the UK will do in collaboration with Scotland, Wales and NI, to establish the international leadership and collaboration they were promoting.

Additionally, many commitments in the net-zero plan require the public to make green choices, such as installing heat pumps and purchasing electric vehicles. It is unreasonable as it overlooks the financial realities of the average UK household, who often cannot afford these technologies, and often the case in the UK when it comes to RE technologies, that buying expensive solutions without financial support is the proposition. This will not help local pile accept the use of RE technologies despite its long-term cost efficiency. Instead, the government should appoint the funding to install RE technologies in homes that are suitable for it, and promote circularity in the automotive industry.

Environmental dimension

The implementation of alternative energy sources, such as wind, solar, and nuclear power, plays a crucial role in diversifying the UK's energy mix and enhancing energy security. By reducing reliance on fossil fuels, which are subject to price volatility and geopolitical risks, RE sources contribute to a more resilient and sustainable energy infrastructure. This diversification not only reduces the UK's vulnerability to supply disruptions but also promotes long-term energy stability and independence. In addition to promoting energy security, the adoption of RE also addresses environmental challenges, particularly air pollution, which adversely affects public health. Heating systems and transportation systems are major contributors to air pollution, emitting pollutants such as particulate matter, nitrogen oxides, and carbon dioxide (KC et al., 2022). The implementation of RE can help mitigate air pollution by reducing emissions of harmful pollutants, thereby improving air quality and public health outcomes. To enhance the acceptability and willingness of communities to support RE projects, incorporating multi-purpose land use and involving local participation in the location of energy plants are critical (Rodriguez-Segura et al., 2023).

On the other hand, there is very little mentioned on environmental indicators. In response to the *Independent Review of Net Zero* suggesting to incorporate more nature-based solutions, the plan explicitly states that it will “monetize the benefits of nature” (Department of Energy Security and Net Zero, 2023). By using the ecological benefits provided by natural systems, such as carbon sequestration and flood mitigation, the UK can enhance its resilience to climate change while simultaneously supporting biodiversity conservation. However, these projects will only receive more attention if they are profitable, it would seem. Moreover, despite numerous RE projects and a diversifying energy mix, there are strong perspectives that “oil and gas will remain crucial energy sources in the energy transition” (*The North Sea Transition Deal*, n.d.). This disregards the importance of integrating environmental indicators into sustainable energy transition policy frameworks.

Governance dimension

The inclusion of a larger number of governance indicators in the UK's net-zero policy framework signifies a comprehensive and multi-faceted approach to addressing the challenges of climate change and achieving net-zero emissions. These indicators provide insights into the various aspects of governmental action and policy implementation required to effectively transition to a low-carbon economy. By considering a diverse range of institutional factors, policymakers can better understand the complexities of transitioning to net-zero and identify areas for improvement in governance structures and processes.

Moreover, the inclusion of governance indicators reflects a recognition of the central role of government in driving climate action and coordinating efforts across different sectors and levels of governance. Effective governance is essential for setting ambitious targets, implementing policies, mobilising resources, and monitoring progress towards net-zero. Additionally, governance indicators can help assess the accountability, transparency, and effectiveness of government actions in addressing climate change and achieving sustainability goals. By incorporating a range of governance indicators, policymakers can foster greater accountability, legitimacy, and public trust in the net-zero policy framework, ultimately enhancing its overall effectiveness and impact.

Technical dimension

User-friendliness is a significant finding within the literature due to its implications for accessibility, transparency, and effectiveness of climate action initiatives. A user-friendly interface for climate-related tools, resources, and platforms can enhance engagement and participation from diverse stakeholders, including policymakers, businesses, and the general public. For example, designing reporting methods and data visualisation tools with user-friendly features can facilitate easier data interpretation and decision-making, thereby increasing transparency and accountability. Moreover, prioritising user-friendliness can address barriers to

access for vulnerable or marginalised groups, such as the elderly, by ensuring that climate-related information and resources are accessible and comprehensible to all segments of society.

Additional Discussion Points

Despite the importance of transportation in the policy framework, there is a notable absence of emphasis on this aspect in the literature. While transportation is indeed vital for achieving net-zero targets, it may not require immediate attention compared to other sectors. For instance, investing in better and more affordable public transportation could yield more significant emission reductions than transitioning all buses to electric ones initially.

Distributional equity is a crucial aspect of the literature, as highlighted by scholars such as Rajagopal (2023) and Spandagos et al. (2023). Rajagopal (2023) underscores the significance of addressing distributional and equity concerns arising from the energy transition, emphasising the need for policies that mitigate “unintended harm”. This observation underscores the complex socio-economic implications of transitioning to RE sources and underscores the importance of designing inclusive policies that benefit all segments of society. Rajagopal (2023)'s insights underscore the necessity of a comprehensive understanding of distributional equity to inform policy design effectively.

Similarly, Spandagos et al. (2023) emphasise the concept of distributional energy justice, which advocates for fair distribution of the burdens associated with the energy transition. This perspective underscores the importance of ensuring that no population group faces disproportionate adverse impacts from policies aimed at achieving net-zero emissions. Addressing distributional energy justice is critical to avoid exacerbating existing socio-economic disparities and fostering a more equitable transition to sustainable energy systems. Moreover, it is essential to consider potential forms of discrimination in the implementation of skills boost and green workforce plans. Despite the emphasis on job creation and skills development, there remains a risk of discrimination against marginalised groups, including people of colour (POC),

LGBTQ individuals, disabled persons, and those from lower socio-economic classes. The absence of explicit measures to ensure inclusivity raises concerns about the accessibility and fairness of these initiatives. To promote equity and social justice, it is imperative for the UK's net-zero policy framework to incorporate measures that actively address and mitigate systemic discrimination in workforce development programs.

The transition towards a green economy, driven by the shift in the energy sector, represents a significant departure from traditional economic models. This transition not only necessitates a fundamental restructuring of industries and businesses but also requires a shift in societal values and priorities. While economic benefits are often touted as a primary driver for climate action initiatives, it is essential to critically examine the underlying assumptions and implications of pursuing endless capitalist growth in the context of environmental sustainability. The statement that "everyone - government, industry, businesses, and civil society - must work together to achieve net-zero to gain the economic benefits and ensure the environment is in a state for future generations" highlights the inherent tension between economic growth and environmental preservation. This underscores the need for political scientists to analyse and address the complex interplay between economic interests, environmental concerns, and societal well-being in the pursuit of net-zero emissions.

Education and job creation are central pillars of the net-zero policy framework, reflecting a recognition of the importance of human capital development in driving sustainable development. The integration of sustainability principles into apprenticeship frameworks, as exemplified by the Sustainability Framework applied by the Institute for Apprenticeships and Technical Education (IfATE), demonstrates a commitment to fostering a skilled workforce equipped to tackle the challenges of climate change and environmental degradation. Moreover, the emphasis on job opportunities and energy efficiency in buildings and homes, as well as improved transportation, highlights the multifaceted nature of the transition to a net-zero economy. However, there is a notable absence of emphasis on transportation in the literature,

indicating a potential oversight in addressing a significant source of carbon emissions. While the installation of heat pumps and the purchase of electric vehicles are cited as important measures in achieving net-zero, there is a need for broader structural changes, such as the promotion of affordable and accessible public transportation, to effectively reduce emissions and ensure equitable access to sustainable mobility solutions.

Limitations

This study has evaluated the sustainability of the UK's net-zero policy framework. As mentioned before, there may have been significant subjectivity regarding the analysis of the literature found from the RLR. This means a more comprehensive analysis is needed in order to create more robust indicator definitions. Moreover, this study focused primarily on the UK. More evaluations should be conducted in other regions of the world. Especially as these indicators have been formulated from a universal application perspective meaning that results can vary depending on the national contexts. Finally, more research should be conducted to distinguish a difference between the timeframe of each indicator. For example, some indicators may need a longer time to implement than others.

Conclusion

In conclusion, this research emphasised the importance of having clear and comprehensive indicators to ensure a sustainable energy transition to achieve the net-zero targets. When applied to the UK's Net Zero Growth Plan, a total of seven out of sixteen indicators were found to be explicitly stated or mentioned. This shows that the UK government does not have a sustainable policy framework. There needs to be clearer statements indicating how public acceptability of renewable energy technologies will be implemented, more inclusion of the public in the decision-making processes and more focus and consideration on environmental indicators as a whole.

Bibliography

Aryanpur, V., Atabaki, M. S., Marzband, M., Siano, P., & Ghayoumi, K. (2019). An overview of energy planning in Iran and transition pathways towards sustainable electricity supply sector. *Renewable & Sustainable Energy Reviews*, *112*, 58–74. https://doi.org/10.1016/j.rser.2019.05.047

Bourton, I., Page, M., Higgins, J., Altman, D., Lundh, A., Hróbjartsson, A., & Cochrane Bias Methods Group. (2023). *Chapter 7: Considering bias and conflicts of interest among the included studies*. Cochrane Training. Retrieved March 10, 2024, from https://training.cochrane.org/handbook/current/chapter-07

Carrington, D. (2024, May 10). 'The stakes could not be higher': world is on edge of climate abyss, UN warns. *The Guardian*. https://www.theguardian.com/environment/article/2024/may/09/world-is-on-verge-of-climate-abyss-un-warns

Department of Energy Security and Net Zero. (2023). Powering Up Britain – the Net Zero Growth Plan. In *GOV.UK* (E02888048 03/23). https://assets.publishing.service.gov.uk/media/642556c560a35e000c0cb167/powering-up-britain-net-zero-growth-plan.pdf

Energy Transitions Commission. (2024, February 23). *Energy Transitions Commission | Achieving net-zero emissions by 2050*. Retrieved March 15, 2024, from https://www.energy-transitions.org/

Falcone, P. M., Lopolito, A., & Sica, E. (2019). Instrument mix for energy transition: A method for policy formulation. *Technological Forecasting and Social Change*, *148*, 119706. https://doi.org/10.1016/j.techfore.2019.07.012

Fankhauser, S., Smith, S. M., Allen, M., Axelsson, K., Hale, T., Hepburn, C., Kendall, J., Khosla, R., Lezaun, J., Mitchell-Larson, E., Obersteiner, M., Rajamani, L., Rickaby, R. E. M., Seddon, N., & Wetzer, T. (2021). The meaning of net zero and how to get it right. *Nature Climate Change*, *12*(1), 15–21. https://doi.org/10.1038/s41558-021-01245-w

Farmer, B. (2024, March 10). Coastal erosion: Expert says moving all cliff homes is unthinkable. *BBC News*. Retrieved May 10, 2024, from https://www.bbc.co.uk/news/uk-england-68487948

Ferrari, S., Zagarella, F., Caputo, P., & Bonomolo, M. (2019). Assessment of tools for urban energy planning. *Energy*, *176*, 544–551. https://doi.org/10.1016/j.energy.2019.04.054

Govindan, K. (2023). Pathways to low carbon energy transition through multi criteria assessment of offshore wind energy barriers. *Technological Forecasting & Social Change/Technological Forecasting and Social Change*, *187*, 122131. https://doi.org/10.1016/j.techfore.2022.122131

Hasund, K. P. (2005). Developing policy indicators of agri-environmental public goods. In *Institutionen För Ekonomi Working Paper* (2005:5). Ämnesgruppen för naturresurs- och miljöekonomi. https://pub.epsilon.slu.se/13287/7/hasund_k_p_160503.pdf

Ilskog, E. (2008). Rural electrification sustainability indicators : - Manual for field workers. *KTH Technology and Health*. http://kth.diva-portal.org/smash/get/diva2:25019/FULLTEXT01.pdf

KC, R., Föhr, J., & Ranta, T. (2022). Public perception on the sustainable energy transition in rural Finland: a multi-criteria approach. *Circular Economy and Sustainability/Circular Economy and Sustainability*, *3*(2), 735–755. https://doi.org/10.1007/s43615-022-00206-5

Khan, S. (2023). Chapter 16 - Carbon neutrality and sustainable development. In *Recent developments in green finance, green growth and carbon neutrality* (pp. 361–381). Elsevier. https://doi.org/10.1016/B978-0-443-15936-7.00018-9

Long, A., Mokhtar, M., Ahmed, M. F., & Lim, C. K. (2022). Enhancing sustainable development via low carbon energy transition approaches. *Journal of Cleaner Production*, *379*, 134678. https://doi.org/10.1016/j.jclepro.2022.134678

Masson-Delmotte, V., Zhai, P., Pörtner, H., Roberts, D., Skea, J., Priyadarshi, R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S. R., Matthews, J. R., Chen, Y., Zhou, X., Gomis, M., Lonnoy, E., Maycock, T., Tignor, M., & Waterfield, T. (2019, January 1). *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,sustainable development, and efforts to eradicate poverty* [Press release]. Retrieved March 20, 2024, from http://www.vliz.be/en/imis?module=ref&refid=323552

Poynting, M., & Stallard, E. (2024, April 25). How climate change worsens heatwaves, droughts, wildfires and floods. *BBC*. Retrieved May 10, 2024, from https://www.bbc.com/news/science-environment-58073295

Purvis, B., Mao, Y., & Robinson, D. (2018). Three pillars of sustainability: in search of conceptual origins. *Sustainability Science*, *14*(3), 681–695. https://doi.org/10.1007/s11625-018-0627-5

Rajagopal, D. (2023). Implications of the energy transition for government revenues, energy imports and employment: The case of electric vehicles in India. *Energy Policy*, *175*, 113466. https://doi.org/10.1016/j.enpol.2023.113466

Rodríguez-Segura, F. J., Osorio-Aravena, J. C., Фролова, M., Terrados-Cepeda, J., & Muñoz-Cerón, E. (2023). Social acceptance of renewable energy development in southern Spain: Exploring tendencies, locations, criteria and situations. *Energy Policy*, *173*, 113356. https://doi.org/10.1016/j.enpol.2022.113356

Rosenow, J., Kern, F., & Rogge, K. S. (2017). The need for comprehensive and well targeted instrument mixes to stimulate energy transitions: The case of energy efficiency policy. *Energy Research & Social Science*, *33*, 95–104. https://doi.org/10.1016/j.erss.2017.09.013

Sandin, S., Neij, L., & Mickwitz, P. (2019). Transition governance for energy efficiency - insights from a systematic review of Swedish policy evaluation practices. *Energy, Sustainability and Society*, *9*(1). https://doi.org/10.1186/s13705-019-0203-6

Smela, B., Toumi, M., Świerk, K., Francois, C., Biernikiewicz, M., Clay, E., & Boyer, L. (2023). Rapid literature review: definition and methodology. *Journal of Market Access & Health Policy*, *11*(1). https://doi.org/10.1080/20016689.2023.2241234

Spandagos, C., Reaños, M. a. T., & Lynch, M. Á. (2023). Energy poverty prediction and effective targeting for just transitions with machine learning. *Energy Economics*, *128*, 107131. https://doi.org/10.1016/j.eneco.2023.107131

Sutton, A., Clowes, M., Preston, L., & Booth, A. (2019). Meeting the review family: exploring review types and associated information retrieval requirements. *Health Information and Libraries Journal*, *36*(3), 202–222. https://doi.org/10.1111/hir.12276

The North Sea Transition deal. (n.d.). The North Sea Transition Deal. https://www.nstauthority.co.uk/the-move-to-net-zero/energy-integration/the-north-sea-transition-deal/

The Paris Agreement (By United Nations Framework Convention on Climate Change [UNFCCC]). (n.d.-a). United Nations Climate Change. Retrieved May 10, 2024, from https://unfccc.int/process-and-meetings/the-paris-agreement

The Paris Agreement (By United Nations [UN]). (n.d.-b). United Nations | Climate Action. Retrieved May 10, 2024, from https://www.un.org/en/climatechange/paris-agreement

United Nations Secretary-General. (2023). *The Acceleration Agenda: Roadmap for a Livable Planet 2040-2050*. https://www.un.org/sites/un2.un.org/files/un_sgs_acceleration_agenda.pdf

Vanegas-Cantarero, M. M., Pennock, S., Bloise-Thomaz, T., Jeffrey, H., & Dickson, M. J. (2022). Beyond LCOE: A multi-criteria evaluation framework for offshore renewable energy projects. *Renewable & Sustainable Energy Reviews*, *161*, 112307. https://doi.org/10.1016/j.rser.2022.112307

Wilson, M. G., Oliver, S., Meléndez‐Torres, G. J., Lavis, J. N., Waddell, K., & Dickson, K. (2021). Paper 3: Selecting rapid review methods for complex questions related to health policy and system issues. *Systematic Reviews*, *10*(1). https://doi.org/10.1186/s13643-021-01834-y

Yürek, Y. T., Özyörük, B., Özcan, E., & Bulut, M. (2023). Socio-political evaluation of renewable energy resources under uncertain environment. *Engineering Applications of Artificial Intelligence*, *126*, 106881. https://doi.org/10.1016/j.engappai.2023.106881