Renewable Energy Decentralisation in Nepal, India, and the United Kingdom

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COVID-19 Impact Statement:

The global outbreak of COVID-19 has significantly impacted the original scope and methodology of my research. Initially, the aim of my thesis was to investigate how transitions to domestic toilet-linked anaerobic digesters (TLADs) in rural Nepal and India emerge, why they often fail and how to foster them. The intended approach was primarily based on conducting face-to-face interviews with households in both countries and setting up a demonstration TLAD in Assam, India. The goal was to determine if a physical demonstration could influence people in renegotiating resistance, as was observed in Nepal. Additionally, I also planned to travel to Gujarat for household interviews with adopters of TLADs in India, providing a comprehensive comparison of how transitions to TLADs occurred within various Indian contexts. Furthermore, I intended to conduct a laboratory experiment in Stirling, aiming to assess the suitability of vermi-composting or black soldier fly as a slurry treatment method, and to determine if it was a product that people might pay for in Assam, encouraging adoption and use of TLADs and their products.

However, due to the disruption caused by COVID-19, my research plans were significantly altered. The travel constraints imposed by the pandemic necessitated an early return from Assam after completing only half of the intended interviews for use in Chapter 3. Moreover, the planned travel to Gujarat and the completion of the demonstration digester project in Assam were both prohibited due to the global travel restrictions that lasted over a year. I made the decision to abort my original plans early on as I believed even if travel restrictions were lifted it would not be ethical to travel, enter people's homes and conduct this research while the impacts of covid-19 were being felt around the world. Furthermore, the intended laboratory experiment in Stirling was also affected as the laboratories were closed for an extended period.

In light of these challenges, the research focus was pivoted, and Chapters 4 and 5 of my thesis are the outcomes of this shift. Chapter 4 persisted with the investigation of domestic biogas, albeit via online expert stakeholder interviews with stakeholders from Nepal and India's biogas programmes. The insights from Chapters 2 and 3 highlighted the impact of higher-level biogas programme factors on socio-cultural resistance affecting the adoption of domestic biogas, a theme I sought to explore further. I also engaged with academics who had previously researched domestic biogas in Assam, and their data sets were utilised to supplement my understanding of the biogas context in Assam in Chapter 3.

To further adapt to the situation, I secured additional funding from the Scottish Alliance for Geoscience, Environment and Society (SAGES). This funding amounted to £2000, and was specifically designed to help students mitigate the impact of Covid-19 by helping them conduct additional UK based research. As a result, Chapter 5 was reframed to focus on the UK context. The energy crisis in the UK offered an opportunity to investigate pertinent and impactful aspects of the UK's transition to decentralised renewable energy. Although the UK work was not part of the initial research scope, this new direction provided an opportunity to explore broader questions surrounding

decentralised RE transitions. These adaptations reflect the resilience and adaptability necessitated by the unprecedented challenges of the pandemic and have added an unexpected, but valuable, dimension to the research.

Statement of Originality

I hereby confirm that this dissertation is an original piece of work conducted independently by the undersigned, and all work contained herein has not been submitted for any other degree. All research material has been duly acknowledged and cited.

Signature of Candidate:

Natalie Boyd Williams

Date: 30th July 2023

Abstract

The decentralised nature of many renewable energy (RE) technologies opens up opportunities for greater citizen involvement in energy governance. It also allows for fairer profit sharing in energy transitions compared to fossil fuels. However, a RE transition is hindered by the firmly established fossil fuel structures, centralised governance, and regulatory processes within existing energy systems. RE transitions necessitate a significant reconfiguration of existing systems. Moreover, being geographical processes influenced by place, space, and scale, they exhibit unique and context-dependent characteristics. To successfully foster decentralised RE transitions, it is crucial to better comprehend the impact of spatial and scalar variations on these transitions. This thesis aims to explore how decentralised RE transitions emerge in different contexts and to better understand why they sometimes fail or do not realise their full potential. Additionally, it seeks to understand how to foster equitable decentralised RE transitions and the social changes required to ensure their success. The two case studies in this thesis, one focusing on transitions to domestic biogas in Nepal and India, and another on RE transitions in the United Kingdom, allow us to examine diverse, and context specific RE transitions.

The central focus of the thesis is to investigate the varied success of long-term domestic biogas programmes in rural Nepal and India, aiming to understand differences in outcomes within seemingly comparable contexts. Domestic biogas digesters convert organic household wastes, mainly animal dung, into a gaseous cooking fuel and a plant fertiliser. In addition, the integration of a household toilet to form a toilet-linked anaerobic digester (TLAD) can improve a household's sanitation facilities. Domestic biogas is considered a rural sustainability solution, particularly in low and middle-income contexts. However, the practical implementation of domestic biogas has achieved limited success. Despite awareness of the recurring challenges in implementing domestic biogas, failures are common. The reasons why biogas, and particularly TLADs, succeeds in one place but not another, even within similar contexts or under the same programme, remains unclear. Socio-cultural resistance is often broadly used to explain local opposition to TLADs and explain their recurrent implementation failures. However, current research inadequately explores what socio-cultural resistance is and why it is sometimes renegotiated upon TLAD adoption.

The first objective aims to improve understanding of local socio-cultural resistance towards TLADs and to evaluate its influence on TLAD adoption. Despite similar socio-cultural barriers opposing human excreta as a biogas feedstock in both regions, Nepal has seen much higher acceptance of TLADs. In-depth semi-structured interviews conducted with TLAD users in Nepal's Province 4 and non-adopters in Assam, India, reveal that socio-cultural resistance is multidimensional and related to an individual's place, personal and social identity. Resistance to TLADs results from both socio-cultural as well as socio-technical concerns and is also sometimes negotiable. Adoption of TLADs is contingent upon an individual's perceptions of the benefits

TLADs would offer them. Adoption can be facilitated through technology demonstrations and group adoption so they become a social norm. Identifying and targeting households with suitable needs and motivations is crucial for TLADs adoption. Without perceived necessity, individuals are less likely to overcome socio-cultural resistance. The findings also imply that socio-cultural resistance of potential users may also signal broader programmatic failures in implementation.

The second objective therefore focuses on identifying the reasons behind the success or failure of domestic biogas programmes in Nepal and India, particularly related to TLAD implementation. This objective also aims to comprehend the multi-scalar and spatial factors influencing programme success more broadly. In-depth semi-structured interviews with biogas expert stakeholders along with a comprehensive literature review suggest that local socio-cultural resistance as well as other commonly cited high-level challenges, such as technical failures and competition from alternative solutions, are in fact symptoms of higher-up systematic issues previously overlooked. These include poor management of the biogas programme, unfitting governance structures and poorly crafted multi-sector policies.

The secondary focus of this thesis was to explore the UK's shift towards RE for electricity generation. Despite historical public support for a RE transition, the recent gas price-induced energy crisis has resulted in increased government and public backing for domestic natural gas. The study examines the public's understanding of the gas price's impact on electricity cost, and its effect on their opinion on the UK's energy transition and their voting behaviour. An online survey of 999 UK respondents suggests the majority of the general public may possess moderate to weak energy literacy, with equal support for increased use of RE and domestic gas for electricity generation. Higher energy literacy was linked with stronger RE support, indicating that enhancing literacy could spur broader public support for an RE transition. The energy crisis may have also increased public acceptance of RE technologies in the UK landscape, with locally-owned energy also perceived as a potential solution creating potential opportunity for decentralised RE. However, despite acknowledging the importance of energy policies, many respondents felt they lacked adequate knowledge to inform their votes or prioritised other policies when voting. Thus, increased public energy literacy and political engagement are critical for facilitating the transition towards a more sustainable, decentralised energy landscape in the UK.

Each chapter of this thesis provides valuable insights into transitions towards decentralised RE in specific geographical contexts. Collectively, the thesis chapters highlight broader, globalised challenges facing successful transitions to decentralised RE. The thesis finds that the global energy regime's techno-centric and centralised approach to energy governance is a major barrier to decentralised RE transitions in Nepal, India and the UK. Such an approach results in policies that overlook cultural and regional diversities and needs, constrain democratic participation, and treat energy transitions as mere technological solutions, thereby marginalising societal aspects and often misinterpreting them as barriers rather than inherent aspects of an energy transition. The thesis

emphasises the need when researching energy transitions to integrate public decision-making within the broader multi-scalar and multi-sector context of a transition to avoid misattributing transition failures to public groups and overlooking more systematic barriers. The research findings underscore the necessity of regulatory frameworks that better support decentralised RE transitions and can adapt to localised contexts. Without such improvements, decentralised RE transitions will only succeed sporadically, only where central and standardised policies happen to fit local contexts. These insights highlight the importance of improving global energy governance to better support decentralised RE solutions. Without a more supportive dominant energy regime for decentralised RE transitions, overall progress will be limited.

Acknowledgements

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Special thanks to Professor Debendra C Baruah and Tezpur University for hosting me and providing assistance and supervision during my fieldwork in Assam. Thank you to Dr Debadayita Raha for generously speaking with me in depth about my research and for sharing your data with me. I am also thankful to Trinakshee Sarmah for generously taking care of me during my stay in Assam. A huge thank you to the amazing fieldwork assistants: Roshni Ghatani, Rahul Sarma, Charmi Haque, Tonaya Borah, Gouranga Nath, and Sudarshana Hazarika. I am most grateful to the research participants who agreed to take part in the interviews and surveys. Additionally, I want to express my gratitude to the families that welcomed me into their homes during fieldwork; their hospitality was profound. I am thankful to Scott and Lynn for supporting various aspects of my PhD at the University of Stirling. The research community at the University of Stirling and the fellow PhD students I met along the way, who made the experience so fun and special.

I would also like to acknowledge that the PhD process has its ups and downs, but it is a privilege to be able to complete one. I am thankful for all the circumstances that have allowed me to do so. A special thank you goes to my family for their support and encouragement. Lastly, I want to express my deepest gratitude to my husband, Mortimer. Honestly, without you, none of this would have been possible. We make a great team. To everyone who has supported me, thank you.

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List of Acronyms

Acronym	Full text
AEPC	Alternative Energy Promotion Centre (Nepal)
BSP	Biogas Support Program (Nepal)
CRE	Community-owned renewable energy (United Kingdom)
DFAD	(domestic) Dung-fed Anaerobic Digester
FiT	Feed-in-Tariff (United Kingdom)
GoI	Government of India
GoN	Government of Nepal
HE	Human Excreta
LPG	Liquid Petroleum Gas
MNRE	Ministry of New and Renewable Energy (India)
NNBOMP	New National Biogas and Manure Programme (India)
OD	Open Defecation
RE	Renewable Energy
RETs	Renewable Energy Technologies
SBM	Swachh Bharat Mission (India)
SNV	Netherlands Development Organisation
TLAD	(domestic) Toilet-linked Anaerobic Digester
UK	United Kingdom

Chapter 1: General Introduction

1.1 Global energy systems: governance and privatisation

Arising from the pressing concerns of climate change, global energy poverty, and the limited success of existing energy systems in delivering stable and affordable energy to all, a renewable, sustainable, and more democratic global energy transition is needed. As technologies are intertwined with social practices, cultures, and institutions (Campos and Marín-gonzález, 2020), this transition necessitates not only new technologies but also a reimagining of dominant systems thinking, alongside new governance and accountability mechanisms to support such a shift (Lammers and Diestelmeier, 2017; Brisbois, 2020). Current energy governance approaches have predominantly co-evolved with fossil fuels, focusing on large-scale infrastructures that produce power that flows to consumers through centralised control (Brisbois, 2020). While industrialised countries primarily rely on centralised grids to supply electricity and gas, lower-income countries often use a combination of grids and supply chains for accessing bottled households fuels such as Liquid Petroleum Gas (LPG) and kerosene. Energy, for many people that have access to fossil fuels, is a commodity to be purchased, not generated, governed, and personally consumed. There is limited opportunity to become a fossil fuel prosumer (i.e. those who both produce and consume energy), because fossil fuels are often geographically concentrated in hard to reach places and require complex processes and machinery to extract, process and transport.

In hand with centralised systems thinking, privatisation has also become the status quo in energy supply and governance. While the private sector is often seen as a solution to the energy trilemma, driving innovation and empowering individuals when governments fall short (Falchetta *et al.*, 2022), it has also concentrated profits among a small elite (Guan *et al.*, 2023; Maximov, Drummond and Mcnally, 2023). The widespread belief that large-scale deployment and market forces will reduce prices and increase affordability has led to the promotion of energy privatisation around the world. For example, in order to borrow money from institutions such as the World Bank, it was made a loan stipulation that low-income countries must undergo economic reforms and open up many of their industries, such as water and energy, to global markets in order to be granted the loans (Jakupec, 2018). However, energy privatisation has not achieved many of its intended goals. Even with government intervention through price caps and subsidies, energy remains unaffordable for many (Guan *et al.*, 2023). Recent events have exposed the fragility of these markets, particularly in relation to natural gas pricing and availability, with the rising gas price in 2022 and 2023 pushing many households into, or further into, energy poverty all over the world (Zakeri, Paulavets, *et al.*, 2022). This could be because market forces, which have driven successful transitions in the past, may not effectively deliver sustainable energy transitions. Sustainability focusses on the collective good, and recognise the planet's finite resources, a philosophy that contradicts the goals of capital markets (Schoenmaker and Stegeman, 2022).

Renewable energy (RE) has the unique advantage of often not being located in geographically concentrated in hard-to-reach regions like fossil fuels. This decentralised nature opens up opportunities for actors, such as individuals, cooperatives, small companies or local communities, to invest and benefit from RE development as well as large private or state-backed companies (Szulecki, 2018). Historically, large-scale energy transitions have had far-reaching implications on society (Mitchell, 2012; Schot and Kanger, 2018). For instance, the discovery of coal and subsequent inventions enabling large-scale extraction and use led to the Industrial Revolution, which catalysed the rise of democracy in Europe. The shift from farm-based subsistence living to the work forces of industrialisation led to the growth of labour unions and local governments. However, it also resulted in global inequality that still persists today as Europe compelled other nations, through slavery and colonialism, to work on the production of industrial goods such as cotton and sugar. The shift to oil and gas, among other factors, led to centralised energy governance and the concentration of wealth and power through private markets. Unlike coal, oil occurs in liquid form and the work of transporting energy could be undertaken by a small elite and thus the power of organised labour forces diminished and control through capitalism took off (Mitchell, 2012). With RE, more global citizens have the opportunity to participate in the energy transition, moving from passive consumers to active stakeholders and decision makers. Prosumers of RE have some level of ownership, which has proven to increase their willingness to better engage in important tenets of an energy transitions such as reduced energy consumption and adapting to use energy when it is in peak supply (Keirstead, 2007; Roth *et al.*, 2018). A comparison of energy governance and supply models from fuel wood, to coal, to oil and to renewables is illustrated in Figure 1.1.

However, progress to a RE transition, particularly decentralisation, has been slow due to the deep-rooted dependence of almost all socio-technical systems, spanning mobility, food, housing, and more, on fossil fuels (Schot and Kanger, 2018). This transition is hindered by the firmly established fossil fuel structures, governance, and regulatory processes within these systems. Established regimes, which pertain to the institutional structuring of the socio-technical system, reinforce dependencies on fossil fuels, making change challenging (Miörner, Heiberg and Binz, 2022). Overcoming these regimes, a necessity for a successful RE transition, is not simple due to resistance from institutions and actors invested in the fossil fuel industry (Mitchell, 2012). Complications also arise from decades-long reliance on fossil fuel subsidies and the challenges posed by their removal (Mcculloch, 2023). Removing them can result in reduced support for, and even animosity towards, a political party (Mcculloch, 2023).

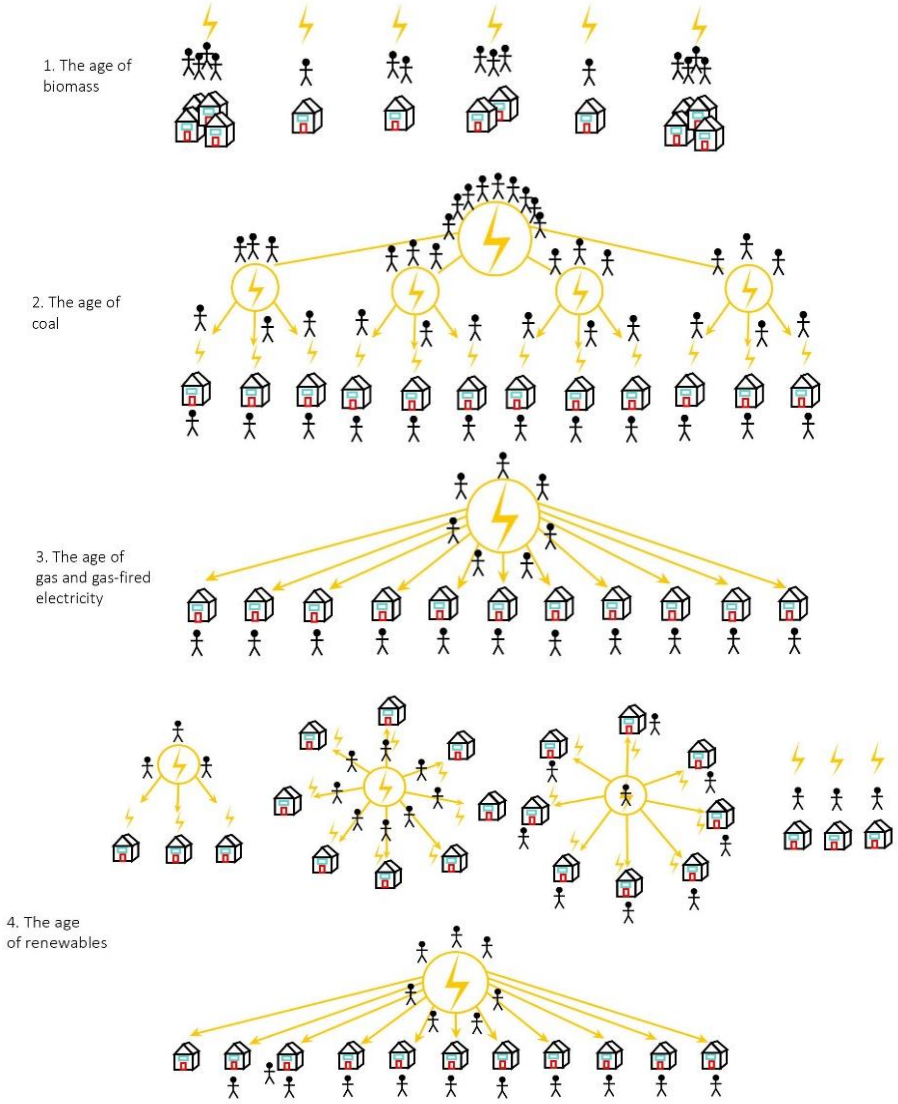

Figure 1.1: *Illustrative interpretation of the different energy governance structures and concentration of actors involved in energy production methods: 1) Biomass - prior to the wide-scale discovery and use of coal, people collected or grew their own wood fuel. This phase was characterised by the involvement of many actors in the processes of collection, generation, and use of energy 2) Coal - with its widespread use in Europe, the majority of people transitioned to become energy consumers, thereby reducing the number of individuals involved in energy extraction, generation, and distribution 3) Oil and Natural Gas - as energy systems in Europe shifted to natural gas and oil, the number of actors involved in the extraction, generation, and distribution processes shrank dramatically. Power became concentrated within a few entities, leading to increased centralisation and privatisation of energy systems 4) Renewables - in transitioning to renewable energy, while it is possible to replicate the centralised and privatised model of natural gas, a multitude of options emerge for energy extraction, generation, and usage. These alternatives pave the way for tailored energy governance that can cater to local contexts and needs.*

While renewable energy technologies (RETs) offer diverse governance and ownership opportunities, they are often integrated into existing centralised and privatised system models (Stirling, 2019; Montalvo, 2022). Regulatory processes around energy governance, having co-evolved with fossil

fuels, favour centralisation and privatisation, presenting significant challenges to change that can impede the growth of decentralised systems (Lammers and Diestelmeier, 2017; Brisbois, 2020). RETs have been blamed for unaffordable energy and opposition to publicly funded RE transitions have arisen (Atkins, 2022). Additionally, many decentralised energy solutions have experienced limited success, and or have required many subsidies to succeed, challenging the idea that they are a viable solution. These arguments overlook the fact that decentralised solutions are trying to flourish in an unsupportive regulatory environment and regime destabilisation is difficult (Schot and Kanger, 2018; Brisbois, 2020). Understanding the challenges faced by decentralised solutions and the protection that centralised and privatised systems, despite their weaknesses, are receiving is crucial for transitioning to more sustainable and equitable energy systems.

Sustainability transitions, including RE transitions, are inherently geographical processes – they occur in specific locations and at varying scales, from households to continents. Over the past two decades, the pressing need for sustainable transitions has sparked a surge of academic interest, primarily focused on identifying the key facilitators, challenges, and understanding how they unfold in various spaces (Hansen and Coenen, 2015). A growing body of research highlights the significance of contextual factors, including political climate, culture, and the interplay of formal and informal actors that either enable the emergence of new technologies, governance structures, and social orders, or not. Socio-technical regimes display substantial spatial variability. For instance, the United Kingdom (UK) has an energy regime that is firmly institutionalised, characterised by large-scale, centralised infrastructure and governance. Conversely, in contexts like rural Nepal and India, the energy regime combines centralised solutions like wide-scale electrification with deeply rooted decentralised multi-fuel household practices, such as collecting firewood and small-scale LPG or kerosene purchasing.

Socio-technical regimes display spatial variation within each country, especially noticeable in Nepal and India with their extensive decentralisation of energy and high regional diversity (Pandey and Chaubal, 2011; Kumar, Pols and Höffken, 2021; Bharadwaj *et al.*, 2022). The national energy regime contrasts with regional or village-level regimes, each marked by unique path dependencies, actor networks, and governance structures. These variances within an energy regime, influenced by scale, significantly affect RE transitions. Therefore, there is a need for research that explores why transitions occur in certain places, and the role of spatial and scalar variations in energy transitions (Hansen and Coenen, 2015).

As climate change becomes widely accepted as a growing crisis, calls for a faster RE transition are growing (Kumar, Pols and Höffken, 2021). Confounding this urgency is the fact that globally, increasingly more households are unable to secure access to affordable energy, and many still have never had the opportunity to do so. Despite discourses centred around urgency and emergency, the 2023 energy crisis, caused by global gas market instability, saw many governments resort to fossil fuel solutions due to their established infrastructure, supply chains, governance and markets (Zakeri, Paulavets, *et al.*, 2022). Ironically, these entrenched energy systems, despite

contributing to price instability and the climate crisis, remain the go-to options in response to crises. Despite the potential of decentralised RE in reducing carbon emissions and improving energy affordability, the pace and competency of such a transition remains uncertain due to its inherent challenges. We run the risk of either reverting to fossil fuel solutions, burdening households with future climate and economic crises, or hastily deploying decentralised solutions without a comprehensive understanding of how to ensure their success (Falchetta *et al.*, 2022; Guan *et al.*, 2023). Attaining a better understanding into the emergence and success of decentralised RE solutions across various contexts is crucial. This enhanced understanding can help foster more sustainable and inclusive energy transitions, designed to meet local needs and adapt to environmental constraints.

1.2 Ontology and Epistemology

This thesis adopts a constructivist ontology assuming that reality is constructed subjectively through individual reasoning (Ritchie *et al.*, 2014; Shannon-Baker, 2023). This approach assumes that individuals actively construct their realities, leading to multiple, co-existing realities rather than one absolute. Contrasting with positivist ontology which assumes there is an absolute truth independent of human knowledge, constructivism delves into personal perceptions and interpretations. Energy transitions are shaped by socio-technical systems, regional dependencies, and individual decision-making. The strength of a constructivist approach lies in its ability to deeply explore diverse and subjective experiences of energy transitions across different geographical and socio-cultural contexts. This is crucial for understanding the nuances of how and why energy transitions occur in specific locations. However, it's important to note the limitations including challenges in generalisability and potential researcher bias when interpreting and analysing data. Despite these limitations, a constructivist approach offers insights into the complexities of individual and contextual experiences, which a positivist approach might obscure.

This thesis adopts a hybrid epistemological approach that combines constructivism and critical theory perspectives. Within this framework, constructivism assumes that individuals create their own understanding of the world and knowledge of this can be collected and made sense of through qualitative research methods. This approach emphasises the interactive process of knowledge creation, where both the researcher and the participant contribute to and shape the understanding (Shannon-Baker, 2023). This contrasts with positivist epistemology, which views knowledge as stemming from an objective reality that exists independently of human perceptions. By integrating constructivism and critical theory approaches, this thesis seeks to achieve a comprehensive understanding of the subject. Constructivism provides insights into the personal and subjective ways individuals construct knowledge and interpret their experiences, while critical theory adds a layer of analysis on the broader social structures and power dynamics that influence these constructions. This combination allows for a rich, multi-faceted view, merging the deeply personal and constructed experiences of individuals with an understanding of how societal factors and power relationships shape these experiences. While this epistemological approach offers a more nuanced

and subjective depth compared to the objective focus of positivism, it also poses challenges in terms of generalisability and ensuring methodological consistency.

This overall methodology provides a strong framework for examining the complex nature of energy transitions. It effectively addresses both the individual, personally constructed dimensions and the broader systemic aspects emphasised in the initial discussion in Section 1.1.

1.3 Research Design

1.3.1 Aims of thesis

This research ultimately seeks to enrich the expanding body of knowledge in the field of geography of energy transitions. The thesis aims to better understand how decentralised RE transitions can emerge in various contexts and why they fail or do not realise their full potential. The overarching aim is to explore how multi-scalar factors as well as differences in place and space can shape a RE energy transition.

Given the need for a thorough and context-sensitive exploration, an approach that facilitates in-depth investigation into specific local contexts and decision-making processes was imperative. A case study methodology was selected and subsequently the thesis investigates three distinct case studies: the adoption of a decentralised RE technology in Nepal and India, in contrast to a national RE transition in the centralised, privatised energy landscape in the UK. The primary aim is to dissect the complexities and challenges inherent in the deployment of decentralised solutions and to critically assess how different contexts shape the trajectory of RE transitions. Consequently, the objectives of this thesis are centred on a detailed examination of energy transitions within these three case studies. The rationale behind the selection of the case studies will be explained in Section 1.4.

1.3.2 Methodological approach – case studies

The research design of this thesis is tailored to explore how RE transitions emerge in different geographies. The methodological choice intentionally diverges from the pursuit of broad, generalisable hypotheses, favouring instead an exploration into the specificities of different contexts. By adopting this approach, the thesis aims to provide a richer, more detailed understanding of the nuances that characterise RE transitions in different contexts.

Case studies are widely recognised for their suitability in exploratory research (Yin, 2009). They are well-suited to exploring the complex, multifaceted nature of phenomena as they unfold in real-life settings. As such they are a common methodological approach used to explore decentralised energy transitions through examining local social phenomena, behavioural patterns, and interactions with technology (Warren and McFadyen, 2010; Wilson and Dyke, 2016; Akintan, Jewitt and Clifford, 2018; Jewitt, Atagher and Clifford, 2019; Kumar *et al.*, 2019; Yadav, Malakar and Davies, 2019). A case study methodology was selected due to its alignment with a constructivist ontology, which assumes that reality is subjectively constructed by individuals based on their experiences and

interactions, and its ability to help fill the research gaps pertaining to better understanding of energy transitions in specific contexts.

While acknowledging the limited scope and generalisability of case studies, these aspects were not the primary focus of this research (Yin, 2009). The case study approach, chosen for its ability to focus on diversity, yields insights that are not directly generalisable but are crucial for improving our understanding of decentralised RE transitions more generally on a sector-wide level (Hansen and Coenen, 2015). This approach enables the development of more effective strategies for RE transitions globally. The necessity for in-depth, context-specific exploration over broad generalisations made case studies the most appropriate methodology for this research.

1.3.3 Case study background and selection

This section provides a rationale for selecting Nepal, India, and the UK as case study locations. Initially, I will introduce domestic toilet-linked anaerobic digester (TLAD) technology, review the existing literature on transitions to TLADs, and identify research gaps. This overview sets the stage for explaining the choice of Nepal and India as case study countries, highlighting their relevance in the context of TLAD technology adoption. Subsequently, I will briefly explore the UK's energy landscape, focusing on the recent energy crisis, to demonstrate why the UK presents an intriguing context for studying decentralised RE transitions.

1.3.3.1 Case studies 1 and 2 – household transitions to toilet-linked anaerobic digesters in Nepal and India

1.3.3.1.1 Domestic toilet-linked anaerobic digesters: technology and function

Biogas is a renewable, gaseous fuel generated during the decomposition of organic materials in the absence of oxygen through a process called anaerobic digestion (Cheng, Li, Mang, Huba, *et al.*, 2014; Garfí *et al.*, 2016; Bharathiraja *et al.*, 2018). Domestic biogas, generated from common household waste streams such as animal dung, mainly cow or pig dung, along with food waste, agricultural waste, and in some cases, HE, is considered to be a clean cooking alternative for some rural populations, predominantly in the low and middle-income contexts (Shakya, 2002; Bond and Templeton, 2011; Ortiz, Terrapon-Pfaff and Dienst, 2017a). Biogas can replace or reduce the use of polluting fuels for cooking such as wood, crop wastes and dung in open fires and inefficient stoves, which are estimated to be used by 2.6 billion people globally, predominantly in low and middle-income countries (Bond and Templeton, 2011). These fuels and practices can lead to high levels of indoor air pollution, which is estimated to cause up to four million premature deaths from associated illnesses (The World Health Organisation, 2020).

In addition to biogas, domestic anaerobic digesters also produce a liquid by-product called slurry that can be used as a plant fertiliser. The process of anaerobic digestion converts the nutrients in the feedstock into a form more readily available to plants (Alburquerque *et al.*, 2012). When a household toilet is connected households can benefit from an improved sanitation system and

increased biogas production (Bajgain and Shakya, 2005; Cheng *et al.*, 2011; Alburquerque *et al.*, 2012; WHO and UNICEF, 2017). Inadequate sanitation is estimated to cause 432,000 diarrhoeal-related deaths annually and is linked to the transmission of many water-borne and bacterial diseases such as cholera, hepatitis A, typhoid and polio (World Health Organisation, 2019). Many countries across Asia, Africa and Latin America have implemented national household biogas programmes over the last fifty years (Bond and Templeton, 2011; Ghimire, 2013).

A typical set up of a cement fixed-dome anaerobic digester, common across China, Nepal and India (Bajgain and Shakya, 2005; Bond and Templeton, 2011; Raha, Mahanta and Clarke, 2014; Bharathiraja *et al.*, 2018) is illustrated in Figure 1.2.

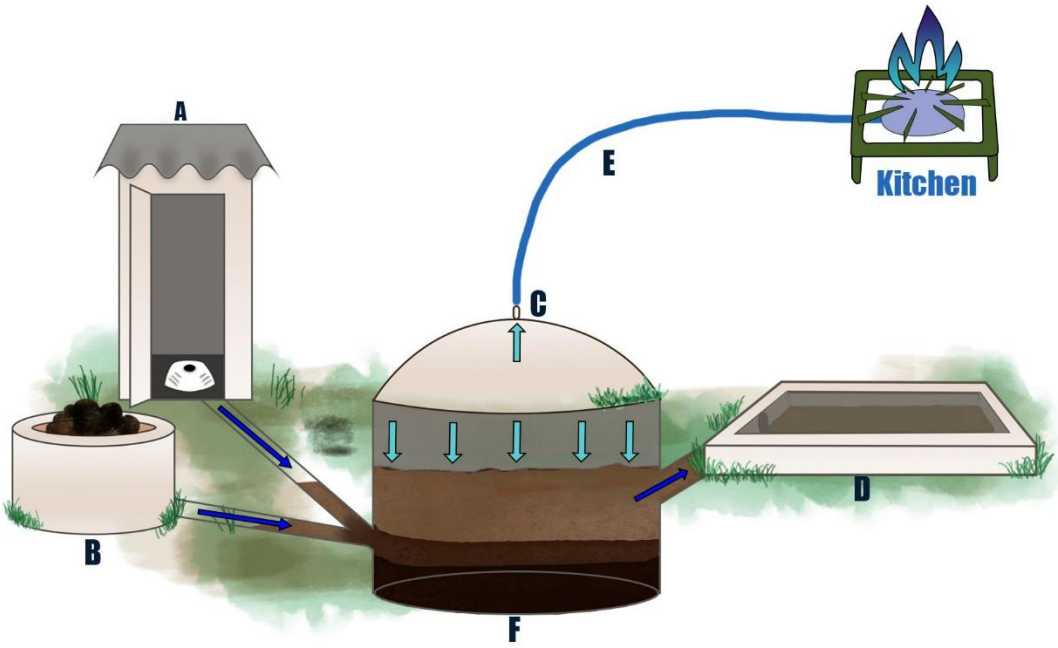

Figure 1.2: *Illustrated schematic of a fixed-dome toilet-linked anaerobic digester (TLAD). Illustrated schematic of a fixed-dome toilet-linked anaerobic digester (TLAD). Dark blue arrows depict the flow of feedstock and the light blue arrows, show the flow of biogas. The feedstocks from A) the toilet and B) the cow/animal dung and other organic waste inlet flows into the digester (F) after mixing with water. As the organic waste decomposes biogas builds up inside the digester and flows through a pipe (E) directly to the kitchen stove via a pressure gradient. The production of biogas increases the pressure inside the fixed dome structure (C) and forces the by-product of the process (a nutrient rich, and predominantly liquid product called slurry that can be used as a plant fertiliser) out and into the slurry storage area (D). Typically, the biogas dome (C) is all that can be seen above ground, though in some cases both (F) and (C) are buried underground. Published in* (Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022)

1.3.3.1.2 Challenges to successful implementation and adoption of domestic biogas technology

TLADs are typically part of broader biogas programs that also promote dung-fed anaerobic digesters (DFADs), i.e., domestic biogas systems without toilet connections, fed with animal dung and

sometimes agricultural and food waste. Successful adoption of TLADs must then be considered under the umbrella of the efficacy of these broader programmes.

Contrary to the benefits domestic anaerobic digesters, with and without toilet connections, can provide, their dissemination has not been universally successful. Data reveals that post installation functionality rates can be extremely low and there are many instances where biogas digesters have been completely abandoned due to technical failure and opposing socio-cultural norms (Zuzhang, 2013; Ortiz, Terrapon-Pfaff and Dienst, 2017b). Many national and aid funded programmes have failed (Chen *et al.*, 2010; Kalina, Ogwang and Tilley, 2022). This failure has led to many investigations and subsequently the challenges facing domestic biogas have been understood for many decades and are summarised in Table 1.1. Despite comprehensive understanding of the challenges facing successful implementation and adoption, many programmes have continued to fail because of these challenges many times over (Chen *et al.*, 2010; Ortiz, Terrapon-Pfaff and Dienst, 2017b; Mittal, Ahlgren and Shukla, 2018; Kalina, Ogwang and Tilley, 2022). An identification of challenges has not led to widespread improved programmes or approaches. Subsequently, research is still unable to confidently answer why biogas succeeds in one place but fails in another, even within the same, or similar, programme and context.

Table 1.1: *Barriers to successful domestic biogas programmes, acceptance and uptake*

Barrier group	Details	References
Financial/ economical	• Investment required is too high • Delays in receiving financial support and difficulty in accessing credit/financial support • Subsidies for users are too high and users do not see value in systems and abandon them • Users cannot take them with them if they move (not attractive for renters)	(Jian, 2009; Arthur, Baidoo and Antwi, 2011; Raha, Mahanta and Clarke, 2014; Bonten *et al.*, 2014; Cheng, Li, Mang, Neupane, *et al.*, 2014; Martí-Herrero *et al.*, 2014, 2015; Rupf *et al.*, 2015; Sovacool, Kryman and Smith, 2015; Garfí *et al.*, 2016; Khan and Martin, 2016; Amuzu-Sefordzi *et al.*, 2018; Mittal, Ahlgren and
Market	• Lack of market competition for initial construction and repairs • Market competition from other energy sources • Lack of private involvement • Lack of market to sell spare feedstock and digestate fertiliser products	
Socio-cultural/ behavioural	• **Resistance to using human or animal excreta as a source of energy** • Gender division • Lack of social acceptance and interest in the technology • It is cultural to cook certain dishes on traditional wood fuels • Social elites involved in dissemination and people outside of their group are denied access to domestic biogas • Food tastes better cooked on firewood • Collecting firewood is a social activity • Higher social status gained from using LPG over biogas	
Regulatory	• Lack of follow up services provided • There isn't good enough local support available/ spare parts available (lack of maintenance services) • Fewer biogas digester dissemination programmes than other initiatives • Lack of political and infrastructural support	

Technical and Infrastructural	• Inadequate supply of feedstock (animal/ agricultural) and so biogas digesters underperform • Inadequate water availability • Biogas flame is not as big or hot as other fuels and cooking is slow • Do not perform well in cold weather - gas supply inconsistent • Difficult to fix • Not enough labour to manage the biogas system • Biogas can't fulfil other roles (heating the home) • Poor technically reliability • Gas production/ leakage problems • Some village locations are hard to access (mountainous, poor roads) which makes installation and repairs difficult • Not enough labour to manage livestock • Slurry is difficult to transport and use in its liquid form	Shukla, 2018; Nape *et al.*, 2019; Nevzorova and Kutcherov, 2019; Sovacool and Griffiths, 2020)
Information/ Knowledge	• Users have inadequate knowledge, information/ agency to run the biogas digesters • Lack of education and information on the benefits of biogas available to users • Users unaware that follow up services are agreed to be provided and government subsidies are available for maintenance • Long term health benefits of switching to gas fuel not valued • Safety concerns with biogas/ digestate • User's perceive nothing wrong with cooking with wood	

1.3.3.1.3 Literature gap: why do TLADs succeed in one place but fail in another, even within the same, or similar, programme or context

The widespread adoption of TLADs has been notably successful in countries like China, Vietnam, and Nepal, often linked to favourable socio-cultural practices or effective promotion of toilet connections (Bajgain and Shakya, 2005; Cheng *et al.*, 2011; Huong *et al.*, 2014). In contrast, many other regions report socio-cultural resistance to using HE as biogas feedstock as a key barrier to adoption (Arthur, Baidoo and Antwi, 2011; Raha, Mahanta and Clarke, 2014; Muralidharan, 2017; Amuzu-Sefordzi *et al.*, 2018; Mittal, Ahlgren and Shukla, 2018).

Considerable research exists on the challenges facing domestic biogas in general as shown in Table 1.1. Most frequently the headline barrier to adoption specifically of TLADs is socio-cultural resistance. However, academic literature generally has not distinguished TLADs as a wholly separate technology from DFADs. This overlooks the transformative role of the toilet-connection that turns TLADs into a sanitation solution in addition to an energy and agricultural technology. Specialised promotional strategies and expertise are needed for marketing sanitation technologies that utilise HE (Jewitt, 2011; Moya, Sakrabani and Parker, 2019; Leong and Lebel, 2020). However, many studies simply attribute TLADs' challenges to socio-cultural resistance without deeply analysing or critiquing the programme's approach to marketing a sanitation technology. Consequently, the literature tends to oversimplify and overstate the unique challenges associated with the toilet integration, especially in terms of localised socio-cultural resistance.

1.3.3.1.4 Summary of knowledge gaps

A number of research gaps around socio-cultural resistance towards TLADs have been identified.

Firstly, understandings of socio-cultural resistance, which is likely diverse, remain extremely limited. More research is needed to unpack how diverse socio-cultural resistance is and how it varies spatially and temporally. Studies have yet to fully explore why similar socio-cultural norms lead to rejection of TLADs in some contexts but can be renegotiated in others (Zurbrügg, Voegeli and Estoppey, 2011; Raha, Mahanta and Clarke, 2014; Mittal, Ahlgren and Shukla, 2018; Dumont, Hildebrandt and Sempuga, 2021).

Secondly, a key gap exists in understanding how socio-cultural resistance influences TLAD adoption compared to other multi-scalar programme inefficiencies at the international, national and local levels. The current focus on user decision-making overlooks critical higher-level factors such as programme governance, actor commitment to promoting toilet connections, and the integration of sanitation marketing and policy design. These elements play a substantial role in determining the impact of socio-cultural resistance as a barrier to adoption. As Table 1.1 shows, the numerous challenges in disseminating domestic biogas imply that solely attributing TLAD rejection to socio-cultural resistance simplifies a multifaceted issue. Targeted research specifically on TLADs is essential to discern the relative impact of socio-cultural resistance alongside other influencing factors. Considering domestic biogas implementation intersects multiple sectors —energy, agriculture, sanitation, and waste management—it involves several socio-technical systems. Nevertheless, current research on domestic biogas overlooks how coordination among these diverse socio-technical regimes can also impacts programme outcomes (Gustafsson and Anderberg, 2021).

Thirdly, socio-cultural norms also likely impact how TLADs and their products are used. However, the influence of socio-cultural norms on biogas programme outcomes beyond adoption success or failure is also poorly understood. Crucially, there is a notable absence of understanding into the local-level transition pathways to TLADs and strategies for encouraging household transitions at higher programme levels. Addressing these research gaps is critical for a more comprehensive understanding of TLAD adoption and why it sometime succeeds and sometimes does not.

In summary, research must deepen its exploration of how local socio-cultural norms influence the adoption of TLADs, framed within broader contextual factors that are shaping decision making and overall programme efficacy. This involves an emphasis on how multi-scalar interactions, i.e., between the global, regional, and local, interact across multi-sectors, such as energy, agriculture, and sanitation regimes.

1.3.3.1.5 Selection of Nepal and India as case study countries

To gain insight into the varying success or failure of TLADs, I required two contextually similar case studies with contrasting outcomes in TLAD adoption. Nepal and India provide ideal scenarios for this comparative study. The two countries allow for an examination of how socio-cultural attitudes

towards the use of HE influence TLAD adoption, as well as the impact of contextual factors and multi-scalar governance structures on the outcomes of biogas programmes, specifically focusing on TLAD adoption and acceptance.

Nepal and India are neighbouring countries that share common histories, demographics and some rural socio-economic characteristics. The two nation's long term biogas programmes have similar policies and different governance structures but it is still unknown why they have succeeded and failed in different aspects. While Nepal's programme is viewed as a historical success with reports of high post installation functionality rates (Bajgain and Shakya, 2005; Prakriti Consult Pvt Ltd, 2018; Government of Nepal: Central Bureau of Statistics, 2019) its effectiveness is reportedly declining and, to date, less than one percent of the total biogas potential has been realised, despite decades of government support and international financing (Lohani *et al.*, 2021). In India, while there are a number of successful biogas case studies, there is evidence in places of post installation functionality rates as low as 40% (Dutta *et al.*, 1997; Bhat, Chanakya and Ravindranath, 2001).

Importantly, both countries offer additional subsidies for toilet connections and have similar religious and cultural demographics where the handling and use of HE and derived products can come with negative socio-political consequences (Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022; Boyd Williams, Quilliam, Campbell, Raha, *et al.*, 2022). Interestingly, in 2017, approximately 80% of domestic biogas users in Nepal had connected household toilets (Prakriti Consult Pvt Ltd, 2018), whereas in India, toilet connections remain limited with reports nationwide suggesting that socio-cultural norms are responsible for the strong opposition.

The selection of Province 4 in Nepal was based on the documented prevalence of TLADs in the region. Through an academic connection facilitated by my supervisors, I identified a locality outside Pokhara known for its significant adoption of TLADs. In contrast, the choice of Assam as a case study site was informed by prior research indicating potential socio-cultural barriers to TLAD adoption in the state (Raha, Mahanta and Clarke, 2014). Moreover, a connection to Tezpur University, established through my supervisor's academic network, provided access to essential resources. The university's prominence in domestic biogas research was anticipated to support the fieldwork in Assam's rural contexts effectively. Detailed descriptions of each case study area are presented in Chapters 2 and 3.

1.3.3.2 Case study 3 – Public understanding of electricity pricing and its impact on public support for a RE transition in the United Kingdom

The UK was selected as a case study largely due to my funding requirements, which mandated a UK-focussed research chapter in the context of Covid-19 mitigation funding. However, the specific focus of this case study investigation emerged from an in-depth literature review of the UK's energy landscape, where I identified a significant gap for further investigation. Initially, this thesis focusses on biogas and I considered a similar topic within the UK for comparative purposes. However, the unfolding energy crisis in the UK shifted my attention to a broader subject. I chose to explore the

underutilisation of decentralised RE in the UK's electricity mix, particularly in light of the advantages in can offer in terms of cost and sustainability over natural gas.

1.3.3.2.1 UK context background

The UK makes an interesting case study to explore decentralised RE transitions. It is an oil producing state where the socio-technical energy regime has lock-ins with fossil fuel industry, infrastructure and culture. The UK was also one of the first countries to privatise its energy system in the 1970s and 80s from extraction of fossil fuels to household supply.

Within this context the UK is currently grappling with an energy crisis that is deeply rooted in its centralised and privatised energy infrastructure and governance systems as well as its over reliance on fossil fuels (Comon Wealth, 2021; Common Wealth, 2023). This crisis has led to a significant portion of the population struggling to afford their energy bills (National Energy Action, 2022), raising concerns about the sustainability and equity of the country's energy landscape. The UK's energy system has created a reliance on global markets and price fluctuations, particularly for natural gas (Zakeri, Staffell, *et al.*, 2022; Guan *et al.*, 2023). The design of the system has consistently shifted the burden of fossil fuel price hikes disproportionately onto UK households for many decades (Mitchell, 2012; Zakeri, Staffell, *et al.*, 2022; Guan *et al.*, 2023). This is because in the wholesale electricity market the price of electricity is tied to the gas price. As long as gas-fired electricity contributes anything to the daily demand, the cheaper production of RE will not be reflected in consumer bills (Tam and Walker, 2023). This system is not unique to the UK but a common feature of all liberalised energy markets (Guan *et al.*, 2023).

Despite the energy crisis and its link to the global gas price, the UK government proposes to increase extraction and use of gas from the UK's Continental Shelf (UKCS) in the North Sea as well as invest in further developing the fossil industry and infrastructure in the UK. This planned direction, if executed, will trap UK households in the same cycle of fossil fuel price spikes followed by unaffordable and unjust household energy bills for years to come. Additionally, UK government policies still largely support a regulatory environment that favours large-scale investment and development of RE energy and a centralised energy market (Mirzania *et al.*, 2019; Hannon *et al.*, 2023). Energy policies have limited the opportunity for decentralisation of RE energy as well for local communities to participate in decision-making processes and benefit from the economic advantages of RE generation (Bauwens, Gotchev and Holstenkamp, 2016; Mirzania *et al.*, 2019).

1.3.3.2.2 The UK public's energy literacy and support for renewable energy and decentralisation

Historically, the UK public has shown support for publicly funded RE investments while demonstrating less support for domestic fossil fuel extraction (Demski, Pidgeon and Spence, 2013; Department for Business Energy and Industrial Strategy, 2021; Evensen *et al.*, 2023). However, this trend shifted in 2022 when public backing for domestic gas extraction increased amid the energy crisis (Evensen *et al.*, 2023). This shift raises questions about the public's understanding of energy

pricing, particularly whether their opinions on energy policies are informed by an accurate grasp of how gas prices influence overall energy costs. It remains unclear if the public comprehends the relationship between gas prices and the higher electricity costs they pay, even for electricity generated from cheaper RE sources. Research into public understanding of the wholesale electricity market's operation and its impact on electricity pricing is scarce though some studies and reports suggest that public knowledge in this area may be quite limited (Institute of Environmental Management and Assessment, 2014; Becker *et al.*, 2019; National Literacy Trust, 2021).

Furthermore, the UK public have exhibited local resistance to the siting of decentralised RETs, particularly onshore wind turbines (Parks and Theobald, 2013; UK Parliament, 2016; Wilson and Dyke, 2016). This opposition often stems from factors such as emotional ties to personal and place identities, misunderstandings of the technology, mistrust in developers, and perceived lack of benefits or consultation (Soland, Steimer and Walter, 2013; Devine-Wright and Batel, 2017; Boso *et al.*, 2020a). Research suggests that public opposition to local RE solutions might reduce if these were locally owned rather than privatised (Upham and Shackley, 2006), implying that the UK's regulatory environment favouring centralised and privatised RE solutions might not be conducive to securing public acceptance and support for decentralised RETs. Additionally, it remains unclear whether knowledge of electricity pricing influences public support for decentralised RETs in the UK, and how.

In a democratic system like that of the UK, the public elects the government, which in turn shapes the nation's energy policies. These policies have significantly influenced the contemporary energy landscape of the UK. It is therefore crucial to understand the public's rationale for supporting these government-led energy policies. Delving into the motivations behind public endorsement of specific energy policies provides key insights into the UK's current energy landscape. This line of inquiry aligns with the approach used in studying transitions to TLADs in Nepal and India, emphasising the importance of understanding how individual or collective decision-making is influenced by the broader socio-economic, geographical, and political contexts, as well as the overall energy environment of the country. Comprehending these dynamics is essential for decoding the factors that currently shape the UK's energy framework.

1.3.3.2.3 Summary of knowledge gaps

There's a notable gap in research regarding the public's understanding of the UK's centralised, privatised electricity system, particularly in terms of electricity pricing and the impact of gas prices on overall energy costs. Studies have not established if there is a link between an individual's knowledge of the electricity market and pricing and their opinion on the future direction of UK energy policy, such as the extent of RE energy transition versus increased domestic natural gas extraction for electricity.

There is a need to explore if and how energy literacy is linked to perceptions of the UK energy landscape, spending on RE investments, as well as voting behaviours. If energy policy is not

considered in voting decisions, a deeper examination of energy literacy and its role in UK democracy is essential. Such knowledge is fundamental for fostering an informed public discourse about energy transitions (Wahlund and Palm, 2022). If the public's understanding of energy pricing and supporting mechanisms is deficient, leading to increased vulnerability, it becomes a justice issue (Jenkins *et al.*, 2016). If they continue to support potentially harmful mechanisms such as increased use of fossil fuels that maintain household vulnerability to market gas prices, despite adequate understanding, it may point to other influences on public opinion (Atkins, 2022). These are crucial missing pieces in understanding public perceptions of RE transition.

1.3.4 Thesis objectives

The specific research objectives of this thesis are:

1. To deepen our understanding of local socio-cultural resistance towards household toilet-linked anaerobic digesters (TLADs), to evaluate its influence on TLAD adoption, and to understand how it shapes the realisation of policy goals tied to TLAD deployment;
2. To identify the reasons for the success or failure of domestic biogas programmes, especially regarding the implementation TLADs and to more broadly understand the multi-scalar and spatial factors that impact programme success;
3. To evaluate the level of understanding the UK public has about electricity pricing in the UK, and to ascertain if this knowledge shapes their opinions on the future trajectory of the UK's RE transition.

1.4 Data Collection and Analysis

Data collection for this thesis was conducted in a systematic and sequential manner. Chapters 2 to 4 were developed consecutively, with the insights gained from each chapter informing the development of research objectives and shaping the conceptual and methodological design of the subsequent chapters. Chapter 5 emerged as a more standalone chapter as it was a response to the Covid-19 pandemic. Due to this unforeseen event, I secured funding to investigate an energy transition within the UK. The research activities undertaken to answer each research objective, including the specifics of data collection and analysis methods, are detailed in Table 1.2. The following section will provide a comprehensive overview of Table 1.2, expanding on what data was collected, why, where and how as well as rationale behind the chosen analysis methods, and the interconnection between each chapter. This detailed explanation will highlight how the research evolved dynamically in response to findings at each stage and external factors like the pandemic, ensuring a cohesive and responsive research process.

Table 1.2: Data collection, analysis methods and academic contribution for each thesis research objective

Research objective	Data to be collected What (1) where (2) how (3)	Data analysis	Academic contribution
1. To deepen our understanding of local socio-cultural resistance towards household toilet-linked anaerobic digesters (TLADs), to evaluate its influence on TLAD adoption, and to understand how it shapes the realisation of policy goals tied to TLAD deployment;	(1) In-depth descriptive and personal accounts of individual's (TLAD adopters and non-adopters) experiences adopting or not adopting TLADs and why (2) In person data collection in the two case study areas Case study 1 – Province 4, Nepal – Data set 1 Case study 2 – Assam, India – Data set 2 (3) In-depth semi-structured household interviews with adopters of TLADs (case study 1) and non TLAD adopters (case study 2)	Qualitative exploratory analysis Case study 1 – Thematic analysis of household interview data in Province 4, Nepal Case study 2 – thematic narrative analysis of household interview data in Assam, India + Thematic analysis of additional second hand data on household biogas adoption (without toilet connections) in Assam, India	A more in-depth understanding into: • what socio-cultural resistance towards TLADs is • how diverse socio-cultural resistance is • how socio-cultural resistance impacts TLAD adoption • how pathways to adoption can emerge and how socio-cultural resistance is re-negotiated • how socio-cultural resistance impacts transitions to TLADs and the realisation of national policy goals

2. To identify the reasons for the success or failure of domestic biogas programmes, especially regarding the implementation TLADs and to more broadly understand the multi-scalar and spatial factors that impact programme success;	(1) In-depth descriptive and personal accounts of Nepal and India's (case study 1 and 2) biogas programmes and why stakeholders believe they succeeded and failed in different regards from a multi-level perspective (2) Online interviews Stakeholder perspectives on national biogas programmes in Nepal and India – Data set 3 (3) In-depth semi-structured interviews with biogas stakeholders of Nepal and India's biogas programmes.	Qualitative exploratory analysis Two stages of thematic analysis of stakeholder interview data 2 1) inductive coding and 2) deductive coding (using the multi-level framework as a template for analysis) + Additional thematic analysis of data sets 1 and 2 using the multi-level framework as a template for analysis + In-depth literature and historical review of each national country context (Nepal and India) and localised context (Province 4 and Assam) to situate interview data in the wider geographical, socio-cultural, political and economic context.	A more in-depth understanding into: • how much socio-cultural resistance impacts transitions to TLADs relative to other factors • how national biogas programmes are impacted by the local context • how transitions to domestic biogas digesters are impacted by diverse localised contexts • how to approach the implementation of biogas programmes that will be interacting with diverse localised contexts • the impact of geography on transitions to household technologies in diverse local contexts common to GS countries Additionally the research study: • is a comprehensive multi-level and multi-sector investigation into domestic biogas programmes • offers a cross country comparison of biogas programme structure and outcomes • evaluates the effectiveness of utilising the multi-level perspective framework to analyse transitions to decentralised household technologies in a Global South context

3. To evaluate the level of understanding people living in the UK have about electricity pricing in the UK, and to ascertain if this knowledge shapes their opinions on the future trajectory of the UK's RE transition	(1) A sub-section of the UK's population knowledge of electricity pricing and their opinions on the UK's energy transition (2) Online survey in the UK (Case study 3) – Data set 4 (3) Online survey	Quantitative exploratory analysis Descriptive statistical analysis	A more in-depth understanding into: • how knowledgeable the UK public are about the wholesale electricity market and how it dictates what they pay for electricity and why • how the price of gas impacts the price of all electricity • how the UK public understand the difference in governance and cost of domestic vs imported natural gas • how the public's knowledge of electricity pricing impacts their opinions on the UKs future energy transitions how much socio-cultural resistance impacts transitions to TLADs relative to other factors • how the public's knowledge of electricity pricing impacts their voting choices And advance theoretical conceptualisation of energy literacy and tools to measure it.

1.4.1 Research objective 1

To explore and answer research objective 1 I compared two case studies. Nepal's Province 4, where TLADs have been successfully adopted, and Assam, India, where adoption of TLADs is assumed to be non-existent or minimal, reportedly due to socio-cultural resistance (Raha, Mahanta and Clarke, 2014).

To comprehensively explore socio-cultural resistance to TLADs within the framework of this thesis's constructivist ontology and epistemology, a qualitative research methodology was selected. While considering various options, including surveys with qualitative questions and structured interviews, I ultimately opted for semi-structured interviews. The scarcity of extensive literature on this topic posed a challenge in designing a survey or structured interview comprehensive enough to cover all potential responses. Additionally, as a foreign researcher, it was crucial to avoid imposing my own cultural biases in the research design. Semi-structured interviews offered the ideal balance: they provided a structured framework to guide the discussion towards household transitions to TLADs and socio-cultural norms, while simultaneously allowing participants the flexibility to express their chosen experiences and perceptions of adopting TLADs.

I also considered, but ultimately decided against, using focus groups. While they could have provided insights into community adoption dynamics and diverse or similar household experiences with TLADs, focus groups presented significant ethical challenges. Navigating the social dynamics within communities, particularly regarding a sensitive topic like TLADs, raised concerns. The potential for stress or social tensions in mixed-gender and or generational groups or among individuals from different social groups was a notable consideration. Conducting focus groups ethically would have required a prolonged stay to ensure a comprehensive understanding of the social structures and dynamics at play. It was crucial to be confident about the composition of each focus group, both in terms of ethical considerations and the potential impact of demographic variations of each focus group on the data collected and its interpretation.

Ultimately, semi-structured interviews were chosen as the most suitable for this exploratory stage. This method provided the flexibility necessary to adapt to new findings and cultural sensitivities, making it ideal for a foreign researcher delving into a complex and potentially sensitive topic in an unfamiliar cultural setting.

1.4.1.1 Data collection round 1 – Case study 1 Nepal, Province 4

Starting data collection in Nepal was the most logical choice. In Nepal I could begin to understand the role of socio-cultural norms can have in the adoption process, and explore how resistance was being navigated. This first-hand knowledge would then inform my approach to interviewing those households in India who had not adopted TLADs, offering a more comprehensive understanding from the perspectives of potential users.

Fieldwork in Nepal was conducted in August 2019 where I travelled with a research assistant to study villages conducting interviews and participant observations. See Appendix 1 for interview schedules used during data collection. Upon returning to the UK, I selected thematic analysis for data analysis. This decision was influenced by the method's structured yet adaptable nature, and its independence from any pre-existing theoretical framework. Thematic analysis is also notably accessible for those new to qualitative research, avoiding the theoretical and technological intricacies often associated with more complex qualitative methods (Braun and Clarke, 2006, 2021). The aim of the study was to extract specific insights regarding TLAD adoption and resistance and to identify any recurring themes among the interviewed households. The approach did not necessitate the development of an extensive set of theories and themes, making more complex analysis methodologies unnecessary. Thematic analysis, known for its structured flexibility, emerged as the most suitable choice for effectively meeting these objectives.

I utilised thematic analysis to conduct inductive coding, a process where themes are grounded in the data, rather than applying existing research or theory as a lens for analysis. This method was pivotal in ensuring that the identified themes represented the data, and that they were not swayed by any prior assumptions or hypotheses. While recognising that complete 'pure' induction is unattainable, as researchers inevitably carry some theoretical preconceptions (Braun and Clarke, 2021), the scant existing research on TLAD adoption was an advantage. It allowed me to approach the analysis with minimal preconceived notions about the nature of socio-cultural norms around TLADs or the pathways to adoption.

1.4.1.2 Data collection round 2 – Case study 2 India, Assam

After completing data collection and analysis in Nepal, I began designing my research collection tools for data collection Assam. Consistent with my previous approach, I continued with semi-structured interviews. The insights gained from Nepal were instrumental in shaping the interview design for Assam see Appendix 2 for interview scheduled used during fieldwork in Assam. For instance, because of the insights I gained in Nepal I included prompts for the interviewers to ask Hindu residents in Assam what specific foods would be acceptable to cook using TLADs gas, how they think their neighbours would react if they installed a TLAD and how they would react if their neighbours adopted one and if they would stop eating at someone’s home. Many of the questions and prompts were included because of my experience in Nepal. In Assam I also approached and interviewed some Muslim, Christian and Buddhist households. Some questions in the interview schedule in Appendix 2 were modified or omitted due to their specific relevance to Hindu contexts. I worked closely with five master's students from Tezpur University's departments of Energy and Social Work, who provided invaluable local and cultural insights on how to adapt the interviews. We also discussed that interviewers would only ask some of the more sensitive questions if they felt like the participant would be open and comfortable answering them.

Fieldwork in Assam lasted one and a half months from January 2020. For analysing the interview data from India, I chose thematic narrative analysis. This method was suitable because the interviews encompassed not just personal experiences with biogas technology but also participants' perceptions of future scenarios regarding TLAD adoption. Including narrative elements in the analysis enriched the understanding of the stories and experiences shared. While maintaining thematic analysis allowed for identifying common patterns, the inclusion of narrative analysis helped construct a cohesive story, facilitating the drawing of substantive conclusions that formed the core findings of the PhD. Analysis of interview data was coded inductively, though I had more ideas of what might happen during an adoption scenario in Assam due to my knowledge gained from Nepal. I reflexively approached the analysis repeatedly coding the data and generating themes and checking themes to make sure the final themes were grounded in the data.

The Covid-19 pandemic unexpectedly facilitated a valuable collaboration with Dr Debadayita Raha, a researcher with expertise in household biogas adoption and implementation in Assam (Raha, Mahanta and Clarke, 2014). The initial themes coming out of the data I had collected in Assam suggested that while socio-cultural norms would significantly influence TLAD adoption other programmatic factors would impact adoption of TLADs more. For instance none of the households interviewed had been promoted a TLAD. Specifically, the data pointed to numerous inefficiencies within the biogas programme, particularly in governance and implementation.

Due to the constraints of the Covid-19 pandemic, which necessitated an early departure from Assam, I was unable to expand my household interviews or engage with key stakeholders, such as local government workers, to explore the broader aspects of the biogas programme in Assam. Engaging with Dr Raha was instrumental in contextualising my findings on socio-cultural resistance within the broader context of household biogas in Assam. Dr Raha and her team also shared their extensive interview data from Assam, comprising insights from 60 households with domestic biogas (without toilet connections). This data, which I analysed using thematic analysis, offered a deeper understanding into household experiences with biogas in Assam. This complementary data set allowed me to better understand the biogas programme's strengths and weaknesses and how these intersected with the socio-cultural factors influencing TLAD adoption. These additional insights, combined with my discussions with Dr Raha, led to a nuanced conclusion: while socio-cultural resistance plays a role in TLAD adoption in Assam, it is not the primary barrier. Instead, the broader inefficiencies within the biogas programme emerged as more critical impediments. This revelation reshaped my understanding of the challenges in promoting TLAD adoption in the region.

The themes that came out of Chapters 2 and 3 were what conceptualised and drove research objective 2.

1.4.2 Research objective 2

The main findings from Chapters 2 and 3 underscored the importance of understanding localised socio-cultural norms in relation to the broader biogas programme and local contexts. A literature

review highlighted a significant research gap: there is an absence of studies that contextualise localised case study findings of biogas adoption within the broader framework of a nation's culture, geography, economy, politics, and overall biogas programme efficacy. This gap is particularly noticeable in the context of Indian and Nepalese biogas programmes. While there is an abundance of research focusing on specific, localised instances of biogas use and adoption, there is a lack of comprehensive analysis that integrates these findings into the wider national narrative. This includes understanding how these programmes operate and succeed or fail at local levels and the role of multi-scalar factors in shaping these outcomes. Focusing solely on localised case studies and factors provides only a fragmentary view of the complex dynamics at play in biogas programme transitions.

Confronted with the limited scope of existing academic studies and available grey literature on biogas programme policies and governance, I recognised that solely relying on these sources would be inadequate to conduct a contextual analysis of the two country contexts. Government documents from both Nepal and India did not provide clear insights into the reasons for varying successes of TLADs, despite both countries having similar policies and subsidies for toilet connections. This discrepancy between policy documentation and actual on-the-ground outcomes necessitated a different approach. To bridge this gap in understanding, I opted to collect first-hand information from stakeholders who were either directly involved in or had substantial knowledge about these biogas programmes. While I was aware that this method might introduce some bias, given its dependence on personal accounts and perspectives, it was a necessity due to the scant detailed information on the actual implementation and effectiveness of policies. This approach was crucial for uncovering the reasons behind the disparity between written policies and their practical execution. To complement these interviews, I conducted a thorough historical, cultural, political, economic, and geographical literature review of both Nepal and India, as well as the specific case study areas of Province 4 and Assam. This multifaceted approach enabled me to place the findings from the initial chapters and the new data from stakeholder interviews into a broader, more nuanced context.

Given the limited availability of detailed information, I determined that in-depth semi-structured interviews were the most appropriate method for this exploratory study. The scarcity of comprehensive data made it impractical to construct a survey or structured interviews with the assurance of capturing the intricate dynamics and factors influencing biogas programmes. The research gap required exploration of areas beyond my existing expertise. Semi-structured interviews provided the necessary flexibility for this investigation. They allowed me to guide the discussions, while also giving stakeholders the liberty to diverge and highlight what they perceived as important. Due to the Covid-19 pandemic, I was unable to conduct in-person interviews or organise focus groups that would have included a diverse range of stakeholders from different levels of the biogas programmes. As a result, online semi-structured interviews emerged as the most viable option to obtain the most comprehensive and detailed information within these constraints.

Thematic analysis was employed due to its ability to generate insightful theories and identify patterns pivotal to the success or failure of biogas programmes, leveraging the expertise of stakeholders involved in the biogas programmes of Nepal, India, as well as other regions in Asia and Africa. The methodology involved an initial inductive coding to explore themes grounded in the data, followed by a deductive phase where the Multi-Level Perspective (MLP) framework guided the analysis, providing a structured approach to understanding the complexities of household transitions to domestic biogas within a broader multi-level context. While there are multiple theoretical frameworks connected to sustainability and energy transitions the MLP was selected for its widespread use and flexibility within sustainability and energy transition research, offering a robust basis for comparison with existing studies. It has also been utilised to investigate a number of transitions to domestic biogas in various contexts so I had examples to inform my methodology and studies to compare it to afterwards. Despite criticisms against the MLP, the MLP's extensive application in the literature offers valuable insights into its implementation and interpretation across diverse contexts and scales, making it an appealing choice for this research (Geels, 2010; Wieczorek, 2018). It stands out for its heuristic nature, allowing for adaptability and alignment with the study's constructivist ontological stance, which acknowledges transitions as phenomena shaped by multiple realities (Geels, 2010). Furthermore, the MLP's emphasis on socio-technical systems and its incorporation of temporal dynamics are crucial for visualising and analysing transitions over time, underscoring the framework's suitability for exploring the historical and dynamic aspects of energy transitions (Geels and Schot, 2007).

1.4.3 Research objective 3

Chapter 5 was designed to answer research objective 3. In Chapter 5, the methodological approach of the thesis shifted all little, driven by the specific research objective and constraints of time, budget and decision to take data collection online. While qualitative methods such as focus groups or in-depth interviews could have provided greater exploration into the relationship between energy literacy and public opinion on the UKs energy transitions, they were not feasible within the given limitations. A survey methodology was an ideal approach to initially determine if there is a relationship between public energy literacy and opinion and subsequently justify if further research is required or not. The survey's findings indicated limitations in the quantitative methodology and suggested the need for follow-up research using interviews and focus groups for more in-depth exploration, and potentially a larger survey for broader insights.

In Chapter 5, the analysis of survey data was conducted using descriptive statistics, suitable for the straightforward nature of the research questions. The analysis focused on understanding the UK public's knowledge about electricity market pricing, particularly examining differences across demographics. It also aimed to explore the correlation between this knowledge and public support for RE transitions, as well as its influence on voting behaviours in general elections. Descriptive statistics were effectively employed to extract insights on these aspects, offering insight into the

relationships between public knowledge, demographics, attitudes towards renewable energy, and electoral decisions.

1.5 Positionality

Acknowledging one's positionality and being reflexive is an important part of the research process (Holmes, 2020; Braun and Clarke, 2021). Throughout my PhD, reflexivity became increasingly integral as I transitioned from an engineering background to embarking on an interdisciplinary PhD. This process involved both learning new social science theories and methods but also unlearning certain preconceptions due to my engineering training. Initially, I approached decentralised energy from a techno-centric perspective, but as my PhD journey progressed, I adopted a more socio-technical lens. This shift significantly influenced the conceptualisation, design of research methodologies, and development of the thesis, marking an ongoing journey of learning and adaptation.

As a white, British female raised in the UK, my experience with energy has been exclusively within the centralised electricity system, without personal engagement in decentralised RE solutions or being an energy prosumer. My exploration into decentralised energy transitions has been largely an intellectual journey, distinct from the lived experiences of those I interviewed in Nepal and India. My perspective on decentralised RE has evolved over the course of this research; initially positive and somewhat detached from the practicalities of daily management and policy challenges these systems face. Chapters 2 and 3 of this thesis, while exploring socio-cultural norms and household adoption decisions centred on TLADs, can read positively about biogas as a rural solution, without in-depth critical examination the broader challenges facing successful adoption of TLADs beyond household decision making. My analysis becomes broader and more critical in later chapters as I delve into the multi-scalar dynamics of biogas programmes in Chapter 4 as well as the UK's energy policies in Chapter 5. As the PhD progressed I understood that promoting decentralised RETs requires a supportive political and policy environment for long-term success and that household decision making is just one small aspect of the transition, although one which has been overly focussed on in literature to date. This shift in perspective marks a significant transformation in my framing of and approach to researching RE transitions. Initially, I questioned why solutions like domestic biogas digesters were not more widely adopted or why decentralised RETs were not more prevalent and supported by the public. However, this PhD journey has led me to a broader critical stance. I now question why programmes are failing to engage with household decision making and localised factors impacting transitions and why regulatory and governance frameworks do not better support decentralised RE. This evolution in thought reflects a deeper understanding of the complex interplay between household decisions, programme execution, and broader policy contexts. It marks a shift from questioning individual adoption choices to critiquing systemic structures and policies that shape these choices.

I recognise that my identity and perspectives as a British citizen, a country with a complex colonial history, inevitably influenced my research in ways I will not fully comprehend. The UK's historical role as an economic and global power has shaped cultural and physical realities across the globe, and I am aware that this background could impact my interactions and research, especially in countries like Nepal and India where the UK has had significant presence. During my fieldwork, particularly in rural areas seldom visited by westerners, my presence as a white foreigner might have elicited reactions from interviewees that are difficult to gauge. The sensitive nature of the topics I explored, particularly around a taboo technology, likely added to these complexities. While I understand that completely neutralising these influences is impossible, I strived to avoid obvious, conscious or systematic bias and to be as neutral as possible in the collection, interpretation and presentation of the data (Ritchie *et al.*, 2014).

Firstly, during fieldwork my approach was to adopt a passive role to minimise influence on data collection. My lack of fluency in the local languages reduced my direct involvement in interviews. I was initially introduced to households by local research partners I was working with but then aimed to be as inconspicuous as possible, letting my research partners take the lead. After each interview, we would reflect on the process and consider any necessary adjustments rather than doing this too much during the interviews. Through my partners I communicated to participants that there were no right or wrong responses, emphasising my genuine interest in their perspectives and experiences.

Secondly, I engaged in post-colonial reading, particularly after analysing data for Chapters 1 and 2. This was sparked by the emerging results, which challenged conventional assumptions about socio-cultural resistance. I found myself questioning why such resistance is often perceived as oppositional to technology rather than an inherent part of the local context. As I developed Chapter 3, this reading, encompassing colonial histories in Nepal and India, profoundly influenced my perspective. I observed that my initial user-centric approach to studying household transitions was a reflection of my own positionality, shaped by Western perspectives. Perspectives that often view socio-cultural dynamics as separate from technology and thus a large barrier to technology adoption. Western approaches to development are technologically focussed with a tendency to adopt one size-fits-all mentality to implementation that cannot engage with complex local diversity. I did not originally challenge these approaches to development I was used to. To contribute a meaningful and novel perspective to the field, I recognised the need to re-examine and unlearn some of my preconceived notions and biases. This realignment was crucial for approaching the topic from a multi-scalar perspective in Chapter 4.

Reflecting on the completion of my data collection, I am struck by a sense of participating in an extractive process. Throughout the PhD I was influenced by an academic culture that discouraged compensating participants for their time and knowledge. This approach never felt entirely right to me, yet I was uncertain how to address it differently. There is also no additional funding or time worked into a PhD for a candidate to specifically spend time sharing their findings

with participants and other stakeholders in the study country and engaging with actors in policy development and learning. My research involved engaging with households to discuss topics I deemed significant but not offering much in return. I remember my research partner Roshni Ghatani in Nepal told me that one of the participants told her at the end of the interview to make sure these interviews were not only going to facilitate my qualifications. I believe current ethical procedures at Western universities and research funding guidelines do not fully encourage or facilitate genuinely non-extractive, equitable research practices. I believe I could have approached the interviews with more openness, spending additional time with participants and focusing more on what they considered important to talk about. I could have also asked them what they thought about me doing this research and what they might expect in return. This experience has led me to resolve that in my future research, I will strive for more participatory approaches, seeking fairer and more just methods of conducting research, particularly in lower-resource settings abroad.

Chapter 5 of my thesis was distinctly influenced by my personal interests and perspectives, particularly in relation to the energy crisis and the nuances of energy knowledge. My decision to focus on this area was driven by my own sense of injustice and frustration regarding the constrained energy choices in the UK. This chapter, therefore, became deeply personal to me. In writing it, I had to engage in rigorous reflexivity, constantly ensuring that my interpretations and conclusions were grounded in the data and literature, not my personal beliefs or political biases. To reduce bias I employed various strategies, including consulting diverse viewpoints and conducting thorough literature reviews. For example, despite my opposition to natural gas, my research led me to a more nuanced understanding of its current role and the complexities involved in transitioning away from it. This process of checking and rechecking my work against the evidence was crucial in ensuring that the chapter accurately reflected the research findings.

1.9. Structure

Chapters 2 and 3 investigate the socio-cultural acceptance of, and resistance towards, TLADs in the respective case study contexts of Nepal and India. Both chapters, having been peer-reviewed and published, fulfil research objective 1. Chapter 4 offers a detailed comparative analysis of Nepal and India's biogas programmes, aiming to address research objective 2. Chapter 5 presents a quantitative study on the UK public's energy literacy and their views on future investments for the UK's energy transition post-energy crisis, addressing research objective 3. The thesis concludes in Chapter 6, discussing the fulfilment of the objectives and providing a wider reflection on the implications of the findings for understanding decentralised RE transitions.

Chapter 2: Taboos, toilets and biogas: Socio-technical pathways to acceptance of a sustainable household technology

This chapter has been published as:

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J. Dickie, R.S. Quilliam, B. Campbell supervised the project. N. Boyd Williams designed the data collection tools with support from all other authors. N. Boyd Williams and R. Ghatani carried out the data collection with support from J. Dickie and B. Campbell. N. Boyd Williams analysed and interpreted the data. N. Boyd Williams produced the manuscript, and all authors commented on draft versions.

See Appendix 1 for semi-structured interview schedule used in Province 4, Nepal.

Abstract

Toilet-linked anaerobic digesters (TLADs) can provide users with a clean gaseous fuel and a fertiliser product as well as offer waste management services. Socio-cultural resistance towards domestic TLADs, due to the use of human excreta as a feedstock, is often articulated as a barrier to adoption. However, no research has specifically investigated the issues associated with TLADs separately from those associated with domestic digesters without toilet connections, consequently, there has been little attempt to discover what motivates users to use TLADs. Drawing on qualitative data from Nepal this paper explores how socio-cultural resistance impacts TLAD adoption and subsequent use of the biogas, and how adoption and transition pathways evolve. We argue that socio-cultural resistance is not a finite barrier to adoption and the opportunity to observe or trial a TLAD can positively influence adoption, especially amongst the older generations. Technical issues affected how TLADs were utilised more than socio-cultural norms and we discuss how socio-technical factors might co-evolve to influence sustainable adoption and use of TLADs. Caste and gender were not found to influence adoption pathways as much as the leadership or 'risk-taking' characteristics of specific adopters. Adoption of TLADs can occur within a year of a user first observing or trialling a TLAD; however,

most users still do not use biogas for ritual cooking, despite having had a TLAD for many years. Grassroots initiatives that understand the diversity of localised socio-cultural norms will likely be imperative for successful TLAD dissemination.

2.1 Introduction

Globally it is estimated that three billion people, predominantly in low and middle-income countries (LMICs), cook using kerosene and solid fuels such as wood, crop wastes and dung in open fires and inefficient stoves (The World Health Organisation, 2020). These fuels and practices can lead to high levels of indoor air pollution, which is estimated to cause up to four million premature deaths from associated illnesses (The World Health Organisation, 2020). These health burdens disproportionally affect women and children who, due to gender norms, perform both the majority of the cooking and fuel collection (Remais, Chen and Seto, 2009; Gosens *et al.*, 2013; Rupf *et al.*, 2015). The harvesting and burning of solid fuels for domestic purposes can also lead to deforestation which has a negative effect on a range of ecosystem services, with subsequent negative impacts on those people who rely on forests for their livelihoods.

Domestic biogas is considered to be a clean cooking alternative for rural populations in LMICs (Shakya, 2002; Bond and Templeton, 2011; Ortiz, Terrapon-Pfaff and Dienst, 2017b). Adopting biogas can reduce the amount of time spent collecting solid fuels and reduce the health burdens associated with the burning of solid fuels (Katuwal and Bohara, 2009; Remais, Chen and Seto, 2009; Gosens *et al.*, 2013). Biogas is generated when organic materials are decomposed in the absence of oxygen in an anaerobic digester (Cheng, Li, Mang, Huba, *et al.*, 2014; Garfí *et al.*, 2016; Bharathiraja *et al.*, 2018). Typical household feedstocks include animal dung, food and agricultural waste, and toilet waste. Animal dung is the most commonly used feedstock and users are often required to have a minimum number of livestock before adopting biogas technology (Raha, Mahanta and Clarke, 2014; Bhattarai, Somanathan and Nepal, 2018). Domestic biogas technology thus provides a waste management service in addition to providing energy. A typical set-up of a fixed-dome anaerobic digester, common across China, Nepal and India (Bajgain and Shakya, 2005; Bond and Templeton, 2011; Raha, Mahanta and Clarke, 2014; Bharathiraja *et al.*, 2018) is illustrated in Figure 2.1.

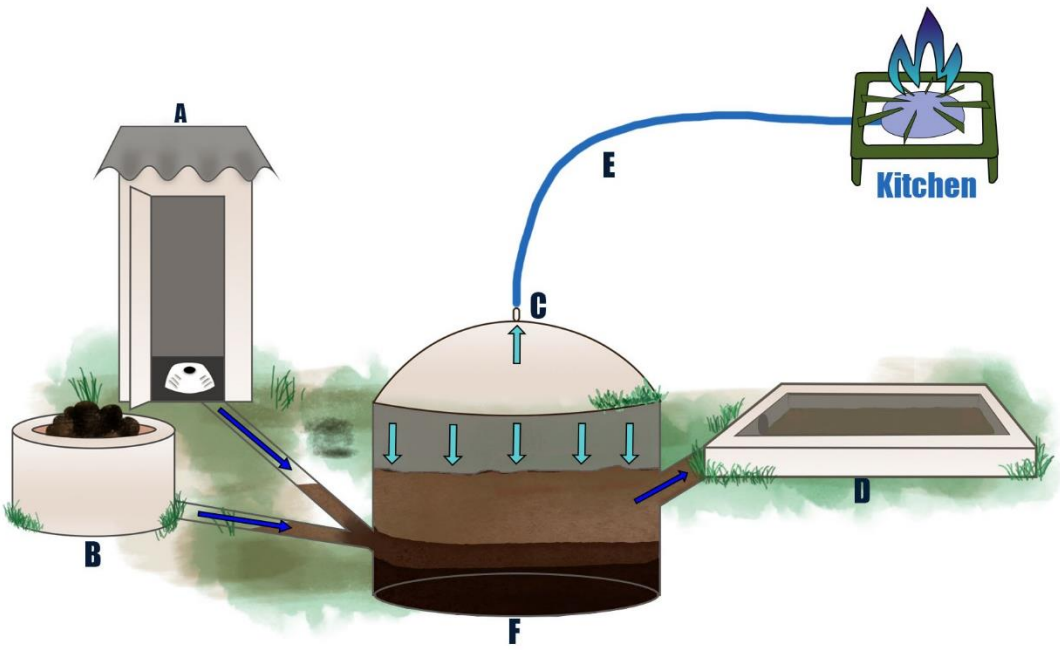

Figure 2.1 *Illustrated schematic of a fixed-dome toilet-linked anaerobic digester (TLAD).* Dark blue arrows depict the flow of feedstock and the light blue arrows, show the flow of biogas. The feedstocks from A) the toilet and B) the cow/animal dung and other organic waste inlet flows into the digester (F) after mixing with water. As the organic waste decomposes biogas builds up inside the digester and flows through a pipe (E) directly to the kitchen stove via a pressure gradient. The production of biogas increases the pressure inside the fixed dome structure (C) and forces the by-product of the process (a nutrient rich, and predominantly liquid product called slurry that can be used as a plant fertiliser) out and into the slurry storage area (D). Typically, the biogas dome (C) is all that can be seen above ground of the main digester, though in some cases both (F) and (C) are buried underground.

In addition to biogas, domestic anaerobic digesters also produce slurry as a liquid by-product. The slurry can be used as a plant fertiliser because the process of anaerobic digestion converts nutrients into a form more readily available to plants than the feedstocks from which it is derived (Alburquerque *et al.*, 2012). Further waste management benefits are gained when a household connects their domestic toilet to the anaerobic digester, which improves sanitation provision and can increase biogas production (Bajgain and Shakya, 2005; Bond and Templeton, 2011; Cheng *et al.*, 2011; WHO and UNICEF, 2017). Inadequate sanitation is estimated to cause 432,000 diarrhoeal-related deaths annually and is linked to the transmission of many diseases such as cholera, hepatitis A, typhoid and polio (World Health Organisation, 2019). The leaching of faecal waste from basic latrines and toilets into the environment is a common hazard in LMICs where there can be inadequate means of disposal (Prasad and Ray, 2019) or where high groundwater and/or monsoon rains increase the risk of human pathogens contaminating drinking water sources (Jewitt, Mahanta and Gaur, 2018). The process of anaerobic digestion can also reduce the odour of feedstocks, which is perceived as an additional benefit of the waste management service (Powers, 1999; Huong *et al.*, 2014). Users of domestic anaerobic digesters have the flexibility to manage fluctuating health, labour availability and markets because they can choose between expending labour on running a digester to obtain the biogas

and slurry, or purchasing gas fuel or fertilisers depending on their circumstances (Damgaard, McCauley and Long, 2017).

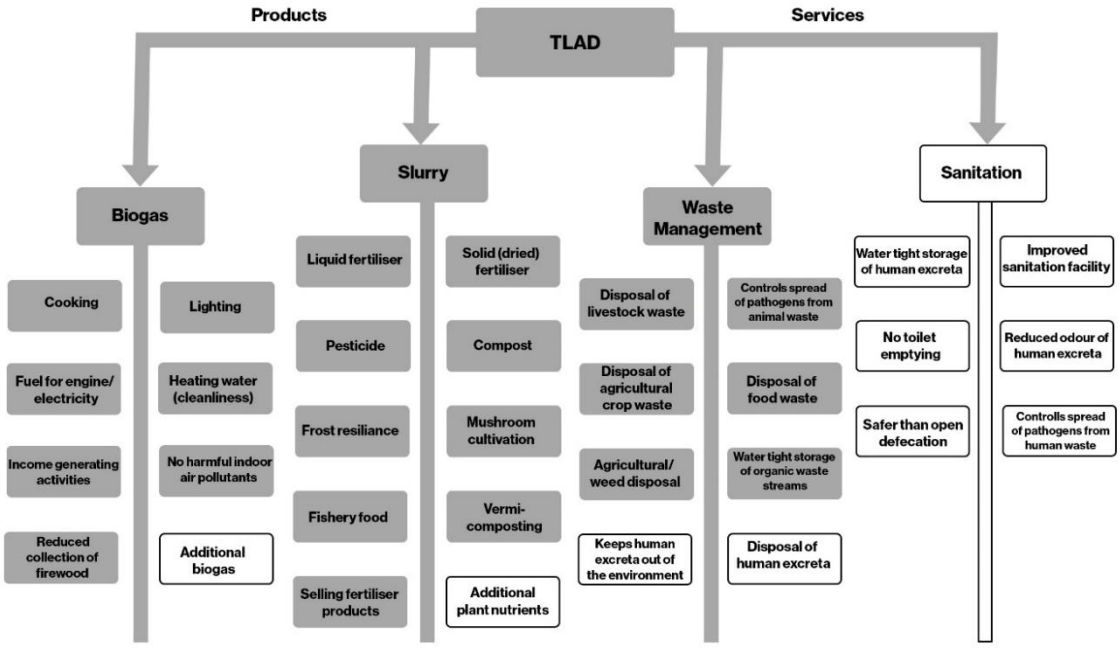

Figure 2.2: *Summary of the benefits of a toilet-linked anaerobic digester (TLAD).* Adapted from (Sovacool, Kryman and Smith, 2015). The benefits offered by domestic dung-fed anaerobic digesters (DFADs) are shown in grey and the additional benefits offered by a toilet connection are highlighted in white.

A summary of the potential benefits that TLADs could offer are presented in Figure 2.2. Despite the additional services that connecting a toilet provides, TLAD adoption is much lower globally compared to domestic dung-fed anaerobic digesters (DFADs). This has been ubiquitously attributed to socio-cultural resistance by users due to the use of human excreta (HE) as a feedstock (Raha, Mahanta and Clarke, 2014; Mittal, Ahlgren and Shukla, 2018; Sovacool and Griffiths, 2020; Dumont, Hildebrandt and Sempuga, 2021) which is often articulated as rejection and an insurmountable barrier to adoption for new users. Consequently, there is a need to broaden our understanding of the meaning of socio-cultural resistance and its drivers.

The research gaps can be reductively grouped into two areas with the first being about adoption of the technology. Importantly, no studies have explored how existing users of TLADs have overcome socio-cultural resistance, what motivated them to do so or what the perceived benefits and challenges posed by TLADs were. Additionally, despite the differences between DFADs and TLADs previous studies have not differentiated between them and so the specific socio-technical opportunities and challenges facing TLADs, from the adopter perspective are unclear. The second research gap is about the technology use; households use a range of fuels to meet their energy needs, which is known as fuel stacking, where selection for use is based on factors such as traditions in

cooking practices, availability, perceived costs and benefits, labour and income (Ruiz-Mercado *et al.*, 2011; Akintan, Jewitt and Clifford, 2018; Jagadish and Dwivedi, 2018). Despite this broader understanding of the complexity of household decision-making around fuel use, the rejection of TLADs and the biogas they produce is often reported as being a binary decision. Whether varying levels of socio-cultural resistance of TLADs exist across different cooking practices has not yet been determined. This paper seeks to address our lack of understanding about the drivers of socio-cultural resistance towards TLADs and the complex decision-making process associated with the adoption of the technology by investigating TLAD uptake in a case study area in Nepal. Whilst extensive literature exists around why traditional fuels are maintained over improved fuels and stoves like biogas (Malakar, Greig and van de Fliert, 2018a; Vigolo, Sallaku and Testa, 2018; Bharadwaj *et al.*, 2021), this study investigates how socio-cultural norms have been navigated or overcome to identify potential adoption pathways of the whole TLAD system, which can include additional health, sanitation and sustainable livelihood benefits.

Many Asian and African countries have had notable national domestic biogas programmes (Bond and Templeton, 2011; Ghimire, 2013), but Nepal's is commonly credited with being a success story (Bajgain and Shakya, 2005; Ghimire, 2013) especially in regards to the number of toilet connections it achieved. In 2015 Nepal's domestic biogas programme had installed approximately 350,000 domestic biogas units and of these up to 79% had a connected toilet (Rai, 2017; Prakriti Consult Pvt Ltd, 2018). Nepal's relatively high uptake of toilet connections challenges the perception that biogas and slurry made from HE are not acceptable due to cultural beliefs as Hinduism, the dominant religion in Nepal, has a strong cultural grounding in purity and pollution practices (Bajgain and Shakya, 2005; Ministry of Health Nepal, New ERA and ICF, 2017). Nevertheless, neighbouring India, which has similar demographics and socio-cultural norms, has much lower levels of TLAD acceptance and adoption (Raha, Mahanta and Clarke, 2014; Mittal, Ahlgren and Shukla, 2018). To date, no research has investigated how pathways to TLAD adoption were forged in Nepal, how the biogas and slurry are used and if and how socio-cultural resistance has shaped these decisions.

Thus, the overarching aim of this case study was to explore the socio-technical pathways and barriers to adoption and acceptance of TLADs in the cultural context of Nepal and make recommendations for future approaches to the transition to TLADs in similar contexts. Specifically, our objectives were to determine: 1) the motivation, and pathways to acceptance, of users who have adopted TLADs and therefore overcome socio-cultural resistance; 2) How socio-cultural norms shape the ways that TLAD biogas and slurry are used and the reasons why; and 3) the socio-technical opportunities and challenges associated with TLADs.

2.2 The Nepal context and literature review

2.2.1 Biogas in Nepal – programme and policy evolution

Nepal is predominantly a rural society where farming practices complement the use of domestic biogas technology (Rai, 2017). More than 80% of the population relies to some extent on subsistence

agriculture and many have cattle living in stalls adjacent to their house (Bajgain and Shakya, 2005; Rai, 2017) providing a regular and easily accessible supply of dung. Nepal's nationwide biogas programme began in the 1970s and is still in continuation today though the programme has evolved over time. The programme pioneered a public-private approach to biogas dissemination and was supported in later years (1992-2010) by the Netherland's Development Organisation (SNV) and other international donors (Rai, 2017). During this phase, the Biogas Support Programme (BSP) was launched to promote biogas, train skilled staff, and set up regional biogas companies. They also provided subsidies that helped users cover costs and incentivise good construction. Biogas companies were only reimbursed the subsidy if they built satisfactory models (Fulford, Devkota and Afful, 2012).

From 2003-2010 a government ministry, called the Alternative Energy Promotion Centre (AEPC), became the main executing body and was set up to fully take over promotional activities, policy development and funding coordination in 2010 when the SNV phase came to an end (Rai, 2017). While the subsidy model remained, the execution of the programme became more state-led, and top-down, with less quality control checks, more focus on annual targets and had a reduced overall budget (Pokharel, 2003; Rai, 2017).

Despite its perceived success, the biogas program in Nepal has been criticised for its ineffectiveness at reaching the rural poor. Though regulated, the private sector involvement does not incentivise private contractors to approach poor households who are less likely to adopt the technology (Bhattarai, Somanathan and Nepal, 2018). The subsidies are criticised as biogas remains unaffordable for poorer households. Uptake has also slowed in recent years due to modernity and migration changing the shape of village life; migration is leaving many villages depopulated (leaving just the elderly), the land uncultivated and the livestock population diminished (Gyawali and Thompson, 2016).

2.2.2 Geographical and cultural context

Nepal was never colonised and although it has been the recipient of much foreign aid money it has managed to keep some autonomy in its socio-political life (Thompson, Gyawali and Verweij, 2017). Subsequently, Nepal has experienced several grassroots development success stories in addition to the BSP such as the community forestry initiative (Campbell, 2018a; Negi *et al.*, 2018). It is, however, a country affected by natural hazards and periods of inconsistent political leadership (Adhikari *et al.*, 2017). Nepal has the capacity to generate all its required electricity (and more) from its hydropower potential but has never accumulated the political will nor economic and knowledge capital to achieve this (Katuwal and Bohara, 2009; Adhikari, 2014; Singh, Nachtnebel and Komendantova, 2020). Thus, it has remained dependent on India for fossil fuel imports. As a result, Nepal's people have historically had to manage both manmade, and natural hazard-induced energy deficits such as the Indian fuel blockades of 1989 and 2016 (Budhathoki and Gelband, 2016), frequent load shedding, and earthquakes and landslides, which can cut off fuel and other supplies

delivered by road. Such disruptions to the energy supply often result in significantly inflated energy costs, which in the past has increased interest in biogas (Rai, 2017).

In addition to the geographical landscape pressures, it is important to understand more localised and day to day socio-cultural norms that characterise the adoption context and shape adoption pathways. In Hinduism, physical and ritual purity are not synonymous with each other (Luthi, 2016; Coffey and Spears, 2017). Cow dung for example, which could contain human and zoonotic pathogens, is revered and is often used as a purification agent (Douglas, 1966; Luthi, 2016). In contrast, a toilet within the home, despite being physically clean, can still be interpreted as ritually polluting (Coffey and Spears, 2017). The ritual pollution of an individual is associated with the caste they are born into within the Hindu social system, (the caste* system) and is reinforced by occupational practices (Gorringe and Rafanell, 2007; Wang and Bailis, 2015; Subedi, 2016). Occupations such as toilet cleaners have been traditionally forced upon groups from lower castes, and to avoid perceived pollution, people of higher castes segregate themselves from these occupations and the people that perform them (Thekaekara, 2003; Simha *et al.*, 2017). People belonging to the higher castes will sometimes refuse to invite people of lower castes into their homes and refuse to accept water or cooked food from them (Bennett, 1983; Luthi, 2016). There have been instances in Nepal where neighbours of TLAD adopters are reluctant to visit or eat food at their neighbour's house (Bharadwaj *et al.*, 2021). Open defecation (OD), the practise of defecating in fields and water bodies can be prevalent in rural populations where socio-cultural norms together with necessity, perpetuate this behaviour (Coffey and Spears, 2017; Vyas and Spears, 2018). Adoption pathways could be shaped by these complex taboos and socio-political implications around toilet use and emptying.

TLADs offer diverse benefits across multiple household domains suggesting that adoption pathways will interact with socio-cultural norms inherent within a diverse range of day-to-day practices. In Hindu village life, religion is not confined to the realm of the personal but cascades into practical life (Bennett, 1983; King, 2011; Campbell, 2013a) where many daily acts are performed to maintain the purity of the home and body. It is useful to contextualise how villagers might understand ritual pollution surrounding cooking, eating and defecation, all of which may influence TLAD adoption. Some of the day-to-day practices that will interact with TLAD adoption pathways in various household domains are shown in Figure 2.3, which illustrates where the use of biogas and slurry derived from HE could oppose traditional socio-cultural norms and influence user's decisions to adopt a TLAD.

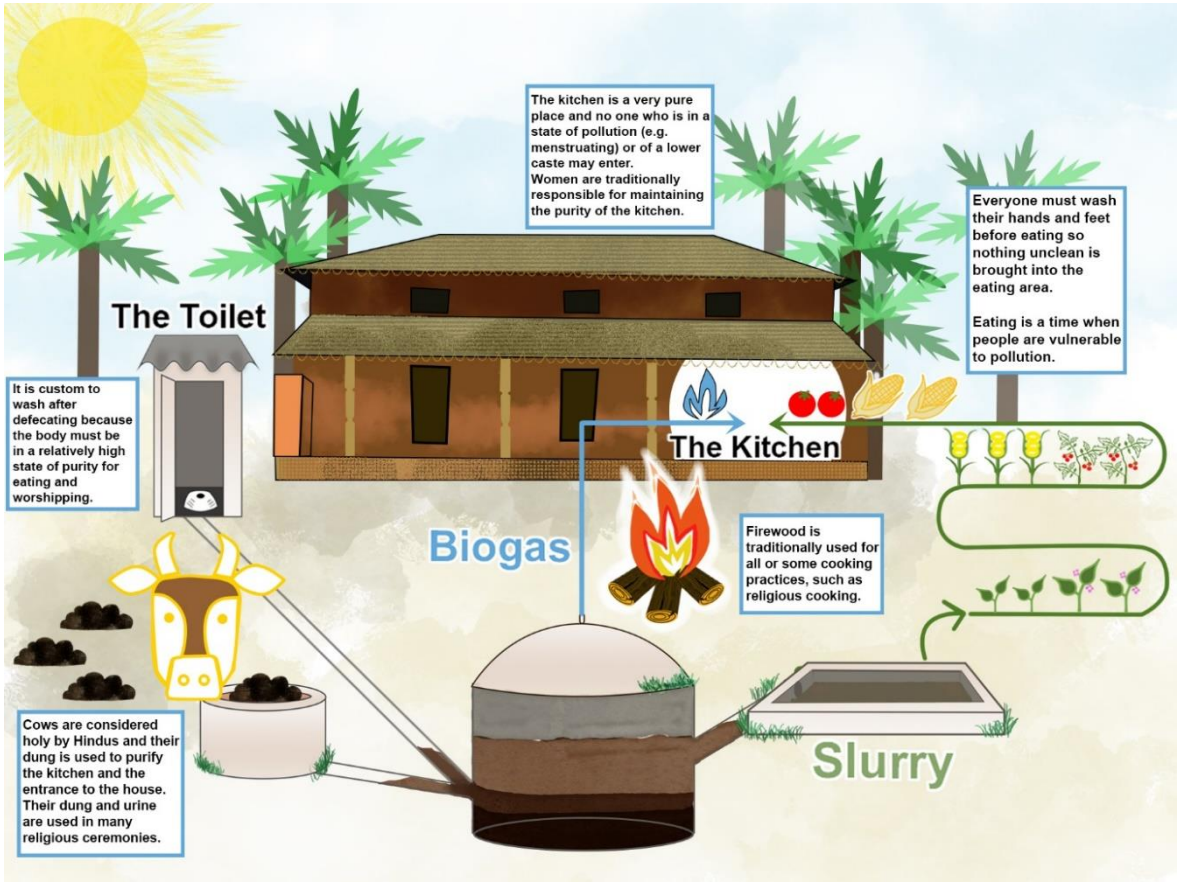

Figure 2.3: *A toilet-linked anaerobic digester (TLAD) within a traditional Nepali village home showing how TLADs connect human excreta with cooking and eating. The text boxes describe some socio-cultural practices around, cooking, eating and defecation that are performed to maintain purity in rural Hindu Nepal* (Bennett, 1983; Rhodes *et al.*, 2014; K. Adhikari and Gellner, 2016; Misra, 2019). *The illustration contextualises how these socio-cultural norms might influence decision-making across household domains when adopting or using a TLAD.*

2.2.3 Transitions: caste and gender

The adoption of new energy technologies is often not linearly correlated to the needs of the adopter, affordability or health agendas (Malakar, Greig and van de Fliert, 2018a; Sovacool and Griffiths, 2020), for example, in India people use liquefied petroleum gas (LPG) because it improves their social status (Malakar, Greig and van de Fliert, 2018a). Caste has also been shown to have an important role in influencing adoption pathways to improved cook stoves in diverse ways (Wang and Bailis, 2015). Some higher caste households, for example, have chosen to maintain high smoke-producing cooking practices due to associations with ritual purity, whereas some lower caste households were motivated by the increased cleanliness of their homes offered by improved cook stoves. Alternatively, lower caste households may implement more stringent traditional cooking practices, to show commitment to purification and ritual practices as a way of improving social status (Srinivas, 2009).

Group membership and social status can also ensure access to resources (Patnaik and Jha, 2020), whereby access to a variety of energy technologies in Hindu contexts can be dependent on caste-based relations that favour higher castes (Raha, Mahanta and Clarke, 2014; Kumar, 2015; Cross, 2019). An individual's caste and social status are more than a title, they embody them, and their positions within the social system can be fluid. People of lower caste, through a process referred to as Sansritisation, seek to increase their social position by adopting the practices and behaviours of higher castes (Srinivas, 2009), for example, through conducting certain religious rites and abstaining from alcohol and eating meat (which is traditional for the priestly Brahmin caste). A Hindu can also lose their caste status for various reasons including breaching caste boundaries, such as through marriage to someone of a lower caste (Bennett, 1983; Gorringe and Rafanell, 2007). Thus, through embodiment of caste an individual's behaviour could affect their ability to obtain access to resources. Understanding this is imperative to explaining why an individual might not change their behaviour or adopt a new technology despite there being an economic incentive. Theories of practice can help explain this complex decision-making within the social context (Bourdieu, 1977; Malakar, Greig and van de Fliert, 2018b; Jewitt, Atagher and Clifford, 2019) and clarify why the needs of an adopter are not always correlated to adoption. Bourdieu (Bourdieu, 1986) theorised that there are three types of capital; economic, social and cultural and that when people make a decision, they are weighing up these forms of capital (Bourdieu, 1977). Social and cultural capital help people gain access to resources; they can be gained and lost, not by individuals alone but in terms of collective status, and have a direct impact on survival and quality of life that may or may not be convertible to economic capital (Gorringe and Rafanell, 2007).

Women in Nepal often hold the responsibility of collecting solid fuels and cooking (Bennett, 1983; Bajgain and Shakya, 2005; Misra, 2019) and thus stand to benefit the most from the reduced labour and indoor air pollution offered by TLADs (Ghimire, 2013). Women are also more vulnerable to attack and sexual harassment during OD (Jewitt, Mahanta and Gaur, 2018; Saleem, Burdett and Heaslip, 2019). However, women often do not have the purchasing power to obtain new technologies and are subject to different social pressures than men such as maintaining the purity of the kitchen and family meals (Agarwal, 1983; Bennett, 1983; Dutta *et al.*, 1997; Malakar, Greig and van de Fliert, 2018a). Traditionally, women in Nepal are the primary cooks, which means that women will be able to provide detailed insights into how TLAD biogas is adopted and socio-cultural norms around cooking navigated. Transitions to TLADs are complex as the main beneficiaries are not always the buyers.

2.3 Study site and methodological approach

2.3.1 Case study location and context

Fieldwork was conducted in four rural villages outside Pokhara, the second largest city in Nepal. Pokhara is situated in the hilly region of Nepal within the Kaski district of Province 4 (Figure 2.4), where high levels of biogas penetration have been reached (Damgaard, McCauley and Long, 2017).

There are seven provinces in Nepal and Table 2.1 compares Province 4 to other provinces across several categories. Province 4 has the highest food security of all provinces and falls somewhere in the middle of the seven provinces in terms of educational attainment and wealth. The Kaski district was the first to be declared open defecation free (ODF) suggesting high levels of sanitation awareness and adoption in the area (Water Supply & Sanitation Collaborative Council, 2019) although there are similar numbers of toilet-connected biogas in the hilly and Terai regions (Prakriti Consult Pvt Ltd, 2018). In diverse societies like Nepal, where adoption contexts will be shaped by ethnic group, geography, ecology and socio-economic status more research studies will be necessary to explore and generalise the TLAD adoption pathways identified in this paper (Bharadwaj *et al.*, 2021). This study represents how adoption pathways could be forged around socio-cultural norms in a geographical context that supports TLAD adoption. The study sites were selected due to the prevalence of functional TLADs, which was informed by using local actors with grass roots knowledge of construction locations.

All households had (or once had) cattle in stalls adjacent to their homes and practised subsistence agriculture. A total of 88% of participants listed agriculture or dairy farming as a source of income but no household listed it as sole income. Due to the proximity to Pokhara some had businesses or worked in the city. In addition, 30% of participants listed remittance income from abroad as a main or secondary form of income. Migration for work is common in Nepal with 47% reporting that at least one person had migrated from the household in the last ten years (Ministry of Health Nepal, New ERA and ICF, 2017). All participants in this study had a TLAD, and access to LPG or biogas (two TLADs were broken and no longer producing biogas), they also had drinking water within their premises and an improved sanitation facility (TLAD or septic tank if TLAD was no longer functional) and all were electrified. In comparison, at the national level, almost all households (95%) (rural and urban) have access to an improved source of drinking water and 69% of households have drinking water on their premises. Overall, 63% of households in rural areas use improved toilet facilities and 21% have no toilet facility. In total, only 11.5% of rural households use either LPG/natural gas/biogas compared to 77.3% of households that use wood fuels and 10.5% who use other solid fuels (Ministry of Health Nepal, New ERA and ICF, 2017).

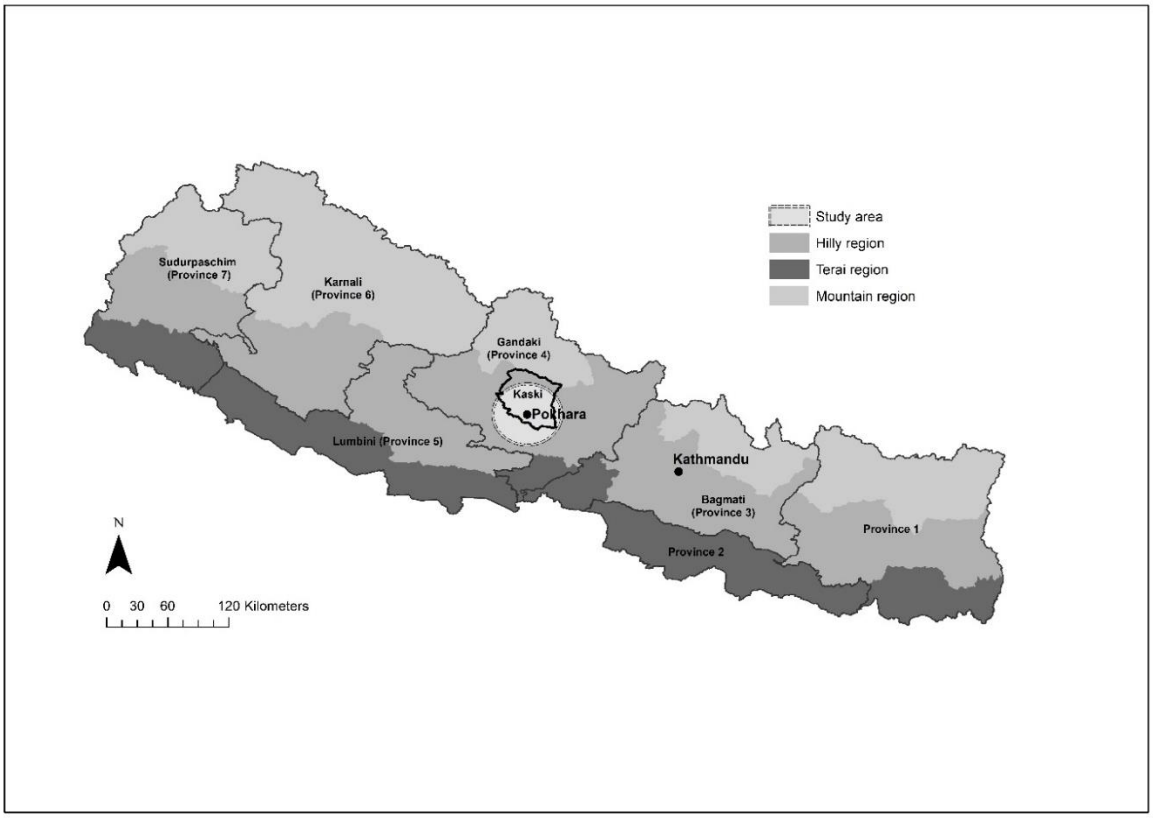

Figure 2.4: Map of Nepal and location of the study are sourced from (Open Data Nepal, 2021)

Table 2.1: *Demographic statistics for Province 4 compared to highest and lowest value of same category in other provinces* taken from the 2016 Demographic and Health survey in Nepal de facto population (Ministry of Health Nepal, New ERA and ICF, 2017)

Category (% of province)	Province 4	Lowest value across all provinces	Highest value across all provinces
Classed as severely food insecure	6	6	17.5
Classed as food secure	56	22.5	56
In the lowest wealth quintile	22	3.9	69.1
In the highest wealth quintile	20.4	2.6	41.6
With no education (F/M)	34.5 / 17.2	33 / 15	52.9/ 30.6
With higher than secondary education (F/M)	11.1 / 13.5	3.3 / 8.3	17.7 / 22.4

2.3.2 Data collection and analysis

Data collection was carried out in August 2019. Due to the explorative nature of the research questions, in-depth semi-structured interviews with 17 participants were used as the main data collection method to obtain detailed narratives of experiences of TLAD adoption. The interview schedules were structured around the adoption and use of TLADs within village and household socio-cultural norms. The questions were broad and did not attempt to direct participants to any one experience of TLADs to ensure decisions around adoption were collected from the user perspective without framing TLADs predominantly as an energy technology. Participant observations, pictorial evidence as well as conversations with two biogas technicians that had installed TLADs in some of the households visited were also collected and used to supplement the data.

The recruitment criteria for this study was necessarily broad due to the exploratory nature of the research questions; the overarching selection criteria was that participants had a functional or non-functional TLAD. Although producing generalisable results was not an aim of this study, to ensure different socio-demographic perspectives were captured, purposive sampling was applied to include both male and female participants from a variety of caste backgrounds. Of the 17 participants, 10 were female and seven were male (all were of Hindu faith, of whom 10 identified as Brahmin, five as Dalit and two as Janajati). The age of participants ranged from 24 to 80 with the majority being between 40 and 60. Interviews 1 – 11 were conducted in village 1 where the fieldwork team were met on arrival by a local male gatekeeper and introduced to other members of the village where they used a snowballing technique to recruit participants. Additionally, the female fieldwork team walked around the village independently recruiting female participants. This allowed for in-depth conversations with females where they could freely talk about what they considered important and how they use biogas. The research team visited villages 2, 3 and 4, which closely neighboured each other, with two male biogas technicians who introduced the fieldwork team to households where they had installed TLADs. The research team requested that they be taken to households from various ethnic backgrounds.

The interviews were conducted and recorded in Nepali and transcribed into English for thematic analysis using NVivo 12 software. Braun and Clarke's (2006) phases of thematic analysis were followed and the identified themes were taken from the explicit surface meanings of the data rather than looking beyond what participants said. The research objectives were used to generate initial themes. To reduce researcher bias, open coding was subsequently applied to the data to identify themes beyond the research questions. This ensured that the data was captured and coded from the participant's perspective. Because the interviews were loosely structured and the study aimed to collect qualitative experiences of TLAD adoption to describe and hypothesise how pathways to adoption can be forged and not to generate generalisable results, it was not considered appropriate to base analysis on any quantification of results (Kitzinger and Willmott, 2002). However, numbers of participants that contributed to a theme have been presented occasionally when it was felt appropriate to draw attention to, and contextualise, a particular finding for the reader. As this is a qualitative

scoping study, quotes have been included to recognise the diversity of participants and individual voices, and to add richness to the narratives provided (Datta, 2018). TLAD adoption has been rarely reported within academic literature therefore the authors felt that it was important to contextualise the lived experience of TLAD adoption from the participants perspectives (Eldh, Årestedt and Berterö, 2020). We have used quotes only to clarify or describe discussed themes, which is a common method for showcasing individual lived experiences of participants (Akintan, Jewitt and Clifford, 2018; Kumar, 2018; Malakar, Greig and van de Fliert, 2018a; Jewitt, Atagher and Clifford, 2019; Eldh, Årestedt and Berterö, 2020).

All participants gave written consent to participate. Ethical approval was obtained from the University of Stirling General University Ethics Board before commencement of fieldwork.

Figure 2.5: *TLAD in a rural household in Nepal. The components of the system are as follows; Cow dung and food waste inlet (A) Toilet (B) Animal holding close to house and digester (C) the main TLAD digester dome is situated underground (D).*

Figure 2.6: *Two cow dung and food waste biogas inlets. (A) shows the inlet with cow dung prior to users mixing with water and moving a stone that blocks the inlet pipe to the digester so the liquid mix can fall via gravity into the digester, (B) shows an empty cow dung and food waste inlet next to the toilet (blue door) and rice field behind the house, the slurry exits the digester and flows freely into the rice fields or can be composted first.*

2.4 Findings

2.4.1 Motivations for, and pathways to, adoption of TLADs

The socio-technical motivations for TLAD adoption were diverse. Respondents liked the improved health, cleanliness and reduced wood collection offered by the biogas compared to wood fuel and the reduced cost compared to LPG. Several female respondents also mentioned that when cooking with biogas they can leave to do other activities whereas with wood they must stay and tend it. All respondents felt that having a TLAD had made their lives more comfortable. However, with loss of cattle and migration from the villages TLADs were not universally seen as a long-term solution that people will keep investing in, although many appreciate TLADs for their sanitation benefits even without much biogas production.

The toilet connection specifically motivated six participants to adopt a TLAD, and others listed the toilet connection as a key benefit. The socio-technical reasons given encompassed practical aspects such as reduced smell and emptying costs as well as emotional benefits. Perceived benefits of the toilet connection were the same regardless of gender or caste, but female participants spoke in more detail about emotional benefits of the toilet connection.

> *"Emptying a latrine is stressful as we need to call a vacuum truck for emptying it but with TLAD there is no such issue, so it is more comfortable than a latrine" (Female #12 V2 Janajati 48)*

"Everyone has a TLAD here. Before there were no toilets at home and I had to go in the field for toilet [and] ... we had to cover our face with cloth which was really shameful and hard. After we had TLAD at home it is like a palace for us." (Female #9 V1 Brahmin 62)

Two participants from village 1 also mentioned that ODF programmes in the local area, that include fines for practicing OD, encouraged them to install a TLAD as a toilet. However, it was observed that, at least for some villagers, females were not allowed into participant's houses or to touch anyone when menstruating and in a state of pollution. This example shows that traditional practices around purity and pollution were not abandoned when TLADs were adopted, instead a new equilibrium has been found.

Adoption pathways were shaped by individual personalities and experiences. Analysis revealed the respondents to be on a spectrum from risk-takers or leaders to more hesitant adopters, but most could be loosely sorted into two groups. The remainder fall somewhere on the spectrum or not enough information was obtained to place them in a group. The first group of respondents (3/17) were risk-takers or leaders of TLAD adoption. They adopted a TLAD before they had experienced its benefits or before they had the support from their families and villages. For this group loss of social and cultural capital was not heavily factored into decision making and the decision to adopt was because they were convinced by the practical benefits of TLADs.

"Yes! That time was hard for me. People who used to pass by my home always used to say in this house they eat foods cooked from the [HE] smoke. I was not discouraged with villagers thought. I just wanted my life comfortable which it was after installing biogas.
I was a policeman and when I was in Pokhara I met people from a national biogas company they told me about TLAD in detail.... and I was convinced to have one." (Male #4 V1 Brahmin 60)

One of the participants in the risk-taker group was the wife of a local biogas technician (not a technician involved in this study), they were one of the first households to install a TLAD in their village area. In addition, another member of the risk-taker group was a policeman who met biogas company representatives whilst working, which suggests that risk-takers could include people that have had access to more detailed knowledge of TLADs. The second group of respondents (9/17) adopted a TLAD or chose to eat food cooked on biogas once TLADs had become more normalised for them through direct or indirect experience.

"Participant 17: My husband he used to hesitate to have food cooked in biogas. He used to ask me to cook in wood fire and said 'I will not eat food cooked from [HE]'

Husband of participant #17 who was present for the interview: I changed my mind over time. After a year it did not take long time since I had it in my home, I saw the process of biogas and I was OK" (conversation with Female #17 V4 Dalit 54 and her husband)

"Before when the first man used biogas [#4] as a fuel, we also did not like it. We used to think how they can eat [food] cooked from HE. But I found it interesting thinking of how that house is facilitated and I went to see it. After using LPG, we just thought about the process of LPG production…. and we convinced ourselves that biogas is also just a gas there is no difference to use biogas as a fuel" (Female #5 V1 Brahmin 40)

The comparison of biogas to LPG was mentioned by four participants and a 'gas is gas' mentality helped them to accept biogas. One participant mentioned that they did not know how LPG was made but thought it was very similar to biogas, and after observing priests using LPG he was convinced that biogas must be acceptable for religious cooking.

Many responses revealed that in general, the older generation needed more opportunities to observe TLAD before they overcame their socio-cultural reservations. However, some never accepted TLADs even after having one in their home.

"[In reference to his mother] I tried to convince her saying that LPG gas is the same so don't hesitate to eat [from] biogas but she used to say 'I have not seen the process of LPG production but I know about the production of biogas and that it is made from HE and dung so I cannot eat food cooked from biogas" (Male #6 V1 Brahmin 65)

Despite this, the initial adoption of TLAD systems took less time than transitions to using biogas for religious cooking. Participant 4 who was the first to get a TLAD in village 1 observed that within a year other villagers were installing TLADs. The husband of participant 17 also shared that within a year he had accepted having a TLAD at home but was not using biogas for religious cooking. Many other participants were also not using biogas for religious cooking despite having one for many years.

2.4.2 How socio-cultural norms shape the ways that TLAD biogas and slurry are used and the reasons why

The uses of biogas and slurry were restricted for some participants depending on a range of socio-technical influences. Biogas was used by all participants for some cooking practices although the majority across all caste groups did not use it for religious cooking practices, where cooked food is offered to the gods (Bajgain and Shakya, 2005), and some did not use it for boiling milk or ghee. These decisions were linked to tradition and socio-cultural norms.

"I don't use biogas for boiling milk and ritual cuisine because of traditional practices that have been going on since our ancestors" (Male #2 V1 Brahmin 51)

"I don't use biogas for ritual cooking because everyone in the village and our parents also say to cook ritual foods in wood fire" (Female #16 V4 Dalit 29)

However, three participants said they have no reservations using it for ritual cooking and a further two suggested they possibly use it or could use it.

"Before I didn't cook food for ritual or worshipping purposes. Now everyone is educated and open minded, so we don't hesitate to cook things used for worship also" (Female #5 V1 Brahmin 40)

Decision making about which cooking practices to use biogas for resulted in complex social interactions between the cook and their recipient. This often resulted in the cooks' selecting fuels based on what they were cooking, and for whom, adding consideration beyond food preferences. These individual aversions resulted from strong negative perceptions of biogas, such as the perception that food may be contaminated, rather than to negative experiences from cooking with biogas.

"My mother-in-law she doesn't like to eat bhaat [rice] cooked from biogas, but she will eat other things. It is because she thinks that the bhaat may absorb the smell of HE from the biogas, so I cook bhaat on LPG for her" (Female #16 V4 Dalit 29)

In one instance, strong individual feelings around biogas use resulted in deception, whereby one participant pretended to use wood fuel to appease a family member.

"When my mother was alive, she would only eat when the cooking utensils were black [cooking utensils are clean if biogas is used but black when wood is used]. I used to pretend by just showing her black utensil, but I used to cook in biogas" (Male #6 V1 Brahmin 65)

Slurry was discussed in less detail than biogas and had fewer restrictions placed on it. All participants that discussed the slurry indicated that it was a good fertiliser. However, some mentioned that they did not like to apply it when it touches the edible parts of food (author interpretation) such as vegetables and salad items. This decision was not articulated in the context of disease or bad experiences but just strong intuition that users had.

"I do not use [slurry] on vegetables because vegetables are smaller and I feel it will get directly absorbed in vegetables … so I just hesitate to use on vegetables" (Male #6 V1 Brahmin 65)

"Fertilisers are not used for vegetables because … of the toilet waste. [We] hesitate to use it though it is a good fertiliser. It's just a thought nothing else" (Male #1 V1 Brahmin 55)

It is evident that a wide range of socio-technical factors influence how biogas was used. A socio-technical interpretation of user choice relating to biogas, LPG or wood fuel is illustrated in Figure 2.7. The quantity of biogas produced by the TLADs made a significant impact on when biogas was used. Many participants communicated that they only used LPG and wood when there was not enough biogas. Biogas reduction due to winter temperatures, breakages or loss of cattle and manpower all affect how much is available. Many of these circumstances are brought about by social factors; loss of cattle and manpower can be a result of migration and changing lifestyles (Gyawali and Thompson, 2016) and repairs are carried out when they are affordable or when time can be prioritised.

"Since my biogas is only dependent on toilet waste…. it only lasts for half an hour, I cannot cook whole meals" (Female #16 V4 Dalit 29)

Operational knowledge was lacking, and a few participants stated that they had received training when the TLAD was first installed but none since, although they would like more. Cattle loss results in a significant drop in biogas production but only some respondents knew about alternative feedstock such as goat dung and food waste, and others indicated they are not knowledgeable or confident trying different feedstock. Four respondents mentioned they feed animal bones in the TLADs which the biogas technicians confirmed can cause blockages.

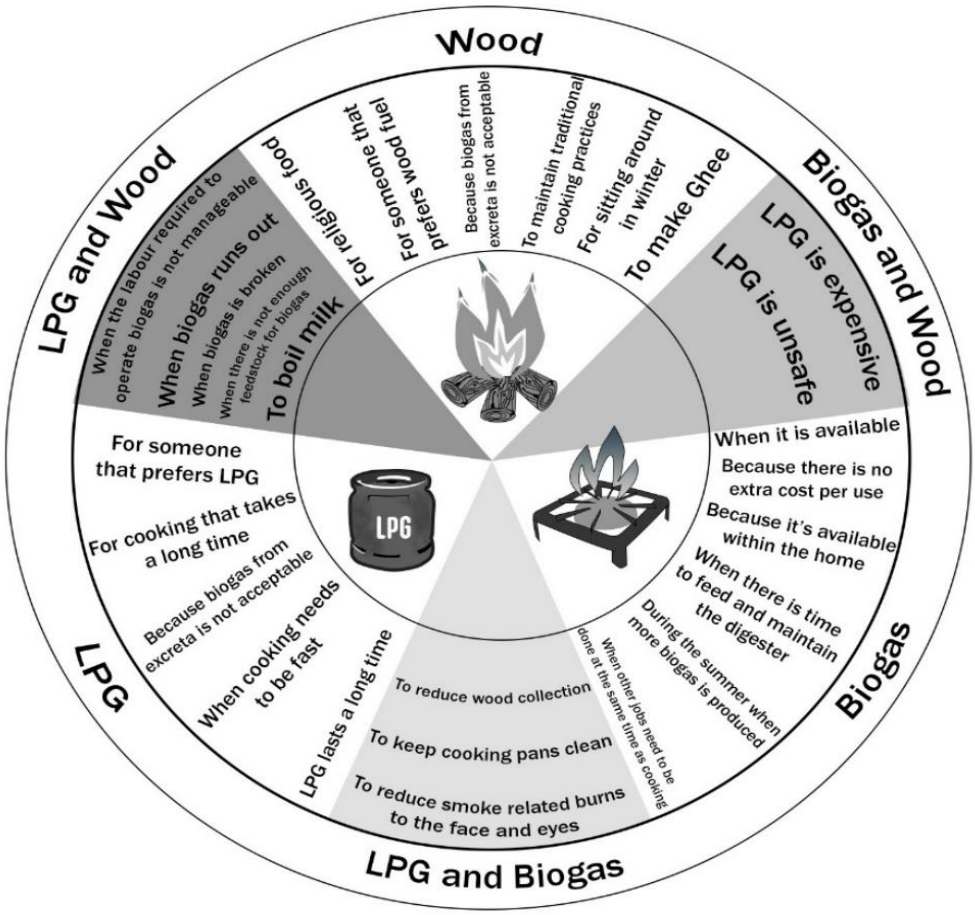

Figure 2.7: *An interpretative summary of why participants choose to use either biogas from toilet-linked anaerobic digesters, wood or LPG.*

2.4.3 Opportunities and Challenges

The socio-technical opportunities and challenges facing TLAD adoption are interpreted and summarised in Figure 2.8. The challenges most discussed by participants were affordability and technical issues commonly associated with domestic anaerobic digesters in general (Rupf *et al.*, 2015; Mittal, Ahlgren and Shukla, 2018) rather than anything specific to TLADs. Although socio-cultural resistance was articulated as a challenge by some and does restrict the use of biogas, it does not prevent users from perceiving TLADs as beneficial overall. The biggest challenge to the continued adoption and use of TLADs is the resultant loss of livestock and labour due to urbanisation and migration. This is compounded by a lack of knowledge of other feedstocks to boost biogas production and the prevalence and affordability of LPG.

The most frequently discussed opportunities specific to TLADs were the improved ease and comfort together with the potential for improved health and sanitation. Participants also mentioned the practicality of installing a TLAD rather than a DFAD and a separate toilet in terms of saving money and space. Combining messaging on OD and sanitation with TLAD and domestic biogas marketing presents an opportunity for TLAD adoption. The widespread use of LPG also presented

an opportunity for increased biogas adoption as people often compared biogas to the more socially acceptable LPG.

Figure 2.8: *Interpretive summary of the socio-technical opportunities and challenges to adoption of toilet-linked anaerobic digesters from the responses in this case study and arranged into most frequently and less frequently talked about by the participants.*

2.5 Discussion

Socio-cultural resistance is the most commonly reported barrier for TLAD adoption yet findings from this study suggest there are more complex socio-technical factors influencing acceptance or resistance. Biogas use was based on socio-cultural norms as well the quantity available, the slurry was used based on its performance and where users were confident using it. The rate of acceptance of both biogas and slurry varied with technical performance and perceived motivations (Jewitt, Atagher and Clifford, 2019). Usage was also continually monitored against shifting social norms as well as external stimuli (such as breakages, migration) and thus transitions are continually evolving rather than being driven by binary decisions. Adoption therefore cannot be considered as a one-off decision; there is the initial decision to adopt a TLAD and then the incremental secondary adoption decisions where biogas and slurry are used for more practices. We identified a possible connection between user knowledge, technical performance and available alternatives and the combined effect they have on biogas and slurry selection. For example, if there was insufficient biogas, and LPG or wood were available, there is little motivation or necessity to overcome socio-cultural norms and use biogas for religious cooking. Similarly, if alternative fertilisers were available there is little incentive to use TLAD slurry on vegetable and salad crops. Although outside of the scope of this study, the

application and use of slurry from TLADs is also a potential hazard to human health (Lohri *et al.*, 2010; Owamah *et al.*, 2014), and education on the safe handling and application of slurry could facilitate safer transitions. Previous studies have identified that factors such as technical performance, training and marketing are important in forging adoption and sustained use of domestic biogas (Sovacool, Kryman and Smith, 2015; Garfí *et al.*, 2016; Amuzu-Sefordzi *et al.*, 2018; Mittal, Ahlgren and Shukla, 2018; Nevzorova and Kutcherov, 2019). However, TLAD adoption should not be solely interpreted as a technological transition where socio-cultural acceptance or resistance occurs separately as it is not reflective of the adoption pathways that are evolving. Transitions to TLADs are socio-technical transitions whereby society and technological relationships co-evolve (Sovacool, 2014; Boamah and Rothfuß, 2018; Sovacool *et al.*, 2020) and due to the additional complex socio-cultural norms around HE, the socio-cultural interactions with TLAD adoption are heightened.

Even though socio-cultural resistance did not universally lead to permanent barriers to adoption, it played a significant role in shaping how the biogas and slurry were used. Notable, however, is that these socio-cultural sanctions were not interpreted as additional barriers to adoption in themselves. There was no evidence that TLADs were rejected because biogas could not be used for all cooking purposes or the slurry for all growing needs, instead, they were used for activities that were perceived as being within the bounds of socio-cultural norms. This can be compared to many other improved cook stove and fuel adoption studies that find adoption does not mean that the new stove or fuel replaces traditional fuels or even becomes the dominant one (Malakar, Greig and van de Fliert, 2018a; Bharadwaj *et al.*, 2021). It means that the adoption of TLADs cannot be assumed to result in maximal use of all the products and services TLADs offer. As Bennett's (1983) observations show the practicalities of Nepali Hindu village life are driven by ritual undertones. Still, the common interpretation of religion, which is grounded in Western ideals, sees it as something restricted to the personal and not the physical and political realms of life (Viswanath, 2010, 2014; King, 2011). This standpoint perpetuates the idea that technological and social evolution occur separately and that technologies solely fulfil a function (Pfaffenberger, 1992). When socio-cultural resistance encounters the practical realm of technology adoption and is interpreted through a lens of 'not belonging', it could be more easily interpreted as an insurmountable barrier to TLAD adoption. The unpacking of socio-cultural resistance in this study offers an alternative interpretation. It suggests that with time, socio-cultural norms shape adoption and use, as they do many other aspects of village life, but do not directly and irrefutably oppose it. Transitions to TLADs will be diverse socio-technical transitions that are unique to the context, but which may nevertheless follow similar pathways.

We have identified several pathways leading to the initial adoption of TLADs as well as increased or diversified use of TLAD biogas and slurry (i.e., secondary adoption) that are summarised and illustrated in Figure 8. These overarching factors, that shape the adoption environment from a top-down or wider contextual angle, are shown as 'higher-level influences' and 'drivers' (Figure 2.9). The first two identified pathways are 'risk-takers/ leaders', and

'demonstration', which encourages adoption as people see the benefits of TLADs. A third pathway identified was 'employment of local actors' who have TLADs within their own homes. The fourth and fifth pathways were identified as the subsequent 'demonstration' (or ripple) effect that the risk-takers and employed local actors have on their communities by showcasing the benefits of TLADs. Demonstration and trialability are key drivers for technology and product adoption (Rogers, 2003; Andersson, 2015; Roxburgh *et al.*, 2020). Due to the perceived risks TLADs pose to social and cultural capital, opportunities for trialability may be more important than with other technologies, and even with DFADs.

Risk-takers, participants who risked social and cultural capital in favour of adoption, played an important facilitation role in their communities adopting TLADs and using biogas, which suggests that they could be used to build pathways to acceptance (Damgaard, McCauley and Long, 2017). Due to these locally specific pathways to adoption, grassroots initiatives will be important for disseminating information about TLADs. However, initiatives that use local actors should be careful not to accentuate existing socio-cultural and economic disparities (Raha, Mahanta and Clarke, 2014; Bhattarai, Somanathan and Nepal, 2018; Cross, 2019) if they favour or exclude certain beneficiaries, and hetero- and homogenous community structure could affect adoption pathways (Negi *et al.*, 2018). The risk-takers were the only group willing to use biogas for religious cooking and thus were the only identified pathway to secondary adoption, although further research is required to determine how socio-technical factors co-evolve for secondary adoption. To encourage wider societal adoption of a new technology incentives are sometimes offered to influential members of a community to adopt and promote the technology to their neighbours (Bhattarai, Somanathan and Nepal, 2018). Whilst it is possible that the identified risk-takers could have received such incentives there was no evidence of this occurring in the villages visited. Nevertheless, with or without incentives, adopting a TLAD risks an individual's social and cultural capital (Bharadwaj *et al.*, 2021) due to opposing socio-cultural norms. Whilst no participant indicated they received such an incentive they did report social difficulties either within their household or village when they initially adopted TLADs. Therefore, the hypothesis that risk-takers could create pathways for community adoption of TLADs is valid, but more research must be conducted to test the hypothesis's generalisability and what factors beyond risk-taking motivated the first adopters of TLADs.

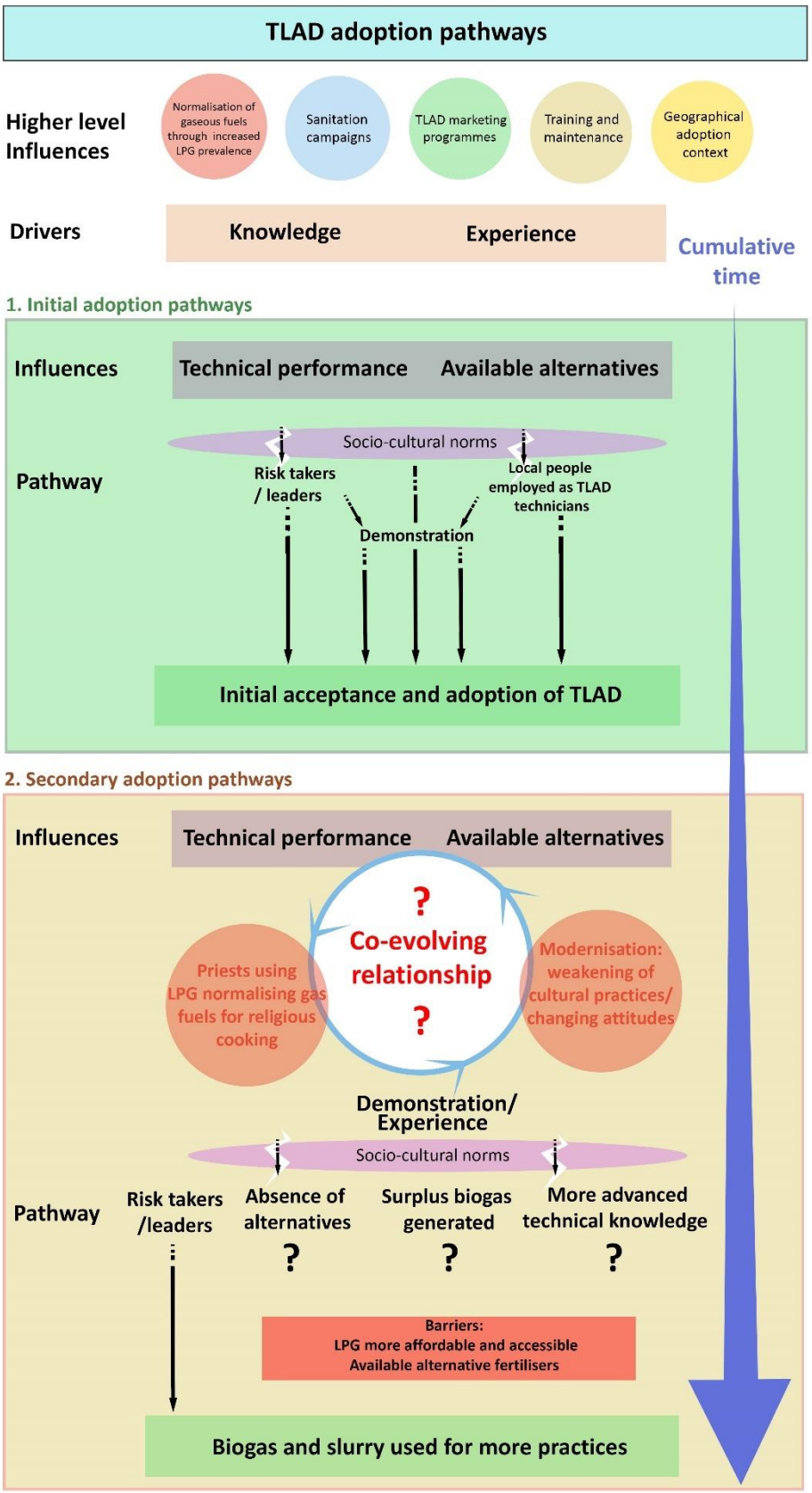

Figure 2.9: *Adoption pathways to initial adoption of toilet-linked anaerobic digesters (TLADs) and secondary adoption (increased or diversified use of TLAD biogas and slurry).*

This case study was not intended to determine demographic influences on TLAD adoption, and the size of the respondent group means that generalisations are not appropriate. The literature suggests that socio-economic backgrounds (caste and gender) would likely influence adoption pathways based on different motivations and perceived benefits and challenges. However, we found that caste and gender did not shape adoption pathways in an obvious way and risk-takers were represented by all caste and genders within this group. The findings from this case study suggest that more emphasis should be placed on understanding diversity amongst demographic groups and its subsequent effect on adoption. A significant amount of research on the effects of gender norms and caste on decision making originates from India, see for example references (Wang and Bailis, 2015; Vigolo, Sallaku and Testa, 2018; Cross, 2019; Patnaik and Jha, 2020; Kumar, 2021); however, the caste system in Nepal is different to India's and rural development has evolved differently in Nepal. The religion, caste or gender of the adopter might not always influence TLAD adoption as much as how religious they are or how caste and gender norms are embodied locally or generationally (older generations in this study required more opportunities to observe TLADs before they accepted them) as well as how much importance they give to how they, personally, are perceived. The adoption pathways that were identified were strongly dependent on individual personalities or core values (Contzen *et al.*, 2021) suggesting that pathways to TLAD adoption will be localised but could nevertheless, have patterns. Local participation in community forestry initiatives in Nepal, another successful grassroots development initiative, was negatively affected by economic and land inequalities amongst the groups as well as local perceptions of the initiative and its governance (Negi *et al.*, 2018). Ethnic diversity was not found to significantly impact success as it is so often reported to do in literature (Negi *et al.*, 2018). Supported by these results, the findings from this case study suggest that the adoption of TLADs will be affected by localised norms and differences within the community structure. Future research and dissemination of TLADs should now consider both overarching socio-cultural norms as well as localised norms and their effect on TLAD adoption pathways.

2.6 Conclusion and recommendations

Attempting to scale up transitions to sustainable livelihood practices and energy sources in LMICs is important for addressing the 'energy trilemma' (Cloke, Mohr and Brown, 2017), a term used to encompass the three challenges of energy security, climate change mitigation and energy access and equity. Thus, understanding transitions to decentralised renewable energy technologies (Damgaard, McCauley and Long, 2017; Islar, Brogaard and Lemberg-Pedersen, 2017; Heldeweg and Séverine Saintier, 2020) such as TLADs, which can facilitate more equitable access to energy as well as offer other sustainable benefits, is a necessity. Understanding consumer rejection of recycled products, which can elicit strong negative emotions is imperative if a more sustainable circular global economy is to be realised (Judge *et al.*, 2021). This paper is the first to inform an academic and wider understanding of socio-cultural resistance towards domestic TLADs and how pathways to adoption

evolve within the Hindu context of Nepal. It provides a strong grounding from which further studies can explore adoption pathways to HE derived products.

Demonstration and trialability were found to play a pivotal role in facilitating users in contextualising benefits and overcoming socio-cultural resistance. Good technical performance, as well as training and maintenance services, fostered sustainable use of TLADs, especially when they are competing with available alternatives. Caste and gender did not shape adoption pathways in an obvious way but generational differences, and people with risk-taking personalities who were the early adopters and catalysed community adoption, did. Thus, adoption pathways will be diverse, and we recommend that grassroots initiatives are utilised in disseminating TLADs. In addition to this, a top-down vision of TLADs is needed to inspire change from a grassroots level as users required information, time and opportunities for demonstration to accept TLADs. A programme without commitment to promoting and installing TLADs will likely not be successful. More research must be conducted to test the generalisability of the hypothesised adoption pathways in other Hindu contexts, within and outside of Nepal. When conducting research in other geographical locations studies should consider the impact of environmental and social contexts on motivating users to adopt TLADs. For instance, local sanitation campaigns, number of cattle and climatic conditions. This study refrained from framing TLADs as an energy technology in order to learn more of the holistic motivations users had for adopting TLAD systems. Biogas production and its use is often the primary focus of biogas programmes and now adoption pathways are better understood, further studies are needed to investigate how TLAD biogas is used and stacked with other stoves and fuels. Similarly, substantial literature has drawn attention to the difference between adoption and use of technologies (Malakar, Greig and van de Fliert, 2018a; Bharadwaj *et al.*, 2021), with post-installation functionality rates of household biogas ranging from 30-90% (Zuzhang, 2013; Ortiz, Terrapon-Pfaff and Dienst, 2017b). Further investigation is needed to assess the role of different adoption pathways in the sustainable use of the technology.

Socio-cultural resistance, in most instances, was found to be a complex socio-technical phenomenon that evolved with time and exposure to TLADs and although it was not a finite barrier to adoption (Andersson, 2015) it did significantly shape how TLADs, biogas and fertiliser products were used. The paper supports the idea that we must challenge and transcend the commonly conceived idea that culture stifles positive change, and; move towards seeing it as something that can enable adaptation (Few *et al.*, 2021). While we accept the findings from this case study in Nepal cannot be generalised, our results do suggest that a lack of research that specifically unpacks the important role socio-cultural norms play in the adoption of TLADs, has led to an over-simplification of the barriers to adoption, and resistance being interpreted as rejection. Researching TLADs separately from DFADs reveals specific information about the adoption of TLADs that had previously been overlooked within the literature. If TLADs are to be promoted in more effective ways, they must be acknowledged as a unique biogas technology that requires a different approach that understands localised socio-cultural norms and does not seek to homogenise groups.

2.7 Acknowledgements

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Chapter 3: Challenging perceptions of socio-cultural rejection of a taboo technology: Narratives of imagined transitions to domestic toilet-linked biogas in India

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J. Dickie, R.S. Quilliam, B. Campbell supervised the project. N. Boyd Williams designed the data collection tools with support from all other authors. N. Boyd Williams, R. Sarma, C. Haque, and T. Borah, carried out the data collection with support from D.C. Baruah. D. Raha and M.L. Clarke data provision. N. Boyd Williams analysed and interpreted the data. N. Boyd Williams produced the manuscript, and all authors commented on draft versions.

See Appendix 2 for semi-structured interview schedule used in Assam, India.

Abstract

Domestic toilet-linked anaerobic digesters (TLADs) recycle organic waste materials, including human excreta (HE), into a clean gaseous fuel and fertiliser product. Socio-cultural resistance is often used to explain local resistance towards TLADs due to the use of HE as a feedstock. However, through qualitative investigation utilising in-depth semi-structured interviews with potential TLAD users in Assam, India, the use of socio-cultural rejection to describe resistance towards TLADs was found to have homogenised local voices and framed them as resistant to technological change whilst ignoring diversity within groups. The narratives revealed resistance to be diverse and related to an individual's place, personal and social identity. Resistance to TLADs results from both socio-cultural as well as socio-technical concerns and is also potentially negotiable. Adoption of TLADs could be facilitated through opportunities such as technology demonstration, social group adoption and a greater perceived necessity. Inefficiencies in Assam's biogas implementation programme have been potentially overlooked due to too much attention being placed on household decision making and generalising socio-cultural resistance across the state. If TLADs are to be disseminated within Assam, authorities must work with communities and employees of the biogas programme to more widely renegotiate social norms around HE as a resource and not a waste product. More generally Assam's biogas programme is ineffectively identifying households with a need and motivation for

domestic biogas and we recommend revaluating the use of local contacts to identify households eligible for the national subsidy as well as the bias towards households with large numbers of cattle.

3.1 Introduction

Biogas is a renewable, gaseous fuel generated during the decomposition of organic materials in the absence of oxygen through a process called anaerobic digestion (Cheng, Li, Mang, Huba, *et al.*, 2014; Garfí *et al.*, 2016; Bharathiraja *et al.*, 2018). Domestic biogas, generated from common household waste streams such as animal dung, mainly cow or pig dung, along with food waste, agricultural waste, and in some cases, human excreta (HE) (Crook, 1976; Estoppey, 2010; Cheng *et al.*, 2011), can replace or reduce the use of polluting fuels for cooking such as wood, crop wastes and dung in open fires and inefficient stoves. These polluting fuels and practices are estimated to be used by 2.6 billion people globally, predominantly in low and middle-income countries (The World Health Organisation, 2020). Their use can lead to high levels of indoor air pollution and is estimated to cause up to four million premature deaths from associated illnesses (The World Health Organisation, 2020).

In addition to biogas, domestic anaerobic digesters also produce a liquid by-product called slurry that can be used as a plant fertiliser. The process of anaerobic digestion converts the nutrients in the feedstock into a form more readily available to plants (Alburquerque *et al.*, 2012). Domestic digesters do not produce adequate biogas for a family's needs from only household HE, so HE is co-digested with other feedstocks (Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022). When a household toilet is connected households can benefit from an improved sanitation system and increased biogas production (Bajgain and Shakya, 2005; Cheng *et al.*, 2011; Alburquerque *et al.*, 2012; WHO and UNICEF, 2017). Inadequate sanitation is estimated to cause 432,000 diarrhoeal-related deaths annually and is linked to the transmission of many water-borne and bacterial diseases such as cholera, hepatitis A, typhoid and polio (World Health Organisation, 2019).The run-off from open defecation (OD) and poorly managed sanitation facilities also pollute surface and ground water (Diane Coffey, Aashish Gupta, Payal Hathi, Dean Spears, Nikhil Srivastav, 2017; Prasad and Ray, 2019). Circular sanitation systems have gained attention in recent decades due to their ability to safely manage HE as well as return nutrients to agricultural soils (Mihelcic, Fry and Shaw, 2011). There is a risk that anaerobic systems do not remove all pathogens; however, users can be trained to safely handle and treat slurry, such as through composting techniques with other organic materials and drying (WHO, 2006; Fulford, 2015). Many countries across Asia, Africa and Latin America have implemented national household biogas programmes over the last fifty years (Bond and Templeton, 2011; Ghimire, 2013). Programmes in Nepal, China and Vietnam have included additional financial incentives for households if they connect their household toilet so human excreta is co-digested with other feedstock (Bajgain and Shakya, 2005; Cheng *et al.*, 2011; Huong *et al.*, 2014)

In India, the nationwide domestic biogas programme began in the early 1980s and is still in continuation today (Dutta *et al.*, 1997; Government of India: Ministry of New and Renewable

Energy, 2018). Its main objectives are to: provide clean cooking fuels and reduce the drudgery of women who predominantly collect the firewood and cook over smoky hearths; provide organic fertiliser and reduce dependency on chemical fertilisers; and improve sanitation in rural areas (Government of India: Ministry of New and Renewable Energy, 2020b). It is estimated that to date around 5 million domestic biogas units have been installed (Government of India: Ministry of New and Renewable Energy, 2021). However, sustainable implementation of the domestic biogas programme has been inconsistent with post installation functionality rates reportedly anywhere from 40 – 100% (Dutta *et al.*, 1997; Bhat, Chanakya and Ravindranath, 2001). This is not isolated within India and a wide range of reasons for why there can be unsustainable uptake of domestic biogas have been identified globally (Bond and Templeton, 2011; Zuzhang, 2013; Rupf *et al.*, 2015; Ortiz, Terrapon-Pfaff and Dienst, 2017a; Mittal, Ahlgren and Shukla, 2018; Pilloni, Hamed and Joyce, 2020). Many of these issues are technical and include poor construction and technical difficulties (Cheng, Li, Mang, Neupane, *et al.*, 2014), unsubstantial or absent follow-up services and lack of training (Rupf *et al.*, 2015; Garfí *et al.*, 2016). Globally, resistance can also arise due to socio-cultural reasons such as the rejection and apprehension of using of HE and animal dung derived products (Raha, Mahanta and Clarke, 2014; Khan and Martin, 2016; Dumont, Hildebrandt and Sempuga, 2021), handling of waste materials, and preferences towards fuels such as Liquid Petroleum Gas (LPG) that have more social status (Martí-Herrero *et al.*, 2015; Malakar, Greig and van de Fliert, 2018a). The use of HE as a feedstock has led to concerns around the safety of the biogas and fertiliser as well as the risk of social stigma due to associated social taboos (Khan and Martin, 2016; Amuzu-Sefordzi *et al.*, 2018; Mittal, Ahlgren and Shukla, 2018; Bharadwaj *et al.*, 2021).

Despite an additional subsidy offered for households that connect a household toilet by the Government of India (GoI) (Government of India: Ministry of New and Renewable Energy, 2018) from early on in the programme (Kharbanda and Qureshi, 1985; Consortium on Rural Technology, 1987), there are very few reports of successful adoption in contrast to the more prolific reports of socio-cultural resistance and rejection (Raha, Mahanta and Clarke, 2014; Muralidharan, 2017; Mittal, Ahlgren and Shukla, 2018). In places where there is socio-cultural resistance towards toilet-linked anaerobic digesters (TLADs) it is often described as an insurmountable barrier and used as a blanket term to describe local resistance (Sovacool and Drupady, 2011; Raha, Mahanta and Clarke, 2014; Muralidharan, 2017; Mittal, Ahlgren and Shukla, 2018; Nevzorova and Kutcherov, 2019; Sovacool and Griffiths, 2020). Socio-cultural resistance towards TLADs in India is largely unexplored or challenged within research despite the heterogeneity of Indian society and the fact that there are some examples of successful uptake within India (Kharbanda and Qureshi, 1985; Estoppey, 2010; Pawan K., 2014), and more in other Asian country contexts (Bajgain and Shakya, 2005; Cheng *et al.*, 2011; Huong *et al.*, 2014; Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022).

The hegemonic western and colonial approach to technological development leaves little space for working with diverse communities or cultural values (Stirling, 2019). Often, the technology becomes the main focus of a development initiative and, when users or local people demonstrate

resistance towards it, the responsibility is placed on them. Little attention is given to understanding the wider context and reasons for resistance (Abdelnour, Pemberton-pigott and Deichmann, 2020; Bharadwaj *et al.*, 2022). For example, in the Global North, local actors that resist technological development have been labelled as having a "Not in My Back Yard" (NIMBY) attitude defined as "*An attitude ascribed to persons who object to the siting of something they regard as detrimental or hazardous in their own neighbourhood, while by implication raising no such objections to similar developments elsewhere"* (Wolsink, 2006). This assignment of a simple term to describe a complex paradigm is relatable to the use of socio-cultural rejection, a term more commonly used in Global South contexts. The use of NIMBYism has been criticised for delegitimising local opposition, obscuring the actual causes of opposition by 'othering' local actors and pejoratively simplifying their concerns into unjustified and selfish resistance (Wolsink, 2006; van der Horst, 2007). This narrative has pitted the science community against irrational users (Qian and Leong, 2016) and been used to dismiss indigenous and local emotional and psychological connections with the land and way of life (Edelstein and Kleese, 1995).

People's lived and told experiences have provided insight into and helped reframe the dominant understanding of NIMBY opposition (Creswell, 2013; Phillips and Dickie, 2014; Moezzi, Janda and Rotmann, 2017). These narratives are critical in both understanding and driving transitions to new technologies and subsequently are becoming a more common research method in energy and sustainable transitions research (Moezzi, Janda and Rotmann, 2017). Narratives have revealed that local resistance towards new technologies can originate from emotional attachments to personal and place identities, misunderstanding of the technology, lack of trust in the developers, negative past experiences and lack of perceived benefits among many others (Soland, Steimer and Walter, 2013; Devine-Wright and Batel, 2017; Boso *et al.*, 2020a). Narratives have helped explain the gap between people's pro-environmental attitudes in contrast to their personal unsustainable practices and unwillingness to change (Flynn, Bellaby and Ricci, 2009). This is important when it comes to sanitation or recycled products, which are considered environmentally beneficial but also taboo and accompanied by disgust reactions (Leong, 2020; Meng and Leary, 2021). For example, waste-to-energy facilities recycle and valorise household waste streams but are often perceived as a stigmatised technology. Acceptance of stigmatised technologies near to where people live has been problematic. People have explained that they have concerns around smells and adverse effects on health as well as negative impacts on property values, and overall, they believe stigmatised technologies oppose how they envision their local environment developing (Edelstein, 2004).

Assam is the largest state in the North East of India (Weiner, 1983) where agriculture and livestock farming play a significant role in the economy (Government of India: Ministry of Statistics and Programme Implementation, 2013; Institute of Social Change and Development, Institute for Human Development and Assam, 2014) suggesting ample biogas feedstock available. However, out of the 6.4 million households in Assam (Government of Assam, 2022) approximately 2.16% (138.5 thousand) households have installed domestic biogas (Government of India: Ministry of New and

Renewable Energy, 2021) and more broadly, only 42.1% of the population use clean fuels for cooking (Government of India: Ministry of Health and Family Welfare, 2020). In 2020/2021 the national biogas programme had a target of building 3400 domestic biogas digesters of all types, not specifically TLADs, in Assam (Government of India: Ministry of New and Renewable Energy, 2020a) and approximately only 12% were constructed (Government of India: Ministry of New and Renewable Energy, 2021). It is therefore important to explore perceptions of biogas technology in the area to understand why biogas is not benefiting more households.

Specifically, our objectives were to determine: 1) perceptions of the challenges and benefits that TLADs and their products and services can offer users; 2) the origins and nature of socio-cultural resistance towards TLADs; 3) the motivations and drivers for changing attitudes to TLADs and how potential pathways to adoption could develop and 4) to obtain a contextual overview of how Assam's biogas programme is supporting sustainable uptake of biogas technology and the connection of household toilets.

Here, we hypothesise that the use of socio-cultural rejection when describing failed adoption of TLADs is masking the complex and diverse reasons that underpin local resistance. In this study, we thematically analyse the narratives of potential adopters of TLADs in Assam, India, to better understand local socio-cultural perceptions towards TLADs. We look for relationships between attitudes towards TLADs and willingness to adopt the technology as well as how potential users describe personal and social-norms and their impact on decision making. We collectively analyse narratives to search for commonalities as well as contradictions between and within them, to make sense of how pathways might develop to adoption of TLADs. This study is the first to enrich a better understanding of the way socio-cultural resistance towards TLADs can be understood in a heterogeneous Indian context.

3.2 Background

3.2.1 Biogas in India and Assam

The promotion of domestic biogas in India is now managed under a programme called The New National Biogas and Organic Manure Programme (NNBOMP), which is run by the Ministry of New and Renewable Energy (MNRE). Subsidies and financial assistance are provided by the MRNE, centrally through a top-down model (Mittal, Ahlgren and Shukla, 2018) and assigned to each state (Government of India: Ministry of New and Renewable Energy, 2020a). The State Nodal Agency (SNA) for each state oversees organising construction, training and maintenance and subsidy allocation along with Khadi and Village Industries Commission, who have promoted biogas for rural development since the 1960s (Kharbanda and Qureshi, 1985), and Biogas Development and Training Centres. The SNA is managed differently in each state, in Assam it is run from the Department of Environment and Forests whereas in neighbouring state Meghalaya for example, it is managed within the Meghalaya Non-conventional & Rural Energy Development Agency.

Despite the additional subsidy provided for household toilet connections, numbers of TLADs in India are unknown but assumed to be low due to reports of socio-cultural resistance. There are few successful TLAD adoption case studies researched within India (Dandekar, 1980; Estoppey, 2010) however, one successful case study is in Gujarat (Pawan K., 2014; DownToEarth, 2019b) where a dairy cooperative and partners invested significant effort into sensitising users over time with the aim of improving local sanitation and biogas outputs (Pawan K., 2014). Many of the beneficiaries overcame initial resistance and later adopted TLADs. In neighbouring country Nepal, where approximately 79% of nationwide domestic biogas users have connected their toilets (Prakriti Consult Pvt Ltd, 2018), long term engagement was required to achieve this level of acceptance (Shakya, 2002; Bajgain and Shakya, 2005; Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022).

The products and services that are offered to users of TLADs can be divided across the sectors of energy, fertiliser and waste management/ sanitation and all have their own market competition. Liquid petroleum gas (LPG) and kerosene are clean cooking fuels subsidised and available in the public distribution system. However, these programmes are criticised for reasons including; not reaching vulnerable households and rural areas; failing to result in long term use; and being vulnerable to fraud among others (Bansal, Saini and Khatod, 2013; Rao *et al.*, 2020). Despite these challenges, the use of clean cooking fuels has increased from 25.1% to 42.1% between 2015/16 and 2019/20 in Assam (Government of India: Ministry of Health and Family Welfare, 2020). Chemical fertilisers are also subsidised in India (Government of India: Ministry of Chemicals and Fertilisers, 2019; Bhardwaj, 2020) although there have been efforts made to encourage chemical fertiliser sellers to co-market compost generated from municipal waste to help clean-up cities and replenish soil carbon (Government of India: Ministry of chemicals and fertilisers, 2020). The Swachh Bharat Mission (SBM) has increased household use of improved sanitation facilities across India with Assam's coverage increasing from 49% to 68.6% between 2015/16 and 2019/20 (Government of India: Ministry of Health and Family Welfare, 2020). Biogas toilets are also promoted in the SBM information (Government of India: Ministry of Drinking Water and Sanitation, 2014) but the predominant design that is promoted, installed and subsidised across India, is the basic pit latrine. Pit latrines only capture HE without containing and treating it and therefore HE is often still reaching the environment and waterways (Jewitt, Mahanta and Gaur, 2018; Prasad and Ray, 2019). There is also evidence that the SBM is not resulting in long-term behaviour change and some areas that have been declared OD free are still engaging in OD (Leong, 2020). Consequently, GoI are promoting and subsidising competing technological solutions through a top-down system (Bansal, Saini and Khatod, 2013). How these alternative products and services are integrated with the biogas programme will likely affect perceptions, and uptake, of TLADs (Bansal, Saini and Khatod, 2013; Mittal, Ahlgren and Shukla, 2018).

3.2.2 Assam cultural, geographical and political context

In order to benefit from biogas technology, households often must have land, cattle dung and/or other feedstock, as well as the financial means to invest in one (Raha, Mahanta and Clarke, 2014; Das, Goswami and Hazarika, 2017; Mittal, Ahlgren and Shukla, 2018). Attainment of these criteria is influenced by a household's demographics, geographical location as well as access to national and state policies that can support households in attaining them. Assam is considered one the least developed states in India despite its high biodiversity and forest wealth, as well as mineral and oil reserves, and tea production and tourism. Land ownership, which facilitates access to services such as bank loans and agricultural policies (Singh and Datta, 2013), is inequitably distributed in contemporary Assam due to a legacy of colonial policies (Handique, 2010). Twenty percent of the people hold about 70% of the total cultivable (Institute of Social Change and Development, Institute for Human Development and Assam, 2014).

Rural development policies from central government have sporadically reached Assam. During colonial rule the north east states of India were segregated from the rest of 'mainland' India and treated as separate. After independence it is thought that to some degree this gap between the north east and central policy was sustained (Murshid, 2016). Colonial rule left India facing severe food shortages and so quickly strengthening the agricultural sector was made a priority. During the 1960's the government invested in agricultural development during a period called The Green Revolution. The investment increased the overall wealth and productivity of India's agricultural industry but, nevertheless, Assam scores very low on green revolution indicators such as fertiliser consumption, machinery use and accelerated growth (Singh, 2009). Minimum support price (MSP) is set and paid for by central government to ensure that farmers will make a minimum price on specific crops to protect them from market fluctuations. However, farmers in Assam were found to have very little awareness of MSP or where to sell their crops for compared to other states that sell a large amount of crops at MSP prices and plan planting on these guaranteed prices (NITI Aayog, 2016).

The dairy sector in India is important in helping to alleviate poverty and inequality as the livestock population is more equitably distributed than the land (Singh and Datta, 2013). In a 2013 survey, Assam along with Punjab, had the greatest number of households reporting a major source of income from self-employment livestock farming (Government of India: Ministry of Statistics and Programme Implementation, 2013). However, unlike other states involved in dairying, Assam has small dairy cooperatives (Sirohi, Kumar and Staal, 2009). Dairy cooperatives are successful in supporting dairying by providing animal welfare, organisation, product valorisation (Singh and Datta, 2013; Bayan and Cell, 2020) and even, in the case of Gujarat, adoption of biogas including TLADs (Pawan K., 2014).

The handling and reuse of HE in India is associated with cultural taboos. The dominant religion in India, Hinduism, has a caste system of social hierarchy rooted in purity and pollution and linked to traditional occupations (Gorringe and Rafanell, 2007; Wang and Bailis, 2015; Subedi, 2016;

Burt *et al.*, 2021). The undertaking of polluting jobs such as sanitation work has historically been forced on one of the lowest caste groups known as Dalits. Some people of higher castes will prevent Dalits from entering their homes and will not accept some food or water from them to avoid pollution (Luthi, 2016). In India, group membership and social status can ensure access to resources such as energy, land and water, in part due to higher castes often having higher paying professions and social status (Patnaik and Jha, 2020). Access to a variety of energy technologies in Hindu contexts have been found to favour higher castes (Raha, Mahanta and Clarke, 2014; Kumar, 2015; Cross, 2019). In Assam, local village contacts, often high caste Hindu males, were found to decide who receives subsidies for biogas and so allocation, rather than simply being about eligibility criteria, is often based on social networks (Raha, Mahanta and Clarke, 2014). Using local social networks to distribute energy technologies can exclude households with lower socio-economic status from accessing them (Kumar, 2018; Cross, 2019). Cultural taboos could significantly affect adoption of TLADs where adoption might result in negative socio-political consequences (Burt *et al.*, 2021), for example, adopters of TLADs can take on a social cost if their social contacts are reluctant to visit their household or are hesitant to eat food cooked with the gas (Bharadwaj *et al.*, 2021). Adopting a TLAD could reduce or reinforce lower socio-economic status for a household due to association with sanitation work and ritual pollution (Srinivas, 2009).

Religion and culture are not analytical categories (Lambek, 2013; Spies, 2013) and thus socio-cultural resistance towards the reuse of HE is likely to be diverse. However, there is surprisingly little information on what socio-cultural resistance is, how diverse it is and how it can influence decision making around the adoption of HE recycled products like TLADs in various contexts. There is a need to better understand the diversity of socio-cultural resistance towards TLADs within India.

3.3 Methodology

3.3.1 Case study location and context

Fieldwork was conducted across 13 rural or peri-urban villages in four districts (Sonitpur, Kamrup, Morigaon and Karbi Anglong) of Assam, (Figure 3.1). Table 3.1 compares Assam to the rest of India across a number of household indicators taken from the latest 2015/2016 full National Family Health Survey of India (Government of India: Ministry of Health and Family Welfare, 2017b). Assam is just below the all-India average for electrification but has a 20% higher average for solid fuel wood used for cooking and it is close to the all-India averages for improved sanitation and drinking water sources. Assam is below the all-India average in terms of wealth. Assam has almost three times the average Muslim population of the all-India average and subsequently less people that identify as Hindu. The Brahmaputra valley was selected for the majority of the data collection because the fertile lands support many people in agricultural pursuits, making them suitable candidates for domestic biogas due to the availability of feedstock and use for the slurry fertiliser. There is also a large

population of dairy farmers who have dung-fed anaerobic digesters (DFADs), without toilet connections, and who are therefore familiar with biogas technology and Assam's biogas programme. Karbi Anglong is not within the Brahmaputra valley but was included to add the perspectives from a scheduled tribe (ST) district (Béteille, 2006). STs are protected groups and have a low representation as biogas owners in India despite the additional subsidies for ST and scheduled caste groups (Das, Goswami and Hazarika, 2017; Government of India: Ministry of New and Renewable Energy, 2018).

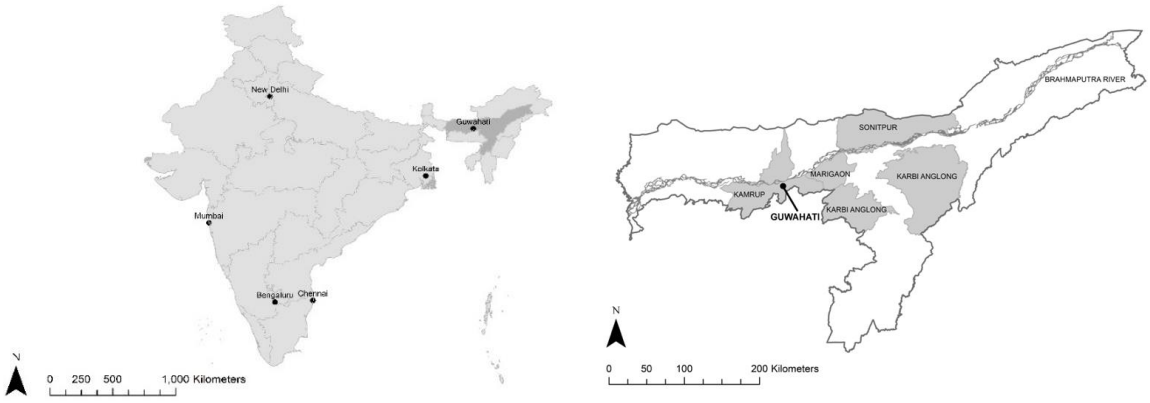

Figure 3.1: *a) Map of India with the state of Assam highlighted in dark grey b) map of Assam detailing with the Brahmaputra and districts included in this study adapted from (Diva-GIS, 2022).*

Table 3.1: *Household indicators taken from the 2015/2016 National Family Health Survey Assam vs National India average*

Household indicator	**Assam (%)**	**India average (%)**
With electricity	78.2	88.2
Improved source of drinking water [a]	83.8	89.9
With an improved sanitation facility [b]	47.7	48.4
Using solid fuel for cooking	74.2	54.7
Living in lowest wealth quintile	24.4	20
Living in highest wealth quintile	6.1	20
Hindu	63.8	81.4
Muslim	32.5	12.5
Christian	3.3	2.7
Sikh	0	1.6
Neo-Buddhist	0.2	1
Jain	0	0.2
Other	0	0.5

[a] Piped water into dwelling/yard/plot, piped to neighbour, public tap/standpipe, tube well or borehole, protected dug well, protected spring, rainwater, tanker truck, cart with small tank, bottled water, community water filtration plant.

[b] Flush to piped sewer system, flush to septic tank, flush to pit latrine, flush to don't know where, ventilated improved pit (VIP)/biogas latrine, pit latrine with slab, twin pit/composting toilet, which is not shared with any other household. This indicator does not denote access to toilet facility.

3.3.2 Data collection

Data for this study was conducted in February 2020-January 2021. Due to the explorative nature of the research questions, in-depth semi-structured interviews with 40 participants from different households were used as the main data collection method to obtain detailed narratives of perceptions of, and intentions around, adopting TLADs. The questions were kept necessarily broad to allow participants to narrate thoughts, feelings and experiences of a socio-cultural or technical nature when they thought relevant. The interview guides included open ended questions on the following topics: experiences of DFADs including how the biogas and slurry are used; perceptions of TLADs; what could make TLADs more acceptable; and experiences and knowledge of the NNBOMP.

Table 3.2: *Participant distribution of data set 1*

District	Village	Number of participants	Brief description of village context
Sonitpur	Village 1	10	Villages are located in close proximity to each other. Villages are predominantly Hindu.
	Village 2	5	
	Village 3	3	
Morigaon	Village 4	15	Most households in Village 4 had DFADs due to cattle rearing being a large source of income, with an active local dairy co-op. Village was predominantly Hindu.
Karbi Anglong	Village 5	3	Villages are in a Scheduled Tribe district. Villages more culturally diverse compared to the villages in Sonitpur and Morigaon. Cattle ownership was much lower.
	Village 6	4	

The study villages were selected based on their characterisation as rural, accessible by road and having a mixture of households that had and or did not have domestic biogas. Convenience sampling using a door-knock campaign was employed (Akintan, Jewitt and Clifford, 2018; Boso *et al.*, 2020b). Interviewers approached different typologies of households to ensure both male and female participants of various ages and religious backgrounds were interviewed. Fieldwork was assisted by local gate keepers and translators who both facilitated as well as limited access to households, due to their personal socio-cultural backgrounds, but were invaluable in having in-depth conversations with participants and contextualising the socio-cultural dynamics of the various villages. Of the 40 participants 14 were female and 26 were male and 62.5% owned or had once owned a DFAD (broken

or decommissioned) and none had a TLAD. Hindu's compromised 82.5% of the sample and of these 28 were Nepali and 5 were from a ST. Three participants were Muslim, three were Christians (two Adivasi (Béteille, 2006)) one was a Buddhist and the age of participants ranged from 19 – 68 years of age. One participant was also a trained biogas technician.

To answer research objective 4 a secondary data set (data set 2), was used to supplement the first (data set 1). Data set 2 was collected in 2013 and consists of 60 semi-structured interviews with owners of functional and non-functional DFADs and an interview with the Senior Officer of the SNA. Participants were asked about their experience and satisfaction around usage and non-usage of DFADs. A full methodology for data collection can be found in Raha et al (Raha, Mahanta and Clarke, 2014). The two data sets were used to evaluate how well the NNBOMP supports people in 1) adopting and accepting TLADs and 2) sustainable adopting and using DFADs.

The majority of the data collection for both data sets was conducted in the Brahmaputra valley where historically many Nepali Hindus settled due its suitability for cattle rearing (Devi, 2007). Nepali Hindus thus make up 70% of data set 1 and 100% of data set 2.

3.3.3 Analysis

The interviews for data set 1 were conducted and recorded in Assamese, Nepali and Karbi and transcribed into English for narrative analysis using NVivo 12 software. For the basis of this study it was understood that 1) people construct and internalise narratives to make sense of their lives, 2) these autobiographical narratives have enough meaning to be told to others as accounts, and 3) these narrative accounts can be analysed for content themes (McAdams, 2015). Thus, thematic narrative analysis was applied where the aim was to extract themes within the narratives (Creswell, 2013). The identified themes were taken from the explicit surface meanings of the data rather than looking beyond what was told. The analysis aimed to find commonalities and contradictions within and between narratives to make sense of how participants explain their decision to accept or reject a TLAD or could be convinced to adopt one at another time. The hypothesis was that socio-cultural resistance would be found to be inadequate in describing and explaining users' resistance to TLADs and that it would not be a finite barrier to adoption. This hypothesis was used to shape the research questions and the interview guides to prompt users to explain socio-cultural resistance in detail. Thus, the research questions were initially used to guide the thematic narrative analysis and to reduce researcher bias, open coding of the data was subsequently applied to the data to identify emerging themes beyond the research questions. Because the interviews were semi-structured and the aim of the study was to collect qualitative perceptions of TLADs and not to create generalisable results, it was not considered appropriate to base analysis on any quantification of results. However, numbers of participants that agreed with a theme have been used occasionally in the results when it was felt appropriate to draw attention to and contextualise a particular finding. All participants gave consent to participate. Ethical approval was obtained from the University of Stirling General University Ethics Board before commencement of fieldwork.

Data set 2 was translated from Hindi into English for thematic analysis using NVivo 12 software. Braun and Clarke's (2006) phases of thematic analysis were followed and the identified themes were taken from the explicit surface meanings of the data. Research objective 4 was used to guide the initial coding followed by open coding to remove researcher bias. The lead researcher discussed the identified themes as well as the narrative themes from data set 1 with the lead researcher who collected data set 2 to ensure both researchers agreed with common themes that had come out of the data and that it accurately represented what the participants had discussed.

One limitation of the study is that remote villages not easily accessible by road are not represented due to logistical challenges. Additionally, Hindus are over-represented due to their numerical dominance in the study villages, experience and knowledge of DFADs and willingness to participate. Other religious groups were less represented although more Muslim households were approached by interviewers but declined when they learnt the interviews were about biogas. Further research should investigate why some Muslims households did not want to speak about biogas. Additionally, perceptions of TLADs and attitudes towards adopting one could have been misinterpreted from participant responses due to the topic being of a very personal nature, and intertwined with locally specific socio-cultural norms. Longer interview time frames and focus groups may produce more nuanced narratives and interpretations due to greater opportunities for participants to reflect and discuss TLADs.

3.4 Results and discussion

3.4.1 Summary of perceptions of TLADs - positive, undecided and negative

To obtain an initial overview of perceptions, participants were thematically categorised as either having overarching positive (indicated they would adopt or consider adopting with some identified challenges), negative (indicated they would never adopt or use a TLAD) or undecided (neither positive nor negative) perceptions and are presented in Table 3.3 by demographic group. This was done only to gauge diversity of perceptions towards TLADs, the numbers are not statistically significant or intended to represent demographic groups. Participants were not universally opposed to TLAD adoption and socio-cultural resistance cannot be accurately used to explain local resistance to TLADs. Within this qualitative study, perceptions of TLADs are not related to the gender, age or religion of the participants nor to the highest educational attainment of the household. Belonging to a high Hindu caste was similarly not linked to attitudes towards TLADs as perceptions were almost evenly split between positive and negative. Although generalisations cannot be made the table suggests older participants could have more positive perceptions of TLADs, which is the opposite of other literature on TLAD adoption it and should be investigated further (Fulford, 2015; Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022).

Table 3.3: *Responses (positive, negative or undecided) by demographics from data set 1*

Response	Male %	Female %	Age group 19-30 %	Age group 31-50 %	Age group 51+ %	Hindu %	Other religions (Muslim, Christian and Buddhist)[1] %
Positive	42	43	33	33	50	42	43
Negative	42	50	44	44	45	45	43
Undecided	15	7	22	22	5	12	14
Total number of participants (/40)	26	14	9	9	22	33	7

[1] Although the results in this table were not used for generalisation Muslim, Christian and Buddhist responses were not presented separately due to such small samples from each group

3.4.2 Perceived socio-technical benefits and challenges around TLAD adoption and use of excreta derived biogas and bio-fertiliser

Literature has shown that adoption, or transitions, to sustainable technologies and practices are inherently socio-technical because they involve alterations to technology, policy, markets, user practices and cultural meaning, among others (Geels, 2011). As literature on TLADs is relatively sparse, with socio-cultural rejection often cited as a main adoption barrier, participant perceptions of TLADs in this study were broken down and organised into socio-cultural, socio-technical and technical benefits and challenges, and are presented in Table 3.4. This provided a basis to better understand the origins of people's perceptions of, and resistance towards, TLADs that is expanded on within this section. Although the number of participants with overall negative or positive perceptions of TLADs were similar, altogether participants perceived a greater number of challenges than benefits. Convincing people that the benefits of TLADs outweigh the challenges (Huijts, Molin and Steg, 2012; Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022), as with transitions to other products and practices that recycle HE, will require a significant amount of sensitisation over time (Pawan K., 2014; Andersson, 2015; Hamid and Blanchard, 2018).

No social benefits associated with TLAD adoption were given suggesting that there is no perceived social value in adopting a TLAD. This is in contrast to TLAD adopters in Nepal, who discussed how shameful it was to practice OD and how improved their situation is now (Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022). All participants in this study had a sanitation solution that may explain why no one perceived social value in adopting a TLAD. Many participants discussed how increasing environmental pressures could pressure them to adopt TLADs in the future.

However, no one expressed positive perceptions towards TLADs based on a perceived environmental good or associated positive emotions with adopting an environmentally beneficial technology (Manika *et al.*, 2021). Many participants did not see the benefits of attaching the toilet in terms of improved sanitation, and no one gave scientific explanations around containment of pathogens or how TLADs are better than pit latrines or septic tanks. Some people agreed that having a TLAD that does not require emptying would be a benefit, but most were happy with their sanitation solution and means of emptying it, which for many was calling a sweeper[2]. Many people did not perceive benefits in the form of increased nutrients in the slurry and biogas output when the quantity of HE that a family produces will be small. Education around the importance of sanitation that extends beyond capture to safe containment and treatment could be lacking in the area. Further research could confirm if households that want an improved sanitation system, have large family groups using the household toilet and/or lower numbers of cattle, perceive more benefits in adopting TLADs.

Table 3.4: *Summary of participants perceived benefits and challenges of toilet-linked anaerobic digesters specifically to the toilet connection and not general to biogas technology, listed in order of most discussed* [1]

Perceived benefits to uptake/adoption	Perceived challenges to uptake/adoption
Technical • Improved sanitation and cleanliness • Disease containment (perception that diseases will exit in the gas) • Economical (utilising waste, no separate toilet, save on LPG cost) • Increased biogas production • Improved fertiliser (more nutrients) • Additional source of biogas if cow dung becomes scarce	Technical • Toilet connection is unnecessary as there is adequate cow dung available • HE is not available in sufficient quantity to produce enough biogas for a household • Additional cost of connecting a toilet is not worth it • Existing sanitation/toilet is preferred • Lack of available space • LPG is easy to obtain
Socio-technical • Labour reduction as toilets will not have to be emptied and cleaned out • Less odour than from existing sanitation/toilet facility • Maintaining and cleaning a TLAD compared to existing toilets will be better work for sweepers[2] • Environmental benefits • Referring to urban centres (not rural) TLADs would be useful cleaning up large amounts of HE	Socio-technical • Concerns that the kitchen and food will smell and taste like the toilet and agricultural fields will be full of HE • Visually and physically connects the toilet with the kitchen which leads to socio-technical concerns • Not suitable for rural areas due to social norms and risk of social exclusion, availability of cow dung and low concentrations of HE compared to urban settings • Maintaining and cleaning TLAD would be a problem as it is considered dirty work • Touching the slurry will be a problem • Eating food cooked on biogas made from TLAD biogas is ritually and physically polluting/dirty • Unsure of benefits due to lack of experience with TLADs • HE perceived as a waste • Not perceived as modern and other more practical options will be available in the future
Social • None given	Social

	• TLADs oppose religious practices and sentiment and will not be accepted in conservative society • Risk of social exclusion and judgement • Older generation will not accept them • Reluctance to be the initial adopters due to risk of social exclusion and perception that it will take a long time for TLADs to be accepted • It is a crime/against customs to mix HE with cow dung • Younger gen will not want to do the hard work they will want LPG or other alternatives

[1] *Responses were considered (i) technical when reasons given were only in regard to the technical workings or practicality of the TLAD, (ii) socio-technical when reasons were due to interrelated socio-cultural and technical reasons e.g. concerns that the biogas is dirty to cook on (socio-cultural) because it will smell like toilet (technical) and (iii) socio-cultural when reasons given were only of a social and cultural nature.*

[2] *Sweeper is a pejorative name for Dalit sanitation workers. The practice has been banned in India but is still apparent and the term still widely used among participants*

3.4.3 Origins and nature of socio-cultural resistance towards the use of human excreta derived biogas and fertiliser

Analysis of the narratives revealed that socio-cultural resistance can be better understood when it is differentiated into socio-cultural and socio-technical resistance. Socio-cultural resistance can be understood as resistance to the adoption of TLADs that arises due to the opposition of personal and social cultural norms independent of technical and practical knowledge. Socio-technical resistance can be understood as resistance that arises due to concerns around social consequences that are based on or reinforced by concerns people had about the technical aspects of a TLAD.

3.4.3.1 Narratives of socio-cultural resistance

3.4.3.1.1 Personal and place-based identity

The adoption of TLADs challenged people's personal or place-based identities and three themes within both were identified. For personal resistance: 1) Personal resistance due to TLADs opposing personal norms; 2) resistance due to TLADs opposing social norms of the group someone belongs to and 3) resistance due to threat of social sanctions from the wider community. For place-based resistance: 1) resistance based on not wanting a TLAD in their home; 2) resistance based on the feeling that TLADs do not belong in their village or villages in general and 3) resistance due to national place identity and feelings that TLADs are not within Indian behaviours or values. Figure 3.2 contextualises this analysis by placing participant narratives on a scale between personal and local resistance to group and national resistance, respectively. Identity can be a strong motivating factor for why people reject technologies and practices (Phillips and Dickie, 2014; Devine-Wright and Batel, 2017), such as OD (Leong, 2020). Identities that translate into beliefs that TLADs do not belong to certain places or people will have strong implications for dissemination. Biogas programmes might have more success disseminating TLADs if they work with communities to

renegotiate personal and place-based identities around what is seen as waste and what has value more broadly (Allison, 2019; Leong, 2020), rather than narrowly addressing only TLADs.

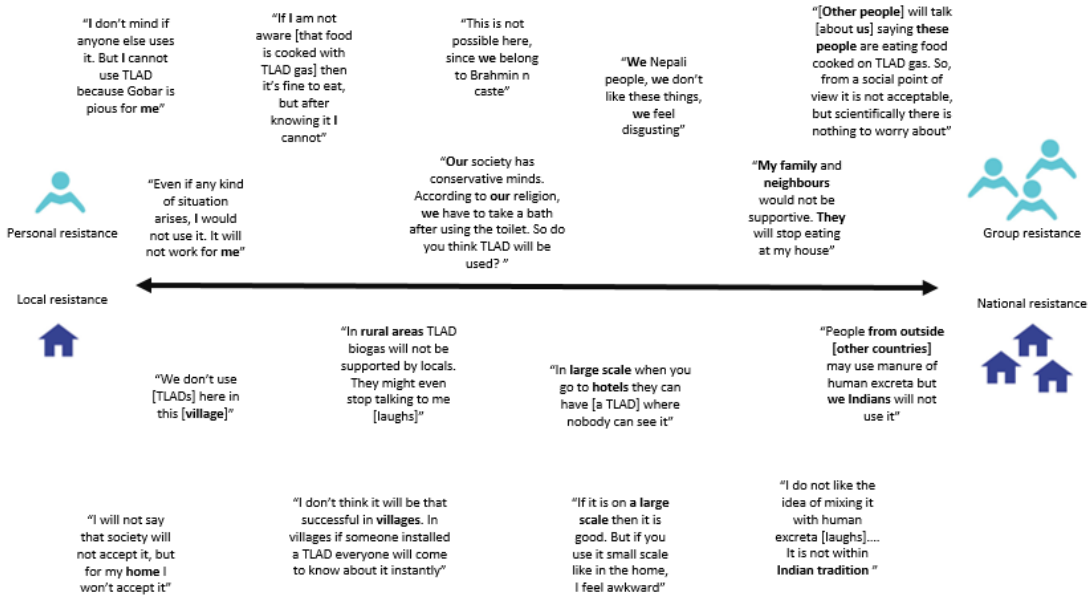

Figure 3.2: *Participant quotes around socio-cultural rejection towards toilet-linked anaerobic digesters arranged on a scale that highlights the difference between personal and local resistance compared to group or national resistance.*

3.4.3.1.2 Narratives of difference – other places and people

Many participants believed that TLAD adoption would be acceptable for other people and in other places, such as urban centres. They argued that more HE is available in urban centres, urban dwellers are often educated to a higher level and benefit from less social pressure through increased anonymity compared to village dwellers. Participants are aware that social norms influencing their decision making are related to the context.

> "In urban areas no one cares from where the gas is coming in someone's home" (M 42 Hindu 203)

> "I think the urban society might use it. They are more educated as compared to village people" (M 34 Hindu 008)

Their awareness of the fluidity of social-norms suggests there is potential for renegotiation of what is acceptable in rural villages and personal places of residence. Alternatively, rural Assam might not have conditions that incentivise people to adopt TLADs. Due to the close association many participants had with Nepal some drew direct comparisons between Assam and Nepal, geographically and culturally. It was argued that villages in Nepal are more congested with houses built closer together so there is less space for separate sanitation facilities as well as less cattle per

household, which they believe make TLADs more of a necessity in Nepal. One participant added that they believe that Nepal has a more flexible culture because many of them migrate abroad for work. Additionally in Nepal, due to topography, access to LPG in rural areas is often limited (Bharadwaj *et al.*, 2022). TLAD adoption in Assam could be more successful in specific contexts; perhaps where LPG is harder to access or there is demand for sanitation facilities.

3.4.3.1.3 Knowledge – never enough or too much

Analysis of the narratives revealed diverse preferences for knowledge about TLADs and the different ways knowledge can influence perceptions of TLADs. For some people, socio-cultural resistance was unnegotiable, no matter what they learn about TLAD benefits they would never accept them.

> *"We go for Ganga bath [according to Hindu beliefs taking a dip in the river Ganga washes away your sins], but the river has been [physically] polluted, we can even see with our eyes... but there is something in our heart. [A belief] … that the water of the river is pure, it is different. The point that you are making about the [technical benefits of TLADs] today's generation may accept it….definitely people might benefit. But for me I will never accept it" (M 69 Hindu 304)*

For these people resistance originates from a social and or religious code of conduct that goes beyond understandings of physical cleanliness and technical understanding (Wilde *et al.*, 2019). This is why technical knowledge of TLADs would not convince them to adopt one. Participants from all religious demographics articulated it would be perceived as a sin to use the TLAD biogas and that it would go against ritual customs.

> *"It's unacceptable [to use TLAD biogas] for both us and for ritual, I think it would be a sin for us to cook a ritual meal" (F 62 Buddhist 101)*
> *"The Hindu people do not want to mix those things (HE and cow dung). They believe it as a crime. That's why people don't build one" (M 54 Hindu 207)*

For others, an absence of knowledge would increase acceptance of TLADs. Their resistance towards TLADs was around the wilful participation of having one in their home or being aware they were eating food cooked on HE derived biogas.

> ***Participant:*** *"No I will not [like] to [eat at someone's home] if I come to know it is cooked with TLAD gas.*
> ***Interviewer:*** *"What if you don't know?"*
> ***Participant:*** *"Then it's not a problem" (M 19 Hindu 403)*

Similarly, some studies have found that the more information people have about products derived from recycled waste streams, such as wastewater or plastic bottles, the more deterred they are from using them (Dahlin, Herbes and Nelles, 2015; Judge *et al.*, 2021; Meng and Leary, 2021). Large scale

anaerobic digestion that does not advertise that its products are derived from HE (Dahlin, Herbes and Nelles, 2015; Burt *et al.*, 2021), or commercially markets it by reframing the narrative (Qian and Leong, 2016) might have more success in specific contexts.

3.4.3.1.4 Religion and religiosity – and the diversity within

Religiosity, defined as the intensity of an individual's faith (Arli, Pentecost and Thaichon, 2021; Urbatsch and Wang, 2021), specifically around purity and pollution practices, was related to resistance towards TLADs. Participants whose responses suggested a more orthodox approach to ideas of purity saw TLADs as directly opposing religious sentiments. Whereas others, who identified with the same religion, could imagine TLADs existing alongside religious practices.

> *"Everyone will say the same that since we pray Namaz and do the Roja (religious fasting). If we use the TLAD it will be impure and the prayers and fasting will not be valid" (F 35 Muslim 308)*
> *"Even I pray Namaz, no I don't think it will be a problem. Even LPG is made from dirty things… all gas is the same" (F 40 Muslim 306)*

A person's religiosity, within many religious groups, can both create feelings of protection over the environment, as well as indifference (Mohamad *et al.*, 2012; Javanaud, 2020; Koehrsen, 2021; Urbatsch and Wang, 2021). Many cultures and religions have rules and practices around purity and pollution (Douglas, 1966). However, there are few studies that make the distinction between diverse interpretations of religiosity or its influence on attitudes specifically towards circular economy practices (Mohamad *et al.*, 2012; Allison, 2019; Burt *et al.*, 2021), especially around the reuse of HE. Specifically, the intensity of someone's beliefs around purity and pollution and how they influence acceptance or rejection of TLADs should be investigated in more detail. A better understanding of this relationship may facilitate working with cultural groups and provide knowledge for how religious institutions can help renegotiate what is a waste and what has value. For example, in Bhutan a Buddhist leader inspired an increase in waste reduction and recycling behaviours of citizens, when government initiatives did not (Allison, 2019).

3.4.3.2 Narratives of socio-technical resistance

3.4.3.2.1 Negative socio-technical imaginaries

The most common concerns people had can be found in Table 3.4 under socio-technical challenges. Socio-technical resistance towards TLADs arose due to a lack of understanding of how a TLAD would work in practice that resulted in resistance due to decisions being made on negative imagined scenarios.

> *"There might be a miss-conception that the digestate will be full of HE and the entire field will be full of it. Even I feared that somehow, we can see the toilet waste coming out of the [TLAD]… Also, I was the first [to get a DFAD] in the village and even I had the fear of people talking about [my DFAD]*

badly. If I would have seen [a TLAD] installed earlier, I might have installed one in my home. But since I was the first [to get a DFAD] it was difficult. People even asked us if our food smells of gobar [cow dung]… But now everyone uses it [now they understand that the biogas and slurry are not like gobar anymore and so would not be like HE if they had a TLAD]" (F 60+ Hindu 211)

This particular participant was deterred from adopting a TLAD both because of a fear of people talking about them and that their technical concerns would materialise. In this instance socio-cultural rejection is one aspect of the final decision not to adopt a TLAD but was reinforced by a lack of understanding of how TLADs work. Negative socio-technical imaginings due to a lack of knowledge or experience is a common reason for resistance to many technologies and practices that can be overcome with learned experience (van der Horst, 2007; Andersson, 2015; Wilson and Dyke, 2016; Roxburgh *et al.*, 2020; Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022).

Some of the technical concerns people had such as slurry touching edible parts of crops and the smell of biogas could be warranted. The slurry can contain pathogens dangerous to human health (Lohri *et al.*, 2010; Owamah *et al.*, 2014) and biogas made from any feedstock contains sulphur dioxide, which can be odorous as well as harmful (Vögeli *et al.*, 2014). These concerns could be addressed with sensitisation and training. However, even if a user can operate a TLAD safely they may still risk social consequences (Bharadwaj *et al.*, 2021) if their community is not knowledgeable. Biogas programmes focussed on TLAD adoption could work best targeting and sensitising whole communities (Andersson, 2015; Leong and Lebel, 2020).

3.4.4 Motivations and drivers for changing attitudes to TLAD that could forge pathways to adoption

Potential pathways to adoption based on different initial attitudes to TLADs were thematically identified and are: 1) people that had positive perceptions of TLADs and decision making not dependent on social approval said they would adopt a TLAD; 2) people that had socio-cultural and or socio-technical resistance to TLADs said they might adopt one if certain conditions were met; and 3) people that said they would not adopt a TLAD no matter what circumstances changed. These identified non/pathways are illustrated in Figure 3.3 and expanded upon in the following section.

3.4.4.1 Leaders or risk takers – people with positive perceptions of TLADs

People with leadership and/or risk-taking personalities could be catalysts for community adoption of TLADs in Assam (Qian and Leong, 2016; Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022). These participants had overall positive perceptions of TLADs in addition to decision making independent of social approval. They either perceived enough benefits from a TLAD that risk of social rejection did not matter, or it was not a concern for them. Some also expected that once they had installed a TLAD that others in their community might follow once they saw the benefits. These

potential leaders of TLAD adoption understand that they could create pathways to wider adoption of TLADs and believe that any social sanctions placed on them would not last forever.

> "Maybe some of them will not like it in the beginning. But if I get the opportunity then I will use it. Also, once the other people see that the fuel is benefitting me then they will also start using it" *(F 40 Muslim 306)*

Evidence from Nepal, where people with risk-taking personalities did catalyse adoption of TLADs in their communities supports, this potential pathway to adoption of TLADs in Assam (Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022). However, using socially determined community leaders to disseminate technologies can risk accentuating existing inequalities (Cross, 2019; Burt *et al.*, 2021).

3.4.4.2 Conditions or contexts that would motivate users to overcome resistance to TLADs – people with negative or undecided perceptions of TLADs

Three potential pathways to adoption of TLADs for people with negative or undecided perceptions of TLADs were identified. Participants reflected on what factors have shaped their current perception of TLADs and how this could change. The reflective narratives adds evidence that resistance towards HE derived products is not driven by users and consumers with irrational resistance (Ching, 2015).

3.4.4.2.1 Demonstration of TLADs – Increased familiarity (linked to disgust)

Some people felt they could not make decisions around TLAD adoption without first using one. Additionally, more people might adopt TLADs in Assam with opportunities to see or trial one. This is because disgust reactions could become eliminated, or less influential on decision making, as the perceived benefits of TLADs, learned through familiarisation, overpower them (Qian and Leong, 2016). Knowledge and experience have been identified as two important factors related to technology adoption (Huijts, Molin and Steg, 2012) and disgust has been recognised as a learned behaviour that can change (Rottman, DeJesus and Gerdin, 2018; Etale *et al.*, 2020). Participants reflected that they might only feel disgusted because they are not familiar with TLADs and with familiarisation they might not feel disgusted anymore. Disgust or hesitation was related to something unknown and threatening (Andersson, 2015):

> *"I will feel dirty, I guess. Because I have never seen a TLAD or eaten any food cooked with TLAD biogas. It will be a new experience. So, I think I will feel disgusting" (M 19 Hindu 402)*

> *"In the beginning I will feel disgusting and dirty. But as time flows, I will be accustomed to handle it [slurry from TLAD]" (M 55 Hindu 205)*

Importantly, initial disgust reactions towards TLADs cannot be used to determine a person's final intention to adopt or reject a TLAD (Andersson, 2015). This is supported by other examples of when the opportunity to trial or observe HE derived products, including from TLADs (Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022), has led to increased acceptance. In Uganda the adoption of human urine as a fertiliser was expedited through group change and opportunities to observe the benefits (Andersson, 2015), and farmers in Malawi indicated greater acceptance of HE derived compost after being shown samples (Roxburgh *et al.*, 2020).

Although participants articulated that opportunities for trialling a TLAD would increase their acceptance, some also expressed that the less they know the better. These are conflicting pathways to adoption and could depend on other factors and warrants further investigation.

3.4.4.2.2 TLADs become normalised within social norms

If TLADs became a social-norm they could be perceived as less disgusting and more people might adopt them. Disgust reactions are hypothesised to originate largely as a response to prevent contact with foreigners or people acting in non-normative ways (Douglas, 1966; Rottman, DeJesus and Gerdin, 2018). With the social exclusion of sanitation workers in Hindu societies, and wider Indian culture, people might feel less risk in adopting a TLAD if it happened in groups (Rottman, DeJesus and Gerdin, 2018).

> *"Toilet is something which we all feel disgusting. And gas from it….. ummm… I don't think I will prefer it now. If someday everyone is using it then I might become accustomed with it and start using it… It is kind of psychology. If everyone uses it then it becomes a kind of tradition" (M 19 Hindu 403)*

Although it is commonly assumed that people gravitate to social groups they already identify with, people can also become more like the group over time (Kitchell *et al.*, 2019). What participants in this study have described is that within a community structure individuals could redefine their identities around what is acceptable and what is not (Qian and Leong, 2016; Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022). In Nepal TLAD use has become normalised but many users had personal restrictions around how the biogas and fertiliser could be used based on where they felt comfortable doing so. Individual norms were still influencing behaviour but the community's equilibrium had shifted so that TLADs are acceptable (Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022). Assam might have more success disseminating TLADs if the programme works with whole communities and not single households.

3.4.4.2.3 Necessity

Feelings of necessity such as a perceived scarcity of resources could encourage people to adopt TLADs. Participants explained that if they lacked access to other fuels or cow dung for their DFADs then they would have no choice but to use a TLAD. TLADs may be more suited to contexts that create a greater perceived necessity for TLAD products and services (Bhat, Chanakya and

Ravindranath, 2001). Alternatively, the promotion and subsidisation of alternative energy, fertiliser and sanitation solutions within the state might be contributing to perceptions that TLADs are not needed (Mittal, Ahlgren and Shukla, 2018). Better coordination between programmes along with promotion of TLADs might encourage people to consider them as an option. Although, experience of water scarcity drove some people to accept water recycled from waste water (Ching, 2015), but for others it did not (Etale *et al.*, 2020). Further research is required to determine when feelings of necessity or scarcity translate into a willingness to adopt TLADs.

> "If situation demands it then I have to accept [a TLAD]. But in my present scenario, I will not have it" (M 34 Hindu 008)

> "If the LPG price rises too high, then we shall use a TLAD connected to our gobar gas as we wouldn't be left with any other options. Such circumstances will compel us to do so!" (M 64 Hindu 303)

With the high consumers predominantly from the Global North causing most environmental issues it is unethical to use environmental pressures to motivate lower-income households and convince them of a necessity to adopt biogas when they can add time, labour and social burdens to people's lives. If people adopt TLADs it must be in their best interests.

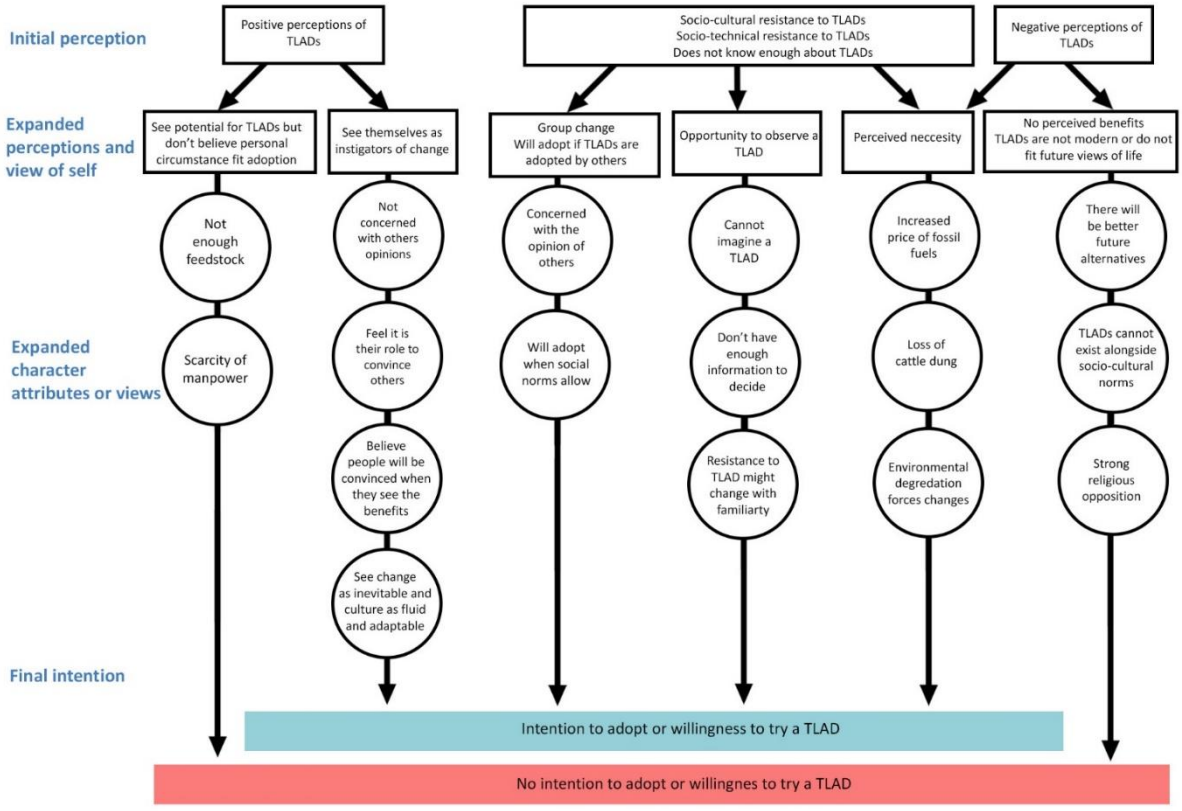

Figure 3.3: Illustrates the potential pathways to a participant either intending to adopt or no intention to adopt

that were identified during analysis.

3.4.5 How Assam's biogas programme engages with communities to support sustainable uptake of biogas technology and the connection of toilets

3.4.5.1 NNBOMP engagement with users around TLAD adoption

The potential pathways to TLAD adoption identified in this study have not been understood or considered in Assam's biogas implementation plan. Most participants who were asked had heard of TLADs, but only one participant had been offered one and very few knew of the additional subsidies for TLADs. No one had had the opportunity to observe a TLAD except a few participants who had visited Nepal. These experiences did not result in adoption of TLADs in Assam, which would suggest that local demonstration is necessary (Tigabu, Berkhout and van Beukering, 2015). There was no evidence that potential users had been engaged with or supported in adopting TLADs. The NNBOMP states that the SNA and other state implementing actors should work with the SBM and sanitation schemes to identify eligible households for TLADs (Government of India: Ministry of New and Renewable Energy, 2018). The target for TLAD installation in Assam between the years 2020/2021 is three hundred units (Government of India: Ministry of New and Renewable Energy, 2020a), this commitment to TLAD installation does not seem to be embodied at the state level of implementation, at least in these study areas.

The absence and low awareness of TLADs could be a result of a negative or dismissive attitudes towards TLADs from biogas programme actors. Both the SNA officer and local biogas technician, who are gatekeepers to knowledge of biogas technology, had dismissive attitudes towards TLADs. The technician said that he has discussed it with people but added that *"we don't use that [TLAD] here in [village]"* and the SNA officer articulated, making assumptions of diverse groups, that people in Assam would not agree to link their toilets with DFADs because of religious and cultural reasons (Raha, Mahanta and Clarke, 2014). Personal resistance of government officials in India towards the reuse of HE in agriculture has been found to be higher than those of small holder farmers and a potential barrier to wider institutional change (Mallory *et al.*, 2020). Renegotiation of how eligible households for the programme are identified as well as programmes of sensitisation and training for staff in addition to users is recommended.

3.4.5.2 Effectiveness of the NNBOMP state implementation in supporting sustainable adoption of biogas technology – the wider context of domestic biogas adoption in Assam

The NNBOMP objectives that encompass energy, fertiliser and sanitary benefits for users are not being fully utilised by biogas users in Assam. Many households were only utilising the biogas and not the slurry (Raha, Mahanta and Clarke, 2014) and none were utilising the sanitary benefits of connecting a toilet. Additionally, many of the participants were not optimally using their DFADs.

Some were confident conducting small repairs, optimising biogas through feedstock management and knowledgeable on how best to apply the slurry. However, others were not optimising biogas production and were discarding the slurry or using it incorrectly by drying it in the full sun, which causes nutrient loss due to evaporation (Bonten *et al.*, 2014). A participant who had tried vermi-composting, suggested by the NNBOMP as a method to treat and valorise the slurry that uses earthworms to compost it (Hanc and Vasak, 2015; Government of India: Ministry of New and Renewable Energy, 2018), explained that it is a lot of additional work and without a market to sell it they lack incentive. There was also variability in the amount of cooking hours a household reported compared to how many cows they had determining how much cow dung they feed their biogas a day (Raha, Mahanta and Clarke, 2014). The variability shows that having cattle and a DFAD does not guarantee sustainable adoption (Mittal, Ahlgren and Shukla, 2018; Bößner *et al.*, 2019), and installation of biogas technology does not mean people will automatically use it to its full capacity, or know how to.

There is a lack of commitment into activities beyond construction that would facilitate users in optimally using biogas technology. There was a lack of, and spatial inequality found in, post installation support. All DFADs in Napaam and Amolapam were non-functional because either no one was available for repairs, or users had sold their cows and decommissioned the DFADs due to lack of feedstock. Almost all other users of DFADs reported working DFADs and that there was a skilled person available for repairs. Napaam and Amolapam are a four-hour drive from the SNA in Guwahati, whereas all other villages (except those in Karbi Anglong) are within 1-2 hours. The distance of users from the urban centres or biogas offices could be associated with the biogas programme efficacy, although a participant in Karbi Anglong reported receiving post installation follow up, which is positive. There was a lack of training around slurry valorisation and utilisation as well as around how to optimise biogas output. Many reported that they do not obtain enough biogas in colder winter months, where feeding of the biogas plants must be increased to boost biogas production. Many of the households had enough cattle dung available to increase feeding but were not doing so, which indicates lack of training and or incentive.

Ineffective targeting of biogas users in Assam could be contributing to inefficient use of the biogas technology. In Assam as well as other states, cattle ownership is required to be eligible for biogas subsidies (Raha, Mahanta and Clarke, 2014; Mittal, Ahlgren and Shukla, 2018). However, owning many cattle suggests a higher income, which would mean greater access to alternative products resulting in less motivation for running a DFAD. This could explain why not all households with more cattle were getting significantly more biogas a day or able to last the winter without using LPG.

> *"Certainly, people who have a good income will not go for gobar gas [DFADs]. They will find other, easier alternatives. They will go and buy LPG. It completely depends on the person's scarcity of money" (F 54 Hindu 209)*

Biogas ownership favours higher socio-economic households across all of India (Das, Goswami and Hazarika, 2017). The NNBOMP offers additional subsidies for lower socio-economic groups (ST and SC groups (Government of India: Ministry of New and Renewable Energy, 2018)). However, offering subsidies to households with cattle is perhaps an oversight of Assam's programme in achieving this objective. Some of the lower socio-economic households in the study villages kept pigs, which require less land to farm compared to cattle (Government of India: Ministry of Statistics and Programme Implementation, 2013; Patr, Begum and Deka, 2014). Pig dung is a common feedstock for DFADs in Vietnam and China (Crook, 1976; Huong *et al.*, 2014). The NNBOMP policy literature refers to the technology as 'cattle dung based biogas plants' (Government of India: Ministry of New and Renewable Energy, 2018) and the online form households use to express interest in applying to the scheme asks how many cattle a household has (Buffaloes and cows) and not other livestock (Government of India: Ministry of New and Renewable Energy, 2023). To more effectively reach lower socio-economic households and work with diversity in the state the programme should be made more accessible for households that keep pigs. Assam not only has the highest number of households deriving a major source of income from livestock farming of all India's states, but the highest numbers of ST and SC households doing so (Government of India: Ministry of Statistics and Programme Implementation, 2013). There is much higher potential for biogas adoption in Assam, especially by lower socio-economic households than is currently being achieved. Additionally, the use of local contacts to select programme beneficiaries, which introduces social bias, will not be effective in identifying the suitable adopter households.

3.5 Conclusions and recommendations

This study provides a better understanding of what socio-cultural resistance towards TLADs is, how pathways to adoption might evolve, as well as how the state implementation of the NNBOMP could become more effective and work better with cultural diversity.

Analysis of the narratives revealed that socio-cultural resistance is sometimes independent of an individual's technical understanding of TLADs as well as more socio-technical, where resistance is related to knowledge of TLADs. Resistance was also related to how orthodox someone's beliefs are around purity and pollution practices and how dependent their decision-making is on social approval. Resistance towards TLADs could be overcome if people are provided with opportunities to observe or trial a TLAD, if TLADs became a social norm and if circumstances changed so TLADs are perceived as a necessity. Many people perceived TLADs as unnecessary due to the small amounts of HE a household produces compared to cattle dung, as well as the availability of alternative products and services.

This study has opened up several opportunities for future research and suggestions for policy development. While a main finding from this study is that perceptions of TLADs and potential pathways to adoption within demographic groups or across communities cannot be generalised, for

practicality, some generalisations within a biogas programme's approach must be made. We recommend that future research investigations aim to obtain a better understanding of the adoption pathways that can develop in communities and when to apply certain approaches to target villages. More empirical research should investigate if demonstration of TLADs and using village leaders or risk-takers as catalysts for wider community adoption are effective pathways to adoption, and if facilitating whole communities to adopt TLADs can remove some of the social barriers to adoption in Assam. Research should also focus on the influence that access to services, i.e. if LPG and or sanitation facilities has on TLAD adoption. Moreover, larger sample sizes should be obtained to gather more diverse perceptions from religious, caste and age groups. Specifically investigating how the younger generation perceive TLADs and differences in generational opinions should be a priority as policy approaches may have to change over time.

Narratives in this study revealed that people are aware that their perceptions towards recycling HE and TLADs are potentially negotiable and related to feelings of identity. Thus, more broadly, research investigations should aim to better understand the fluidity of social norms around recycling HE in regards to place and personal identities. This could facilitate better engagement with potential adopters of TLADs as well as other technologies and practices that recycle HE. More broadly working with people to renegotiate seeing HE as a resource and not a waste product might have better results, rather than specifically focussing on the promotion of TLADs (Leong, 2020).

We recommend that the NNBOMP in Assam improves how it identifies biogas adopter households through needs assessments, and works with diverse local groups to overcome resistance towards TLADs. A re-evaluation of the use of local contacts to identify households eligible for the subsidy as well as the condition, or the bias towards households that have high numbers of cattle is suggested. Lower socio-economic households could benefit more from biogas but often have less cattle or keep pigs (Government of India: Ministry of Statistics and Programme Implementation, 2013). Moreover, some stakeholders within the programme were found to have negative perceptions to TLADs therefore education of stakeholders within the NNBOMP on the benefits of toilet connections is recommended. Without commitment from state authorities to promote and support users adopting TLADs, the additional subsidies offered by the central NNBOMP for toilet connections are obsolete (Kotsila and Saravanan, 2017). Additionally, a better commitment to offering post installation services and training to domestic biogas users is essential. Some households were not using biogas technology optimally even if they had enough feedstock, and many others wanted to keep their biogas functioning but did not have a technician available locally to help them to do so.

Finally, we recommend that the state integrates the biogas program with other programmes, such as the SBM, to work with users within specific local contexts, to assess which energy and fertiliser products as well as sanitation and waste management solutions are best for a household (Pattanayak *et al.*, 2019).

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Chapter 4: Why does domestic biogas succeed in one place and not another? A multi-level perspective comparison of Nepal and India's domestic biogas programmes

J. Dickie, R.S. Quilliam, B. Campbell supervised the project. N. Boyd Williams designed the data collection tools with support from all supervisors. N. Boyd Williams carried out the data collection of expert stakeholder interviews. Interviews collected for Chapters 2 and 3 were reanalysed for Chapter 4 by N. Boyd Williams. N. Boyd Williams analysed and interpreted the data with consultation support from all supervisors and D. Raha who was consulted to discuss findings in Assam. N. Boyd Williams produced the manuscript, and all supervisors and D. Raha commented on draft versions.

NOTE: interview guides were adapted for each stakeholder and cannot be included in the Appendix to maintain anonymity of the stakeholders.

Abstract

Despite the numerous benefits of domestic biogas and the significant investments from governments, international aid agencies, and households, biogas programmes have consistently encountered failure. Previous research highlights various challenges facing biogas programme success yet lacks a definitive understanding of the root-causes of the persistent engagement with these same challenges. This paper presents a multi-level, multi-sector investigation into the successes and failures of domestic biogas programmes across different contexts. Utilising the Multi-Level Perspective Framework (MLP), this study compares the biogas programmes of Nepal and India—two countries with varying degrees of success and failure. It delves into local case studies within each country to examine how national, regional, and local factors collectively influence the success of domestic biogas programmes. Particular attention is given to the distinct socio-cultural, political, and geographical contexts of each case study area. Findings indicate that failures are primarily due to higher-level national and regional factors, such as governance structures, the effectiveness of implementing agencies, and the knowledge and agency of programme staff. The allocation of funding towards peripheral activities like training, maintenance, regulation, and the coordination and resource sharing across sectors also play crucial roles. Notably, integration with the sanitation sector significantly enhances the diffusion of toilet-connected domestic biogas. This study illuminates the varied outcomes of biogas programmes and offers insights critical for guiding future investments and strategies. This knowledge is vital for improving biogas programme success rates and recognising situations where biogas may not be the optimal solution.

4.1 Introduction

Domestic anaerobic digesters breakdown organic household waste streams, in the absence of oxygen, into biogas. This can be utilised as a clean cooking fuel, as well as slurry, a predominantly liquid by-product that acts as an organic plant fertiliser. In addition to these products, biogas digesters provide a waste disposal service for the management of livestock dung, food and agricultural waste and, if a sanitary toilet is connected, human excreta (HE). Domestic biogas is promoted for its numerous benefits to human and environmental health, as well as positive impacts on rural livelihoods, and is often heralded as a golden solution to many sustainability challenges (Crook, 1976; Mendis, Nes and Lam, 1999; Fulford, 2015). Over the decades, the main narratives around the promotion of domestic biogas have evolved in relation to global focusses (Barnhart, 2014). Initially in the 1970-90s development and implementation of domestic biogas technology was in response to the oil crisis due to its potential to decouple farming and household energy needs from fossil fuels. Biogas technology was viewed as a means of rural and agricultural development, as well as a means to reduce deforestation by displacing firewood as a cooking fuel (Barnhart, 2014). Subsequently, the focus evolved to encompass reducing diseases associated with indoor air pollution and inadequate sanitation and waste management, along with empowering women by reducing the burden of collecting firewood.

In the 2000s domestic biogas became a solution to fight climate change. A more neo-liberal and market-led approach to biogas has emerged as biogas plant have revenue potential in global carbon markets (Buysman and Mol, 2013; Barnhart, 2014; Thapa, Morrison and Parton, 2021). Due to its potential in addressing various sustainable development goals, domestic biogas has attracted significant investment from governments, individuals, and international aid agencies. Many African, Asian and South American countries have implemented national domestic biogas dissemination programmes facilitated by national and international funding, subsidies and supportive policies (Ortiz, Terrapon-Pfaff and Dienst, 2017b).

However, the global uptake of domestic biogas has been low and many projects have failed for various reasons. The challenges facing domestic biogas have been understood for many decades and yet they have been repeated many times over (Kalina, Ogwang and Tilley, 2022). Much research has been dedicated to understanding why domestic biogas so often fails but has predominantly over-focussed on identifying higher-level failure trends which are summarised in Table 4.1. Research is still unable to confidently answer why biogas succeeds in one place but fails in another, even if it is a similar programme and context. Moreover, despite this history of failure, the theoretical promise of domestic biogas often overshadows the practical challenges (Kalina, Ogwang and Tilley, 2022). It still attracts significant investment and is continually being promoted and implemented as a sustainability solution. An over focus on the potential benefits of biogas as a reason to continue installations despite programme failures has overshadowed the importance of understanding the root-causes of these failures. There is very little research that investigates factors such as policy design and coherence, implementation, governance (Abdelnour, Pemberton-pigott and Deichmann, 2020;

Bharadwaj *et al.*, 2022) as well as the influence of various aid mechanisms and the effect of context on all these factors (Kalina, Ogwang and Tilley, 2022). Without this understanding, we risk repeating the same mistakes, with the consequences most heavily felt by users or beneficiaries of domestic biogas, often low-income households that invest their limited resources into these technologies. Consequently, there is a need for critical, reflective, qualitative research investigating the reasons for biogas programme failures from a multi-level perspective. This study aims to answer the question: "Why does domestic biogas succeed in one place and not another?"

Table 4.1: *A summary of the common barriers to domestic biogas*

Challenges/ barriers to domestic biogas		References
Technical factors	Poor construction Unsubstantial or absent training and follow-up services Decline in cattle dung supply, coupled with limited awareness of alternative feedstock materials such as agricultural and toilet wastes poses significant challenges to the current and future viability of domestic biogas.	(Cheng, Li, Mang, Neupane, *et al.*, 2014)(Rupf *et al.*, 2015; Garfí *et al.*, 2016)
Economic factors	High initial investment High maintenance costs, especially for the rural poor	(Bhattarai, Somanathan and Nepal, 2018; Nevzorova and Kutcherov, 2019)
Socio-cultural factors	Rejection and apprehension of using excreta feedstock and the derived biogas and fertiliser products Particularly, the use of HE as a feedstock has led to concerns around the safety of the biogas and fertiliser as well as the risk of social stigma due to associated social taboos	(Raha, Mahanta and Clarke, 2014; Khan and Martin, 2016; Dumont, Hildebrandt and Sempuga, 2021) (Khan and Martin, 2016; Amuzu-Sefordzi *et al.*, 2018; Mittal, Ahlgren and Shukla, 2018; Bharadwaj *et al.*, 2021)
Market and institutional barriers	Competing products and services such as Liquid Petroleum Gas (LPG) which has more social status and requires less technical effort to manage compared to biogas Weak political support for biogas and the efficacy of programmes	(Nevzorova and Kutcherov, 2019) (Martí-Herrero *et al.*, 2015; Malakar, Greig and van de Fliert, 2018a)

4.2 The study context and research objectives

Biogas technology is considered particularly well suited to the rural South Asian context like India and Nepal due to the warm climate, the large number of people that live in rural areas and rely on agriculture and livestock rearing for livelihoods and income (Ghimire, 2013; Fulford, 2015). The two countries, which are predominantly Hindu, have a culture of rearing cows and buffalos whose dung is widely used as biogas feedstock (Damgaard, McCauley and Long, 2017; Das, Goswami and

Hazarika, 2017). Importantly, livestock is often kept tied up close to the home so that there is an accessible supply of dung that can be easily collected. The high population density in rural areas and scarce forest resources puts pressure on forest ecosystems. Subsequently, to encourage biogas adoption, both governments have national biogas programmes that have been operating since the 1980s. The programmes provide subsidies to offset installation costs. As of 2019, Nepal has installed approximately half a million domestic biogas digesters (Rai, 2017; Government of Nepal: Central Bureau of Statistics, 2019) and in India it is estimated that to date around 5 million domestic biogas units have been installed (Government of India: Ministry of New and Renewable Energy, 2021).

Nepal and India's biogas programmes are excellent case studies to begin investigating why biogas sometimes succeeds and sometimes does not. They are neighbouring countries that share common histories, demographics and some rural socio-economic characteristics. The two programmes have similar policies and governance structures but it is still unknown why they have succeeded and failed in different aspects. While Nepal's programme is viewed as a historical success with reports of high post-installation functionality rates (Bajgain and Shakya, 2005; Prakriti Consult Pvt Ltd, 2018; Government of Nepal: Central Bureau of Statistics, 2019), its effectiveness is reportedly declining. To date, less than one percent of the total biogas potential has been realised, despite decades of government support and international financing (Lohani *et al.*, 2021). While there are success stories in India, post-installation functionality rates as low as 40% are reported in literature (Dutta *et al.*, 1997; Bhat, Chanakya and Ravindranath, 2001). Both countries offer additional subsidies for toilet connections and have similar religious and cultural demographics where the handling and use of HE and derived products can come with negative socio-political consequences (Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022; Boyd Williams, Quilliam, Campbell, Raha, *et al.*, 2022). Interestingly, approximately 80% of domestic biogas users in Nepal had connected household toilets (Prakriti Consult Pvt Ltd, 2018), whereas in India, toilet connections remain limited with reports nationwide that it is heavily opposed due to socio-cultural norms (Pawan K., 2014; Raha, Mahanta and Clarke, 2014; Mittal, Ahlgren and Shukla, 2018; DownToEarth, 2019a). Using a multi-level perspective, this study aims to investigate the reasons behind these differences by conducting interviews with stakeholders knowledgeable of, or involved in, the national biogas programmes, as well as users of domestic biogas from two case study areas in each country.

The objectives of the study are:

1. To use the multi-level perspective as an analytical framework to understand how socio-political and geographical context, governance structures, implementation strategies affect domestic biogas uptake and success in India and Nepal
2. Considering the different transition dynamics of each country context, explore the reasons why:
    - The programmes have succeeded or failed over time

- Why Nepal has succeeded in implementing more biogas digesters with toilet-connections than India

3. To identify key, multi-level factors that make a successful domestic biogas programme

More widely, there is an identified need for research that explores why transitions occur in specific places and others not, and the role of spatial and scalar variations in sustainable transitions, inclusive of energy (Hansen and Coenen, 2015). We believe this study will not only fill in some persistent research gaps specific to domestic biogas, but also contribute to understanding the spatiality of transitions more generally. The study also acts as a methodological experiment. We will utilise the multi-level perspective (MLP) framework, commonly applied to study transitions in institutionalised and formal contexts in industrialised nations, and apply it to diverse, less formalised rural contexts in low- to middle income-contexts in South Asia (Hansen *et al.*, 2018; Köhler *et al.*, 2019). Thus, we aim to assess how the MLP framework can be improved for analysing transitions to domestic biogas.

4.3 Biogas programme history in Nepal and India

4.3.1 Nepal

In response to the oil crisis the Government of Nepal (GoN) supported the first biogas programme in 1974 (Crewe, 1997; Barnhart, 2014). The ministry of Agriculture supported the construction of domestic biogas plants with interest free loans from the Agricultural Development Bank Nepal (ADB/N). In 1977 a private limited company, the Gobar Gas Company (GGC) was established, kick-starting Nepal's long term public private approach to biogas dissemination. From 1992-2010, international donors including the Netherland's Development Organisation (SNV) provided financial aid and technical assistance, accelerating biogas installations (Rai, 2017; Thapa, Morrison and Parton, 2021). During this period, the Biogas Support Program (BSP) was launched to promote biogas, train skilled staff, and build the capacity of Nepal's biogas programme. The BSP helped users cover installation costs by providing subsidies that were only reimbursed to the private companies if they built satisfactory models (Fulford, Devkota and Afful, 2012). The ADB/N continued providing affordable financing to farmers through providing loans to cover the capital cost of biogas. During this time the promotional discourse around biogas shifted towards forest protection, while the GoN began nationalising forests and restricting access rural people had to their forest based livelihoods (Barnhart, 2014).

In 1996, a government ministry called the Alternative Energy Promotion Centre (AEPC) was created to take over promotional activities, policy development and funding coordination when the SNV supported phase came to an end. The AEPC fully took over the programme in 2010 (Rai, 2017). In 2005 the AEPC registered the domestic biogas programme as a Clean Development Mechanism (CDM), aiming to cover future subsidies and maintenance costs through carbon payments instead of donor financial support.

4.3.2 India

The first biogas model widely disseminated across India was developed by the Khadi and Village Industries Commission (KVIC)[1]. The KVIC were predominantly responsible for promoting biogas for rural development during the 1960s and 1970s along with the Central Ministry of Agriculture, who provided subsidies. In 1981, the National Programme for Biogas Development (NPBD) (1981-1985) (Gustavsson, 2000) was created under the Ministry of Agriculture. The ongoing oil crisis of 1973 led to the creation of the Ministry of Non-conventional Energy Sources (Dutta *et al.*, 1997), later called the Ministry of New and Renewable Energy (MNRE) which took over the NPBD. The programme design was very top-down and heavily reliant on subsidies and construction targets. In 2005, the programme was renamed the National Biogas and Manure Management Programme to make biogas a holistic rural livelihood solution. (Raha, Mahanta and Clarke, 2014).

The programme, now called the New National Biogas and Organic Manure Programme (NNBOMP), adopted a decentralised multi-agency and multi-model implementation strategy. Subsidies and financial assistance are provided by the MRNE, centrally through a top-down model (Mittal, Ahlgren and Shukla, 2018) and assigned to each state (Government of India: Ministry of New and Renewable Energy, 2020a). The State Nodal Agency (SNA) for each state oversees construction, training and maintenance and subsidy allocation along with the KVIC and Biogas Development and Training Centres. The SNAs are organised differently in each state (Government of India: Ministry of New and Renewable Energy, 2018) and successful implementation depends on the state capabilities as well as involvement of various informal actors. The SNAs are supposed to send a quarterly report to MNRE regarding the number of plants installed in the State and how many of them were functional/ non-functional but many states often fail to do this and so it is not very well known how successful the biogas programme is (Comptroller and Auditor General of India, 2015).

[1] KVIC is a statuary body, established in 1957, by an act of parliament. The wider objectives of the KVIC are to build a stronger rural community.

Table 4.2: *Timeline of Nepal and India's national biogas programmes including major actors and events (Dutta* et al., *1997; Gustavsson, 2000; Bajgain and Shakya, 2005; Raha, Mahanta and Clarke, 2014)*

Year and large events	Nepal	India
Before the 1950s **1947 – India gains independence from British rule**	First biogas digester constructed in 1947	Biogas development pioneered by agricultural researchers
50-80s **1973 – Oil crisis** **1973 – National parks created in Nepal to protect forested areas**	1968 – KVIC demonstration in KTM 1974-75 – Agriculture year - government supported dissemination of biogas digesters with the ADB/N 1977 - GGC created – private company with local offices – subsidies from ADB/N and international organisations	KVIC design promoted by KVIC as a rural development initiative for small and medium farmers 1975 - The first large-scale biogas diffusion programme was the All India Co-ordinated Biogas Programme
80-90s **1989 – India fuel blockade in Nepal**	GGC led programme	1981-1985 - National Programme for Biogas Development (NPBD) under the responsibility of the Ministry of Agriculture with the KVIC and Action for Food Production (AFPRO) 1981 – Department of Non-Conventional Energy Sources created (later called the Ministry of non-Conventional Energy Sources and now called the Ministry of New and Renewable Energy (MNRE) 1982 – Department of non-Conventional Energy Sources take over programme renamed NBOMP
90s-2000s **1990s – Economic liberalisation in Nepal and India, opened up economies to foreign investment and markets** **2015 – Nepal earthquake** **2016 – India fuel blockade in Nepal**	1991 – The government, ADB/N and GGC proposes the involvement of the SNV 1992 – Formalisation and initiation of SNV/ BSP in Nepal. BSP a dedicated organisation for the promotion and dissemination of biogas technology 1996 – AEPC created 2010 – AEPC take over the programme 2017 – International financial aid stops	2005 – the NPBD was renamed the National Biogas and Manure Management Programme (NBOMP) 2017 – New NBOMP (NNBOMP)

4.4 Theoretical approach: the multi-level perspective framework

We applied the multi-level perspective (MLP) framework as an analytical tool. The MLP is a leading framework used to investigate how different levels of actors, mechanisms and exogenous factors

enable or impede socio-technical transitions over time (Geels, 2002, 2011). The MLP examines interactions among three levels that represent increased stability, across time: socio-technical niches, regimes, and landscapes. *Niches* are unstable and experimental environments where innovations develop. Niches can be protected spaces such as subsidised demonstration projects, or community niches, where users are willing to support emerging innovations. *Regimes* form the 'deep structure' supporting the innovation becoming a more stabilised socio-technical system. Important regime dimensions are governance, production systems, markets, infrastructures, and policies. *Landscapes* represent the encompassing environment surrounding the socio-technical transition and include demographical trends, political ideologies, societal values, economic patterns and environmental pressures as well as rapid shocks like wars or environmental disasters (Geels, 2005, 2011; Ravena, Schota and Berkhoutb, 2012; Fuenfschilling and Binz, 2018).

4.4.1 Applying the MLP to understand sustainable transitions in South Asian contexts

The MLP has been predominantly developed and applied to understand national and centralised transitions, most often in industrialised high-income country contexts (Wieczorek, 2018). Adapting the MLP to analyse transitions to a decentralised sustainable solution in diverse low-income contexts within South Asia[2], requires some discussion. It is recommended that the concepts of niche, regime, and landscape should be treated as guides, and not considered only as national boundaries (Geels and Schot, 2007; Geels, 2011; Fuenfschilling and Binz, 2018). Domestic biogas has been implemented top-down with the aim of solving a number of global challenges, such as deforestation and indoor air pollution. As such, a biogas programme will be influenced by global regime factors such as markets, economic systems and methods of energy governance. The culture of foreign aid will likely diffuse through all levels of a biogas programme, even in local niches, and must be accounted for (Fuenfschilling and Binz, 2018; Wieczorek, 2018). Additionally, analysing transitions narrowly through a national lens can overlook important differences in local diversity. In diverse societies like rural South Asia, considering differences in scale, between the national and local context will be critical. In lower income contexts there are more examples of weak policy coherence and implementation structures that mean informal institutions such as norms, values and cultures can have a stronger influence on the outcome of development policies and must be considered carefully (Wieczorek, 2018). Transitions to technologies related to the collective good, like biogas, may not be driven by traditional market forces due to the absence of incentives for private actors to profit and

[2] Although India has a GDP of 3.176 trillion, many people in rural areas, similar to rural Nepal, earn less than $2.15 a day and rely on subsistence agriculture. We chose to use "South Asia" over "Global South" to avoid inaccuracies and acknowledge the diversity of countries. However, no literature specifically recommends applying the MLP to South Asian contexts, so we reviewed literature that recommends how to apply it to developing countries and Global South contexts. We recognize the term "developing countries" is contested due to ambiguity and the assumption of following a specific development trajectory. We used "low-income" to refer to rural areas in both countries, meaning areas with low income, underserviced, and often reliant on informal socio-political structures for basic needs. For further discussion on these choice of terms please see (Khan *et al.*, 2022).

the lack of supportive market structures or regulatory systems (Geels, 2011; Buysman and Mol, 2013; Schoenmaker and Stegeman, 2022). This necessitates reconsidering global forces such as capitalism that are normally assumed to drive transitions (Feola, 2020).

4.4.2 Examples of the MLP applied to understand transitions to domestic biogas

A literature search identified a small number of academic studies applying the MLP framework to investigate transitions to domestic biogas. These studies used either the national programme (Tigabu, Berkhout and van Beukering, 2015; Kamp and Bermúdez Forn, 2016; Bößner *et al.*, 2019), or localised case studies (Campbell and Sallis, 2013; Pilloni, Hamed and Joyce, 2020) as the units of analysis, but none combined both. All but one directly apply the MLP without adapting it, though interpretations of niche, regime and landscape are diverse. Studies focussing on national programmes provided detailed temporal overviews of biogas programme development and insights into general interdisciplinary barriers and opportunities for biogas uptake. Applying the MLP at this scale revealed how interactions between actors from various government ministries, or regimes, can positively or negatively affect implementation of the programme (Kamp and Bermúdez Forn, 2016). However, these studies could not account for local socio-cultural, demographical and geographical diversity at the local level and were unable to explain why domestic biogas succeeded or failed in different localities within a single country context. Conversely, the studies that focussed on a localised case study offered a more detailed understanding of adoption pathways in niches but were limited in their exploration of how local outcomes resulted from multi-level interactions. Pilloni, Hamed and Joyce, (2020) adapted the MLP, adding a sub-regime level to account for localised actions working under the national regime. Narrowly focusing on either national or local contexts as the unit of analysis, obscures both multi-level interactions between national and local governance levels as well as global influences on all MLP levels. To better understand transitions to domestic biogas, a more comprehensive multi-level approach could be beneficial.

4.4.3 Interpretations of MLP levels used for this study

Nepal and India are both federal republics. Nepal is divided into seven provinces and India has 28 states and 8 union territories with their own local institutions acting with, and under, central administration. We concluded that the traditional MLP must be adapted to account for these political, geographical, cultural and demographical regional differences. We propose a creative reformulation of the MLP and have introduced a sub-regime and a sub-landscape level to represent the localised environment within one example state and province in India and Nepal respectively.

Interpretations of the MLP for this paper and how they have been fitted to the context of Nepal and India can be found in Table 4.3. For clarity, the *socio-technical niche* is represented by multiple case study villages, in each country, under the umbrella of one province and one state in Nepal and India respectively. The *regime* and *sub-regime* levels are interpreted as multi-sector regimes. Domestic biogas technology is a part of both the energy and sanitation regime in each

country, being a niche technological energy and sanitation solution. Analysis will investigate how biogas has penetrated both regimes as well as how both regimes impact household transitions to domestic biogas. Slurry is often not such a large focus of domestic biogas programmes. As the scope of the study is large already, we decided to omit the agricultural regime, encompassing fertiliser practices, from the investigation.

Table 4.3: *MLP level conceptions used in this study when comparing Nepal and India's biogas programme within a single province in Nepal and a single state in India*

MLP Level	Nepal description	India description	Description
Landscape	National and global	National and global	Overarching socio-political context, geography and climate, socio-cultural norms, global development culture, environmental pressures, international interests, global commitments e.g. SDGs, environmental and man-made shocks**.**
Socio-technical regime	National	National	National biogas programme structure Energy and sanitation regimes at the national level which encompass: competing technologies, markets, policies and political structures, culture, user preference.
Sub-landscape	Provincial	State	Overarching local socio-political context, geography and climate, socio-cultural norms, development culture, environmental pressures, environmental awareness, education levels, interpretations of landscape development goals and priorities.
Sociotechnical-regime	Provincial	State	Local biogas programme structure Energy and sanitation regimes at the regional level which encompass: competing technologies, markets, policies and political structures, culture, user preference.
Socio-technical niche	Community, villages, households	Community, villages, households	Motivations for biogas technology adoption, pathways to adoption, how the biogas is used, socio-technical innovation socio-cultural norms around biogas use, training and support received, grassroots development.

4.5 Methods

4.5.1 Case study locations and context of the socio-technical niche, sub-regime and sub-landscape

4.5.1.1 India

In India, the state of Assam provides the context for the sub-landscape and sub-regime context. The 13 case study villages that represent an example socio-technical niche are located in the Assamese districts of Sonitpur, Marigaon and Karbi Anglong. Assam is considered one the least developed states in India despite its high biodiversity and forest wealth, as well as mineral and oil reserves, and

tea production and tourism. Land ownership, which facilitates access to services such as bank loans and agricultural policies and favours livestock and biogas ownership (Singh and Datta, 2013; Das, Goswami and Hazarika, 2017), is inequitably distributed in contemporary Assam due to a legacy of colonial policies (Handique, 2010). Twenty percent of the people hold about 70% of the total cultivable land (Institute of Social Change and Development, Institute for Human Development and Assam, 2014).

The majority of the biogas user participants were located in three case study villages within the Brahmaputra valley. The remainder were from three villages in the scheduled tribe district of Karbi Anglong. The fertile lands of the Brahmaputra valley support many people in agricultural pursuits. The availability of feedstock and agricultural uses for the slurry fertiliser makes many households suitable candidates for domestic biogas and thus there are many dung-fed anaerobic digesters (DFADs) (no toilet connections) found in the valley (Boyd Williams, Quilliam, Campbell, Raha, *et al.*, 2022). The majority of the participant households were high caste Nepali Hindus, who historically settled in the Brahmaputra Valley due to its suitability for cattle rearing and because they were granted land under British imperial rule (Devi, 2007).

4.5.1.2 Nepal

In Nepal, Province 4 provides the context for the sub-landscape and sub-regime context. The four case study villages, representing an example socio-technical niche, are located in the Kaski district. The case study villages are close to Pokhara, the second largest city in Nepal, and where high levels of biogas penetration have been achieved (Damgaard, McCauley and Long, 2017). Close proximity to a city would indicate increased access to services, both biogas and alternatives like LPG and other initiatives. The Kaski district also has a relatively warm climate and good road access, factors favourable to biogas adoption (Bharadwaj *et al.*, 2022). The Kaski district was the first to be declared open defecation free (ODF) suggesting high levels of sanitation awareness and adoption in the area (Water Supply & Sanitation Collaborative Council, 2019) although there are similar numbers of toilet-connected biogas within other sub-landscapes (Prakriti Consult Pvt Ltd, 2018). Thirty percent of the biogas user participants listed remittance income from abroad as a main or secondary form of income.

A full description of the study areas and maps of the study locations can be found in (Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022) for Province 4 in Nepal, and in (Boyd Williams, Quilliam, Campbell, Raha, *et al.*, 2022) for Assam in India. In-depth descriptions of the case study areas are included in the descriptions of the sub-landscapes and sub-regimes in the results section.

4.5.2 Data collection

Due to the explorative nature of the study a qualitative approach was applied through the use of in-depth semi-structured interviews with various expert stakeholders and users or potential users (heron referred to only as user) of domestic biogas. In total 24 expert stakeholders were approached for

interview and 15 agreed to participate. Stakeholders were considered to have experience either working for or researching the domestic biogas programmes in either country, particularly people with knowledge of the national implementation of the programmes. Table 4.4 summarises and describes the stakeholder participants. No stakeholder currently working in a government capacity in India was available for interview. Interviews were conducted between September 2020 - January 2022. All interviews were conducted over the phone or online, in English. Each interview was recorded and transcribed with the written permission of all participants and ethical approval was obtained from the University of Stirling. Stakeholders were asked a variety of questions about the biogas programme implementation with a particular focus on identifying causal relationships between various multi-levels of actions. However, the interview structures were left open to allow the stakeholders to discuss what they thought relevant. Prompts were used to bring the conversation back to the research questions if the interview diverted. All identifiable information about stakeholders has been removed from the results.

The biogas user interviews have previously been used in two research publications (Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022; Boyd Williams, Quilliam, Campbell, Raha, *et al.*, 2022). The users were originally asked questions around adoption and use of domestic biogas, their perceptions of toilet connected biogas and their experiences with the respective national biogas implementation programmes and thus were suitable to use for this research investigation.

A review of relevant literature was also used to inform the description of the MLP levels particularly the global landscape and national regime where the scope is very broad and could not entirely be covered in stakeholder interviews. Only using stakeholder interviews would also not be accurate as they are also personal experiences and ideas and while used to guide the analysis they cannot be used on their own to cover such complex and long-term transitions.

Table 4.4: *Description of stakeholders with identifiable information removed*

Actor	Number of participants	Description	Participant number
Government association	Nepal – 1	Participant had experience working with or for a government organisation that has participated in the biogas programme	1
Researchers	Nepal – 2 India – 3	Participants had experience researching domestic biogas as well as other clean cooking programmes and wider developmental projects	3,5 2,4,6
Works for NGO/ International government organisations, private companies	Nepal – 6 India – 3	Participants worked for international NGOs, International government organisations or private companies such as private biogas installation companies and or carbon credit schemes that build biogas to offset emissions	7,9,11,13,15,17, 8,10,12
Users or potential users of biogas	Nepal – 17 user participants India – 40 user participants	Province 4 - All participants had toilet-connected biogas (functioning or non-functioning) A full explanation of study area can be found in (Boyd Williams, Quilliam, Campbell, Ghatani, *et al.*, 2022). Assam - 25 participants had dung-fed digesters (no toilet-connections) (functioning or non-functioning) and 15 had no biogas digesters A full explanation of study area can be found in (Boyd Williams, Quilliam, Campbell, Raha, *et al.*, 2022).	U1 – U17 U18-U58

4.5.3 Data analysis

The stakeholder interviews were conducted and transcribed in English for thematic analysis using NVivo 12 software. Braun and Clarke's (2006) phases of thematic analysis were followed and the identified themes were taken from the explicit surface meanings of the data rather than looking beyond what participants said. Biogas user interviews, previously collected for Chapter 2 and 3, were reanalysed deductively, using thematic analysis through an MLP lens. All the collected data was initially coded guided by the research objectives and was coded into the defined MLP levels for this investigation. The MLP was critically used as a guide to search for causal interactions between multi-levels of action and agency (Geels, 2011).

The coded interview data was then used to generate narratives around causal effects within, and between, each MLP level for each country programme. Narrative explanation has been used by many scholars of the MLP because narratives capture complex interactions between agency and changing contexts (Geels, 2011). The narrative exercise often required a review of previously coded data as understanding around what research findings were relevant to each MLP level evolved. Despite the MLP levels being quite clearly defined in the Introduction of the paper, during analysis the ambiguity of the MLP came to light. During the written description many overlaps were identified

and it was often difficult to make clear distinctions between each level and where interlinkages occurred. The presented results and discussion are a result of an iterative written analysis process.

The study's large scope required decisions on relevance, making direct comparison for every MLP level between the countries impossible. To mitigate researcher bias, analysis and the generation of narratives were discussed among co-authors, and broader literature was consulted. As the case study villages were pre-selected and the original interview data used for other research studies, potential bias exists, and results should not be generalised to compare the two countries' entire biogas programmes. The results should only be interpreted as an example of how the two biogas programmes materialise in one case study area within each country. The villages in Province 4 of Nepal were selected because of the prevalence of TLADs but they are niches where TLADs have not been so successful. Similarly, there are a small number of examples of successful TLAD adoption in India (Estoppey, 2010; Pawan K., 2014) and if another case study location had been chosen the comparison would look very different. Multiple case studies within various contexts in each country should ideally be analysed, but this was beyond the study's scope. Covid-19's lasting effects and restricted access to recent census data limited research being undertaken for this study, resulting in older data or national family health surveys used instead.

4.6 Results

First, each level of the MLP was constructed (see Table 4.4) using descriptive narratives for each country context using a combination of wider literature, expert stakeholder interviews, and biogas user interviews. Next, the MLP's effectiveness in facilitating the analysis is explored and recommendations for potential improvements are made. Lastly, crucial aspects of multi-level, multi-actor coordination that influenced the success or failure of programme outcomes are discussed.

4.6.1.1 Landscape

4.6.1.1.1 Landscape factors common to both Nepal and India

Although India has a GDP of approximately 3.1 trillion compared to Nepal’s 36.3 million, similarly 10% of the Indian population and 8% of the Nepali population are estimated to live in poverty (The World Bank, 2023). Nepal and India share common histories, languages and lineages especially between the Northern Indian states such as Assam (Vindegg, 2022).

Global landscape influences are vast and can pertain to formal commitments such as the UN Sustainable Development Goals (SDGs) as well as climate agreements but also common understandings around what rural development is, what it should achieve and how (Jakupec, 2018). The notion of development has become internalised by many nations and actors as following a pre-determined trajectory of development set by high-income countries that results in the end goal of economic development (Lopez-claros and Perotti, 2014; Jakupec, 2018). Foreign aid initiatives have commonly adopted technologically focussed programme models with inadequate governance models

that have largely failed to achieve their stated aims (Ruiz-Mercado *et al.*, 2011; Abdelnour, Pemberton-pigott and Deichmann, 2020; Ha and Kumar, 2021). These programmes often promote a single technological design to large, culturally, economically and geographically diverse regions that assumes large spaces as uniform and overlooks diversity (Gyawali and Thompson, 2016; Santha, 2019; Bharadwaj *et al.*, 2021). Rural areas in both countries have been the recipients of large amounts of national and international development initiatives.

Both countries are rooted in a society of Hindu caste-based hierarchy attached to understandings of ritual purity and pollution linked to traditional occupations (Thekaekara, 2003). Sanitation work, which is ritually as well as physically polluting, has been typically forced upon people of lower castes whom higher castes will segregate themselves from (Thekaekara, 2003). Falling into a ritual state of pollution, such as through using excreta derived biogas can have negative socio-political consequences such as no longer receiving visitors after adopting a TLAD (Bharadwaj *et al.*, 2021). Adoption of a TLAD could thus affect a household's social status, which in Hindu contexts can often ensure a households access to resources such as energy, land and water, in part due to higher castes often having higher paying professions and social status [93]. In Hindu village life, religion cascades into practical life (Bennett, 1983) where ritual practices have co-evolved within specific socio-ecological contexts and may oppose the adoption of TLADs. Cooking with wood fuel is linked to ritual purity and connects users with traditional cultural cooking practices but it also connects households to their socio-ecological systems, providing space heating and resources such as ash that is used as a detergent and pesticide and is a means of disposing of waste (Lam *et al.*, 2017; Malakar, Greig and van de Fliert, 2018a; Bharadwaj *et al.*, 2021). Open defecation (OD), the practise of defecating in fields and water bodies can be prevalent in rural populations in Nepal and India where socio-cultural norms together with necessity, perpetuate this behaviour (Diane Coffey, Aashish Gupta, Payal Hathi, Dean Spears, Nikhil Srivastav, 2017; Vyas and Spears, 2018). In addition a social reluctance to have latrines near homes or share them with relatives can be due to adherence to embodiment of ritual purity and pollution rules (Vyas and Spears, 2018). People belonging to higher caste groups in both Nepal and India hold the majority of civil service and political jobs (Macfarlane, 1990). Foreign and national aid has overlooked these socio-cultural norms and diverse social structures and among other reasons this could be why many rural development initiatives have not reached the people most in need (Crewe, 1997; Abdelnour, Pemberton-pigott and Deichmann, 2020).

4.6.1.1.2 Nepal

Nepal has three geographical regions: the Terai, the southernmost region, is the flattest as well as the warmest; the Hilly and the Mountainous regions get gradually steeper, colder and less accessible into the Himalayas. In mountainous regions, colder temperatures, poor road access, and cultural transhumance practices—where livestock, such as yaks, are not kept close to homes, necessitating the collection and transportation of dung—pose significant challenges to the construction, operation,

and production of biogas (Campbell and Sallis, 2013). Due to these challenging conditions the centralised programme has installed many more domestic biogas in the Terai and Hilly regions (Bharadwaj *et al.*, 2022). The majority of biogas adopters nationwide are from the higher caste groups (AEPC, 2011; Bhattarai, Somanathan and Nepal, 2018).

Indian stakeholders described Nepal's culture as potentially being less orthodox compared to India's. The civil war in Nepal (1996 -2006), which challenged the elite landed classes, had various socio-economic implications including a reinstatement of Nepal's multi-ethnic origins and women's empowerment (Pant and Standing, 2011; Campbell, 2013b; K. P. Adhikari and Gellner, 2016). The war, in addition to many other socio-environmental factors such as the search for employment has led to a mass migration to Nepal's urban centres as well as abroad. In 2016 approximately 47% of households reported that at least one person had migrated from the household in the last ten years (Ministry of Health Nepal; New ERA and ICF, 2017). Mass migration could have led to a relaxation of some socio-cultural norms due to increased knowledge and experience of migrants. *'See ... my relatives are there in Nepal…many young boys go to abroad [to work]…they see the world and get educated about what is going on…The mentality of people of Nepal has changed. So I think there is no problem in installing a TLADs in Nepal.' (M 34 Hindu U25 Assam)*. Migration is also transitioning rural areas from an agrarian to a remittance economy (Campbell, 2018b). Many rural households are selling land and cattle, while agricultural labour including the management of domestic biogas falls on women, children, and the elderly. Many domestic biogas plants have been abandoned for this reason.

Nepal has historically had an unstable energy landscape that has favoured domestic biogas uptake and use to manage energy security and affordability issues. Although Nepal has the capacity to generate all its required electricity, and more from its hydropower potential it has never actualised this potential (Katuwal and Bohara, 2009; Gyawali and Thompson, 2016). Nepal depends on fossil fuel imports from India and consequently much of Nepal's energy security relies on market forces as well as international relations (Herington and Malakar, 2016). The Indian fuel blockades of 1989 and 2015 were disastrous for Nepal and forced many households into energy poverty and caused many to revert back to using polluting wood fuel for cooking (Herington and Malakar, 2016). Nepal also experiences many natural hazard-induced energy deficits like earthquakes and landslides, which can cut off fuel and other supplies delivered by road. The mountainous geography and poor road transportation to some areas in Nepal can make LPG up to four times as expensive as it is in urban areas due to transportation costs (Bharadwaj *et al.*, 2022). As a result a robust culture of energy resilience has developed (Herington and Malakar, 2016; Underwood, Hill and Lamichhane, 2020; Vindegg, 2022) and *'the government has made a target that by 2030 penetration of LPG should not exceed 39% [of households]' (expert stakeholder #1)*.

Nepal's biogas programme and other development initiatives have received large amounts of foreign aid (Gyawali, Thompson and Verweij, 2017). Despite this, Nepal has successfully implemented some grassroots development initiatives that have incorporated more horizontal

methods of governance such as Nepal's famous community forest initiative (Negi *et al.*, 2018). While stakeholders reported that many government departments successfully collaborated on the biogas programme through a multi-regime approach, government corruption hampers rural development in general and limits biogas success as a result. *They are not focussing on what needs to be done in rural areas to keep rural population there. There is no policy and they are just tousling for power (expert stakeholder #9)*'. Although foreign aid to the biogas programme ended in 2017 the programme's enrolment in the Clean Development Mechanism introduces other global influences.

4.6.1.1.3 India

India was colonised under British Imperial rule until 1947. The British, among other atrocities, formalised and strengthened the caste system in many ways, not limited to, the granting of land and government jobs to higher castes and the formalisation of the work of sanitation workers to the lowest castes (Riser-Kositsky, 2009; Saldanha *et al.*, 2022). The British also imposed a centralised top-down government and governance structure and introduced British ideas of what the end goal of development meant (Srinivas, 2009). Following India's economic reforms of the 1990s, which opened up its economy to the world, many people migrated to urban centres to gain employment which has, like in Nepal, created a rural drain of youth and labour (Das, Saha and Chouhan, 2020).

After independence India faced severe food shortages and during the 1960's the Government of India (GoI) invested in agricultural development focused on industrialised practices dependent on oil during a period called the Green Revolution. The oil price became very important to agricultural and rural development for many reasons including its close link to chemical fertiliser production. In response to rising oil prices in the 1970s the GoI took an increased interest in domestic biogas to decouple farming practices and household energy use from fossil fuels and wood. However, LPG is a common household fuel in India that is promoted and heavily subsidised so households can afford it. LPG is heavily politicised as subsidies are used as a political election tool and removing them would be very difficult.

Foreign aid organisations have not been formally involved in the national biogas programme which is now solely developed and funded by the MNRE. Despite this, both the government and development culture have been criticised for being top-down and heavily focused on construction targets (Leong, 2020; Patnaik and Jha, 2020; Boyd Williams, Quilliam, Campbell, Raha, *et al.*, 2022; Saldanha *et al.*, 2022). Many critics and some stakeholders are of the opinion that the government lacks commitment to really overcome some of India's social issues and has a history of focussing too much on policy and not implementation. Stakeholders believed that the government avoids tackling taboo social issues because they would lose favour with some voters. Despite the nationwide achievements of the GoI's Swachh Bharat Mission (SBM) or 'Clean India' in increasing sanitation

provision, mainly through construction, the scheme has mostly side-lined issues related to the rights of manual scavengers[3] who are still employed across India (Saldanha *et al.*, 2022).

4.6.1.2 Socio-technical regimes

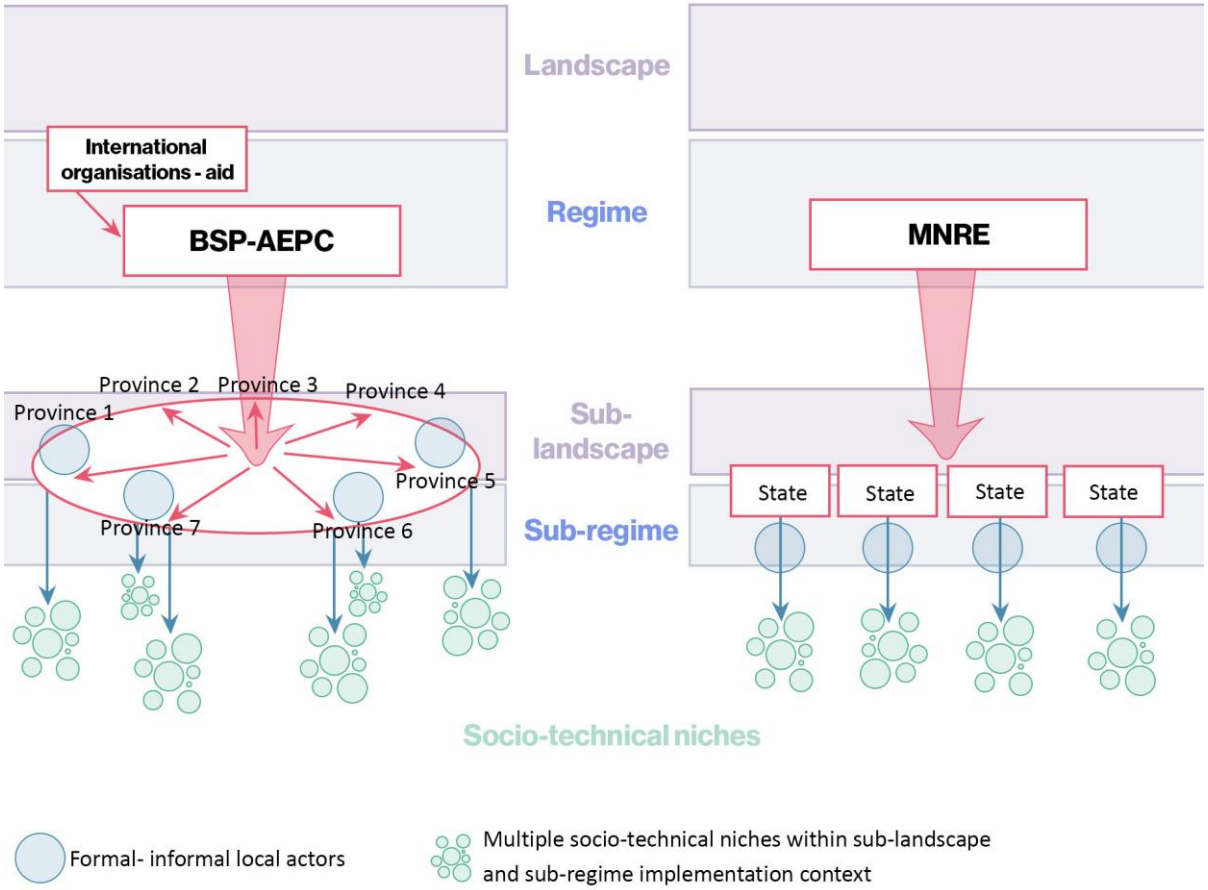

Figure 4.1: *Biogas programme arrangements in Nepal and India**.** At the level of the national regime both programmes have a centralised managing body creating policies. Until 2017 the central managing body for Nepal's biogas programme, previously the Biogas Support Program and now the Alternative Energy Promotion Centre, worked with International aid agencies. In Nepal the central managing body also works at the level of implementation in the sub-regimes, which are the 7 Provinces of Nepal, along with regional private biogas companies. In India the central managing body is the Ministry of New and Renewable Energy. In India, the central managing body is only involved in central management and policy generation, implementation is the responsibility of the sub-regimes, which are the 28 states and 8 union territories of India. Each sub-regime environment in each country will have its unique sub-landscape environment based on unique local history, culture, demographics and geography of the state, territory and province. Within each province, state and territory biogas adoption and use will emerge within a number of socio-technical niches of various sizes where transitions to and use of biogas products will likely be unique to each niche.*

[3] Manual scavengers are sanitation workers who manually clean human waste for a living and face considerable occupational health risks. They are subject to caste-based stigmas around ritual pollution which result in a dangerous substandard working conditions and lack of social mobility with women facing the greatest hardships (Thekaekara, 2003; Saldanha *et al.*, 2022)

4.6.1.2.1 Nepal

Nepal's demographic and health survey (2016) suggests that the rural household cooking energy regime is still dominated by solid fuels at approximately 88% (Ministry of Health Nepal, New ERA and ICF, 2017). Clean fuels (electricity, LPG/natural gas/biogas) make up approximately 12%. The last census, which breaks down household use of clean fuels was conducted in 2011, at this time LPG made up 10% of the rural regime, biogas 2.6% and electric cooking contributed 0.1% (CBS, 2011; Paudel, Jeuland and Lohani, 2021). A study found that areas where there was a higher than average number of households reporting biogas as their main fuel lived in the warmest sub-national regions, had good road access and also participated in community forest user groups (Bharadwaj *et al.*, 2022). However, users normally stack fuels and could use many fuels together (Sharma, 2019). Although the GoN aims to limit LPG market penetration it is still growing in Nepal. Among other factors rural outmigration has made LPG more affordable and informal ways of obtaining LPG have developed. *'My brother visits my parents [village] every 2/3 months and he puts LPG cylinder in the back (expert stakeholder #9)'.* However, most of the LPG users are still concentrated around urban areas or have good road access which shows there is still a large population in rural areas not being reached by LPG, biogas or electricity (Ministry of Health Nepal, New ERA and ICF, 2017; Bharadwaj *et al.*, 2022).

The rural household sanitation regime was declared open defecation free by the GoN in 2019 but a recent report from the World Health Organization and UNICEF estimates that approximately 11% of the rural population still practises OD (World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), 2021). Safely managed sanitation, which is a system where excreta is safely disposed of in situ or treated off-site and not shared with other households, is used by 50.24% (World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), 2021). The remainder use unimproved to basic sanitation services (World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), 2023). Biogas toilets make up a very small percentage of the rural sanitation regime. Approximately 79% of domestic biogas users have a toilet connected (Prakriti Consult Pvt Ltd, 2018) which is approximately 1 % of the total population of Nepal.

Since conception the biogas programme has been managed centrally through a top-down model. Local biogas companies, under a public-private partnership, promote and install biogas under the supervision of a central managing body. Stakeholders explained the biogas programme successfully achieved many of its intended outcomes when the central managing body was the BSP because it also acted as a dedicated implementation agency on the ground working with the private partners (Bajgain and Shakya, 2005). Although the policies were top-down, governance at the implementation level was more egalitarian and could be why a number of key policies were developed that included quality regulation, user training, women-focused initiatives that helped *'make sure they didn't have to wait for the men to come and address these [maintenance] issues' (expert stakeholder #5)*, and toilet connection promotion. The implementing actors found a

progressive household who were willing to connect a toilet immediately and then *'took all these [other] users to [their] farm and showed them… this is biogas that goes to kitchen. It is no different to yours [biogas without a toilet connection]'* (*expert stakeholder #9*). This demonstration of toilet-connected biogas as well as the policy that strongly encouraged households to connect an additional pipe to their digester in case they wanted to connect their toilet at a later date strongly influenced more households to connect toilets and made it easy when they decided to. Multi-regime coordination was also important in driving the success of TLADs. The '*principle driving factor [for promoting toilet connections] was the [sanitation promotions]… together with the subsidy that was granted by the government [for toilet connections]. Because it made sense, I think the biogas and the toilet together'* (*expert stakeholder #5*).

In contrast to these successes the programme has been criticised for not reaching the rural poor. This could be because the uniform subsidy model and the lack of incentive, due to the market-led approach, for private companies to approach poorer households who are less likely to be able to afford biogas (Damgaard, McCauley and Long, 2017; Bhattarai, Somanathan and Nepal, 2018). The biogas programme was also governed from Kathmandu by the social elite. With a better culture of inclusion the programme might have innovated better with mountainous communities as well as poorer groups.

Since the AEPC took over many stakeholders believe *'the management of the programme…[has] totally failed' (expert stakeholder #5)* because the approach is more top-down, focussing on construction targets (Pokharel, 2003; Rai, 2017) with reduced regulation. *'The quality and control part was very relaxed…so there were many incidents where I heard of complaints' (expert stakeholder #13).* However, limited government financial resources have reduced funding available for essential technical assistance activities. The AEPC understand that investing in supportive activities is important but *'because [the] government has very limited resources and in many instances they see the technical assistance activities as non-important and non-essential (expert stakeholder #1)'.* The rise in global cement prices and trained masons leaving for other sectors have negatively impacted the biogas programme (Kamp and Bermúdez Forn, 2016). A stakeholder said to address these challenges the AEPC is considering introducing prefabricated plastic biogas digester designs that do not need skilled masons to construct them onsite, into the subsidy programme.

4.6.1.2.2 India

The rural household cooking energy regime is mostly clean fuels (Electricity, LPG/natural gas, biogas) at approximately 43 % in 2021 which has increased from 24 % in 2016 (Government of India: Ministry of Health and Family Welfare, 2017b; Ministry of Health &Family Welfare, 2021). The full fact sheet is not yet available so break down of these fuels is not possible for 2021. In 2016 LPG made up 23%, biogas 0.6% and electricity 0.3% of the total regime (Government of India: Ministry of Health and Family Welfare, 2017b). The accuracy of this is uncertain as users normally

stack fuels and could use all of these together. Additionally, these numbers might not represent a stable regime and reflect transitions that are occurring locally because *'rural households that get LPG [subsidised] from the scheme have no money to get [LPG] refills every month so they may have LPG but they have gone back to fuel wood (expert stakeholder #6)'.* Due to reasons such as transportation costs to rural areas LPG is sold at prices higher than the subsidised rate within informal markets. The MNRE is in charge of the domestic biogas programme alongside other renewable solutions such as household solar energy. The Ministry of Petroleum and Natural Gas promotes LPG and through the Pradhan Mantri Ujjwala Yojana programme aimed to install 80 million new LPG connections to low-income households between 2016-2020 (Government of India Ministry of Petroleum and Natural Gas, 2021).

The rural household sanitation regime was declared OD free by the GoI in 2019 but the same report estimates that approximately 22% are still practicing OD. Safely managed sanitation is used by 50.5% (World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), 2021). The remainder use unimproved to basic sanitation services (World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), 2023). Through the SBM programme there has been a huge push from GoI to encourage toilet construction and use and end OD. Biogas toilets are promoted in the SBM information (Government of India: Ministry of Drinking Water and Sanitation, 2014) but the predominant design that is promoted, installed and subsidised across India, is the basic pit latrine (Saldanha *et al.*, 2022). Pit latrines only capture HE without containing and treating it and therefore HE is often still making its way into the environment and waterways (Jewitt, Mahanta and Gaur, 2018; Prasad and Ray, 2019). There is evidence that the SBM is not resulting in long-term behaviour change due to its focus on construction targets (Leong, 2020).

Structurally, the biogas programme is managed centrally by the MNRE which generates nationwide policies and provides financial assistance through a top-down model (Mittal, Ahlgren and Shukla, 2018). Implementation of the programme is the responsibility of the state governments in the sub-regime. While stakeholders acknowledge that the NNBOMP has strong policies and objectives that includes an additional subsidy for toilet connections and for poorer vulnerable groups (Government of India: Ministry of New and Renewable Energy, 2020b) they also note a that '*there is always a complete lack of monitoring of the system (expert stakeholder #8)'* (Lichtman, 1987; Zurbrügg, Voegeli and Estoppey, 2011; Raha, Mahanta and Clarke, 2014; Comptroller and Auditor General of India, 2015) and many of the programme objectives are unmet. Post-installation functionality remains low in some cases (Das, Goswami and Hazarika, 2017; Mittal, Ahlgren and Shukla, 2018). Prefabricated plastic digesters have the potential to overcome issues with poorly constructed cement digesters. A stakeholder, working for a foreign company making prefabricated biogas digesters said the MNRE are slow or reluctant to approve some designs under their subsidy scheme. Thus when promoting their design they *'never calculate [the] payback based on the subsidy…It should pay itself back by comparing prices to LPG but the problem with India is that LPG is subsidised' (expert stakeholder #10).*

Though the programme is implemented through the sub-regimes, the regime also bears some responsibility for the policies not achieving their goals. The NNBOMP's focus on promoting and targeting biogas to households with large heads of cattle (buffalo and cows) (Government of India: Ministry of New and Renewable Energy, 2018, 2023) makes it difficult for the programme to be inclusive and reach poorer households. While the NNBOMP has policies to promote toilet connections through a multi-regime approach with the SBM, the programmes do not, to our knowledge, formally coordinate at the regime level. One stakeholder said that the NNBOMP and the SBM had tried to combine their subsidies for toilet connected biogas but the department of finance *'objected. [They said] it is not feasible because there are two different ministry funds (expert stakeholder #8)'*. Perceptions of TLADs in India are polarised within literature as well as amongst the stakeholders. One stakeholder said they *'would strongly recommend biogas from climate change mitigation perspective... [But] if you ask me I would not [recommend TLADs] because [HE] is so little [in quantity] and you have so much effort to keep it hygienic (expert stakeholder #6).'* Another stakeholder is enthusiastic about the benefits of TLADs and believed that *'if you are able to demonstrate that the system has economic value… then the psychological taboos can be overcome' (expert stakeholder #8).* The lack of direction from the regime results in low and uneven uptake across India, as promotion and implementation depends on the agency of individual actors.

4.6.1.3 Sub-landscape

4.6.1.3.1 Nepal – Kaski district, Province 4

As there is a central agency in the regime monitoring the quality of the private biogas companies and engaging in implementation activities the aims and objectives as well as the culture of the programme in the sub-landscape level should be consistent with the landscape level. The data collected for this study could not be used to evaluate how sub-landscape agencies and actors might affect the biogas programme culture but this could be researched in the future in a provincial comparison of biogas implementation across Nepal.

Stakeholders and user responses confirmed that sanitation campaigns had shifted the sub-landscape norm away from OD towards owning and using a toilet, at a similar time to when biogas dissemination was highest in the 90's and early 2000s. Many users said that ODF educational campaigns that included penalties for openly defecating encouraged them to adopt a TLAD. Now more recent biogas adopters are still connecting their toilet to biogas because it is a sub-landscape norm and people understand the benefits of doing so. Additionally, despite the overarching caste system culture at the landscape level, user responses suggested that it is a sub-landscape norm for households to clean and empty their own toilets, or although expensive, call a vacuum truck, which made TLADs a better option for households. How prolific or localised this norm is within the Kaski district is unknown.

Although the size of the respondent group means that generalisations cannot be made, the responses suggest that in this sub-landscape environment caste and gender do not influence biogas

adoption as much as expected. Leaders of TLAD adoption were represented by both male and females of various castes and ethnicities although other female interviewees were not so empowered in their decisions around household biogas. The Kaski district has a high number of Janajati or ethnic groups who are known for practicing much more relaxed ritual caste practices and gender norms compared to the higher castes and will provide a notable diversity to the range of socio-cultural norms across Nepal's sub-landscapes. Many of these tribal groups in the Kaski district were also recruited into the Gurkha armies for over 200 years and the area has been shaped by a long history or out and return-migration and remittances (Libois and Singh, 2020). The study villages were also close to the urban centre of Pokhara where socio-cultural norms are often more relaxed compared to very rural areas.

4.6.1.3.2 India – the state of Assam

The culture of each state's biogas programme will be influenced by the department responsible for implementation. In Assam, the SNA is located in the Department of Environment and Forests, which has objectives to reduce deforestation, thus biogas is considered a way to replace households wood fuel use leading to an energy-centric approach (Raha, Mahanta and Clarke, 2014). One stakeholder said there will likely be *'a more engaged approach from the forest department in some villages [close to forests]. And those are the villages where if biogas has not worked they have got an engineer to come in and fix it…It's the remote [biogas digesters] that are slightly … away from the usual contact to the government departments that have gone in to disrepair, to some extent, [been] neglected (expert stakeholder #2*). SNAs within state government departments may also lack the expertise, workforce, and funding for essential supportive activities, as biogas is not the main focus of the department. '*In the policy paper it mentions there should be regular monitoring of the systems…Government of India cannot monitor all …32 states it is not possible... But [the state] nodal agency practically they do not have sufficient man power, sufficient infrastructure' (expert stakeholder #8).* Furthermore, biogas implementation depends on individual actors' agency, making it vulnerable to changes in government priorities because *'if the government changes then [jobs] change hands and [biogas and rural development] doesn't become a priority for some of the members (expert stakeholder #2)'*.

Household interviews suggested that there is also a top-down culture towards biogas dissemination in the sub-landscape. The state biogas actors overlook complex socio-economic diversities within the state and instead operate the programme through a construction target model rather than selecting and working with households that would most benefit from biogas. For example, Assam has almost three times the average Muslim population of the all-India average and there is a large population of scheduled tribes or ethnic groups who often rear pigs as integral part of their livelihood (Patr, Begum and Deka, 2014). Pig dung is a common feedstock for domestic biogas in China and Vietnam but not India (Cheng *et al.*, 2011; Huong *et al.*, 2014).

4.6.1.4 Sub-regimes

4.6.1.4.1 Nepal – Kaski district, Province 4

The last National Population and Housing Census that supplies information on household cooking and sanitation regimes by district was conducted in 2011. Though outdated, it shows that LPG makes up a large percentage of the regime in the Kaski district with 61% of households stating it is the usual fuel used. This is probably because the district includes the large urban centre of Pokhara. As the case study villages were all within an hour of Pokhara, LPG access and use will be higher than average compared to many other rural areas in Nepal. Wood fuel constitutes approximately 33% of the regime (not all solid fuels). Biogas use in the Kaski region is also above the national average for rural Nepal at approximately 4% of households stating it is their usual fuel. Although the rural regime has been quite stable between 2001 and 2011, the hilly areas, including the Kaski district, has seen over a threefold increase in LPG use. Although wood fuel use has remained quite stable (Paudel, Jeuland and Lohani, 2021), there has been a large reduction in Kerosene use. As households stack fuels these numbers do not mean these fuels are used exclusively by households.

Approximately 1% of the population in the Kaski district live without a toilet facility and most households have a flush to septic tank. The census did not collect data on the number of households using a TLAD. However, participants who no longer have sufficient cattle dung or labour to run biogas said they continue using it as a toilet with a septic tank arrangement, some obtain small volumes of biogas only from toilet waste.

At the sub-regime level, local private biogas companies promote and implement biogas technology. Interview data was not sufficient to analyse the efficacy of the sub-regime in implementing the programme. However, there was no evidence of a reduction in effectiveness due to the AEPC reducing regulation and monitoring, all participants said that there was a technician available for post-installation support. There were high levels of functionality and the causes of most TLAD failures were mainly social factors such as migration and not technical failure. The high numbers of TLAD connections due to joint promotion with the sanitation sub-regime showcases what can be achieved through cross regime coordination. The success of implementation in the sub-regime can be seen in the evidence that TLADs have become a norm with no negative socio-cultural consequences adopted by women and a variety of caste groups.

User accounts suggest that the sub-regime is not responding to more recent landscape changes. Many households, who no longer have cattle dung available, said they would like feedstock diversification training to boost biogas production but they had not found or received training. It is unknown if the private biogas companies approach households without cattle.

4.6.1.4.2 India – the state of Assam

The National Family and Health Survey of 2019-20 states that approximately 34% of the rural population use clean fuels for cooking (electricity, LPG/natural gas, biogas) which is around 10% lower than the national rural average. The full survey that breaks down type of clean fuel used is not

yet available so biogas users are unknown. The sub-regime has seen a significant increase in the use of clean fuels which was 16% in 2016 (Government of India: Ministry of Health and Family Welfare, 2017a).

The survey also states that 69% of the rural population use an improved sanitation facility. It does not state if any of these are a TLAD. There were also many government SBM pit latrine toilets seen around the study areas and every household that was interviewed had a toilet with the majority stating that they call a sweeper to empty it.

Evidence suggests the sub-regime is not working with grassroots actors and is failing to implement centralised policies (Raha, Mahanta and Clarke, 2014). The governance at this level is neglecting supportive activities such as monitoring and maintenance services as well as failing to adapt the programme to cultural diversity. Post-installation support was unequally distributed across the state and the programmes have difficulty reaching lower-income households (Das, Goswami and Hazarika, 2017; Mittal, Ahlgren and Shukla, 2018), which could be because the SNA has mirrored the nationwide approach and used implementation methods that accentuate the bias towards households with many cattle. It is also counter intuitive as one stakeholder explained that households with many cattle are more likely to have a good income and *"people who have a good income will not go for gobar gas [DFADs]…They will go and buy LPG" (F 54 Hindu U41 Assam).* Stakeholders believe the SNAs use of local village contacts to identify eligible households, which is employed in some areas, is an ineffective method for identifying households with the right motivations as well as needs for biogas adoption, which could include poorer households (Raha, Mahanta and Clarke, 2014).

Although national policy sets targets for the number of TLADs that should be built in each state per annum there is no evidence that the state is working with households to achieve this. Most households asked had not heard of the additional subsidies for toilet connections and had not been engaged with about connecting their toilet. Officials working for the biogas programme in the sub-regime had the opinion that no one would connect toilets in Assam, but were also found to have negative attitudes towards TLADs themselves (Boyd Williams, Quilliam, Campbell, Raha, *et al.*, 2022).

4.6.1.5 Socio-technical niches

4.6.1.5.1 Nepal – Kaski district, Province 4

4.6.1.5.1.1 Motivations and adoption pathways

Users adopted toilet-connected biogas for a wide range of energy, agricultural, and sanitary benefits and they were knowledgeable about the wide range of benefits it provides for human and environmental health. Despite the availability of alternatives like LPG and wood, biogas remained competitive due to the additional value users perceived in its agricultural and sanitation benefits. Within households, a fuel stacking equilibrium emerged, with LPG and wood being chosen for

specific uses alongside biogas. The multi-regime programme approach also fostered motivation specifically for the toilet and the subsidies made it economically more beneficial to install a TLAD rather than install biogas and toilet separately. Motivations for overcoming socio-cultural resistance towards TLADs could also be because many people did not have an existing sanitation facility when TLADs were first being promoted in the area. *'Before there were no toilets at home and I had to go in the field ... which was really shameful and hard. After we had TLAD at home it is like a palace for us."(F 62 Hindu U9 Province 4).*

The effects of rural outmigration were evident, with some households no longer investing in maintenance. Despite the ritual pollution associated with TLADs the adopters in the case study villages were predominantly from Nepal's higher Hindu castes. Over time socio-cultural norms have been renegotiated and TLADs have been incorporated as a valued addition to daily life. For some households this acceptance has occurred over generations.

Interviews revealed the effectiveness of the BSP's top-down policy of using progressive farmers to promote TLADs within their communities. In one village, a participant installed a TLAD despite initial opposition; after witnessing the benefits, other villagers also adopted TLADs. Demonstration was critical, as many people wanted to see the benefits before installation, and due to socio-cultural restrictions, they needed time to adjust. Local private biogas companies played a significant role in promoting and demonstrating the TLADs in these niches, fostering adoption in other villages as well.

4.6.1.5.1.2 Innovation

Well-constructed biogas digesters last for many years and are critical in fostering socio-technical innovation. They provide long term demonstration so more households can learn of the benefits of biogas technology but it also allowed households to renegotiate socio-cultural norms over long time frames. The decision to initially adopt biogas technology happens relatively quickly compared to the renegotiation of what specific cooking practices HE derived biogas can be used for, which can take place over years and even generations. Even though many households had TLADs for up to 20 years only some were using biogas for ritual cooking. Some cooks also selected when to use biogas to satisfy the preferences of guests or family members that did not want foods cooked on HE derived biogas.

The niche is changing faster than the regime is responding. The loss of cattle and out migration of younger populations mean that alternative biogas designs as well as training in feedstock diversification are now needed. However, only cement digesters were seen in the study area and none of the more modern prefabricated plastic digesters. Many households said they did not know how to run their biogas without cow dung even though all households indicated there were technicians available.

4.6.1.5.2 India - Assam state

4.6.1.5.2.1 Motivations and adoption pathways

Users adopted biogas primarily for energy provision, not for agricultural or sanitary benefits, which reflects the energy focus of the regime and sub-regime departments designing and implementing the programme. Slurry and toilet connections were not popular motivations as many households were throwing the slurry away or not using it optimally and no households had a toilet connected to their biogas. Households from high socio-economic groups were more likely to be approached by the SNA and subsequently adopt biogas. LPG, which was easily accessible, was seen as competition for biogas. Attitudes towards biogas were not universally positive. Many users had non-functioning digesters and reported there were no local technicians they could call to fix it and they lacked knowledge on alternative feedstock. Subsequently, many were unmotivated to maintain biogas systems.

The main adoption pathway that became apparent during interviews was if a household had cattle and had been exposed to biogas promotion. A local technician in one village helped foster adoption as they provided local promotion and follow-up services. Many people in the village of the technician had biogas digesters, with high cattle ownership being a contributing factor. Households not adopting TLADs experienced fewer socio-cultural restrictions, which simplified adoption pathways compared to Nepal. Despite the biogas programme stakeholders expressing doubts about the possibility of TLADs in Assam (Raha, Mahanta and Clarke, 2014; Boyd Williams, Quilliam, Campbell, Raha, *et al.*, 2022), some participants indicated they might adopt TLADs if given a chance to see or trial them, if they became a social norm, or if alternatives like LPG became less accessible. Currently, there is no evidence to show that the SNA are actively demonstrating and promoting TLADs within the socio-technical niche.

4.6.1.5.2.2 Innovation

In Assam, biogas was used without reservation for cooking as toilets were not connected to digesters. There is potential for innovation in slurry management as many users were throwing their slurry away or not using it properly (Raha, Mahanta and Clarke, 2014; Boyd Williams, Quilliam, Campbell, Raha, *et al.*, 2022). Users could be trained to use it skilfully, and or sell the slurry or produce they grow with it. One user believed the biogas programme would have more success if they created markets so that users had somewhere to sell their slurry, which would incentivise users of biogas to use it properly. Instead, subsidised chemical fertilisers and other organic alternatives inhibit a market for biogas slurry developing. Users showed little interest in learning how to diversify their feedstock even though cattle dung was declining. This lack of interest in innovation warrants further research to determine if biogas is perhaps not suitable to many areas in Assam or if lack of interest is to do with poorly designed and integrated policy mixes that are inhibiting the diffusion of domestic biogas.

Some users acknowledged that socio-cultural norms opposing toilet connections are potentially negotiable. With promotional activities like those undertaken in Nepal, toilet connections

could become a socio-technical innovation in Assam. However, due to existing sanitation options in the study villages, toilet-connected biogas might only be relevant in areas lacking sanitation facilities where users will have more motivation to overcome possible socio-cultural resistance.

4.6.2 An adapted multi-level perspective visualisation of a transition to toilet-connected biogas in a geographically defined socio-technical niche

The MLP figure, a key component of the MLP framework, often accompanies analyses to depict transitions over time (Geels, 2002; Yadav, Malakar and Davies, 2019; Pilloni, Hamed and Joyce, 2020). We modified the MLP figure to depict a decentralised transition to domestic biogas including the additional sub-landscape and sub-regime levels. Figure 4.2 does not specifically represent the biogas programmes of either Nepal or India. Instead, it serves as a generic example to illustrate what an MLP transition might look like and to further evaluate the applicability of the MLP framework for analysing transitions to domestic biogas in diverse contexts covered in section 4.6.3.

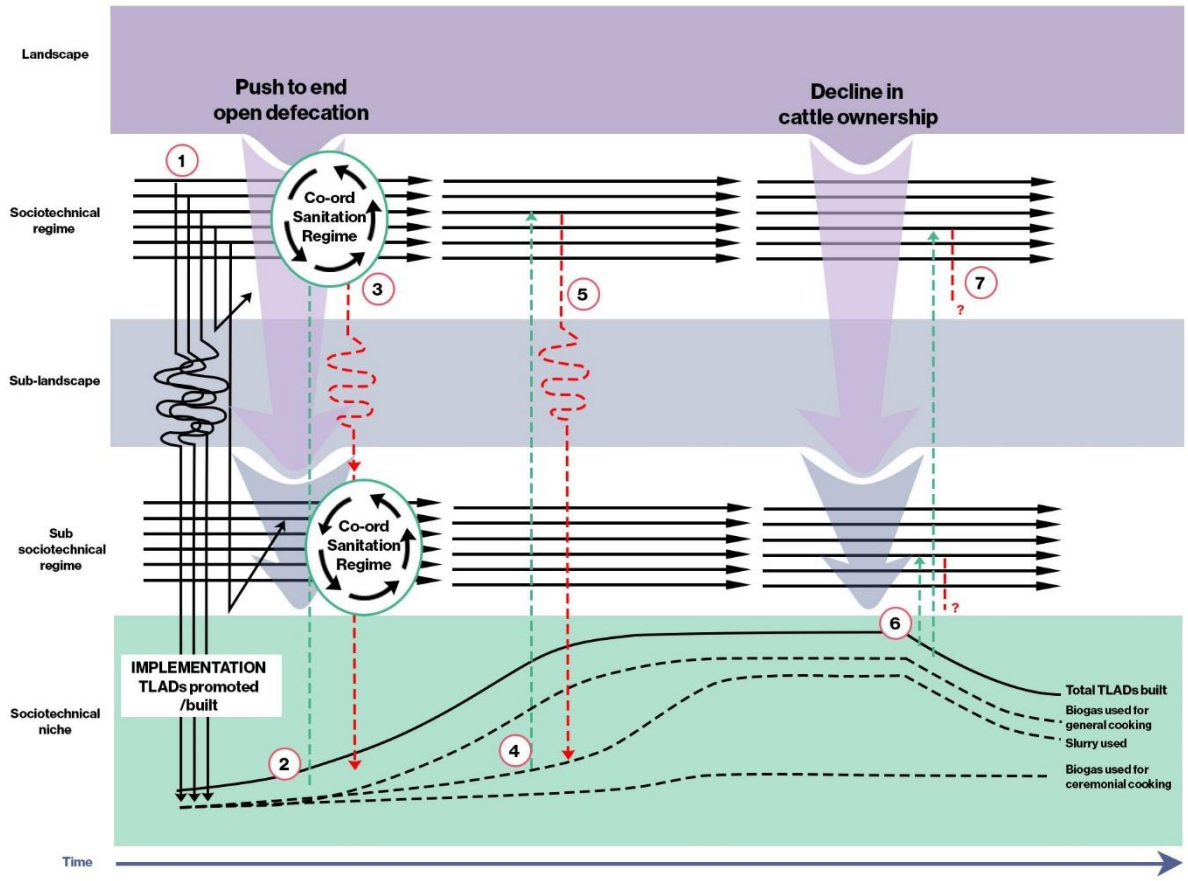

Figure 4.2: *An example multi-level perspective depiction of a transition to domestic toilet-linked anaerobic digesters (TLADs) within a single geographically confined niche environment adapted from* Geels, (2002) and Pilloni, Hamed and Joyce, (2020). *1) The national regime implements a biogas programme promoting TLADs. Policies and actions diffuse through local contexts, impacting the niche where biogas adoption occurs. Some policies may not be suitable to some sub-landscape contexts. 2) Due to socio-cultural resistance and or lack of interest in the toilet feature, adoption of TLADs is low in the niche. This feedback is directed to local or national regimes, contingent on programme structure. 3) Regimes can respond by partnering with sanitation sectors, promoting TLADs with sanitation campaigns and combining subsidies to enhance economic appeal, leading to increased adoption. 4) Despite increased adoption, the usage of the slurry is low in the niche, feedback is relayed to the regime/sub-regime. 5) The regime responds by providing funding or expertise for user training on slurry processing and usage and usage increases in the niche 6) Landscape trends of rural outmigration result in declining cattle populations, reducing dung availability for feedstock. 7) If regimes do not react, for example, by promoting different digester designs and feedstock diversification training, biogas adoption and product usage could decrease. Depending on the context, this could mark the end of a window of opportunity for domestic biogas or signify a failure of biogas programmes to adapt.*

4.6.3 Suitability of the MLP framework for investigating transitions to domestic biogas

Identified in Section 4.3, the MLP's application to domestic biogas transitions revealed significant shortcomings. Despite its popularity and effectiveness in studying sustainability transitions, the

studies that used the MLP struggled to provide a comprehensive explanation for the varied success and failure of household transitions to domestic biogas. To make it more suitable for application to decentralised technology transitions in diverse rural contexts, we adapted the MLP by adding sub-regime and sub-landscape levels. Although this modification addressed some of the MLP's shortcomings, it also highlighted its inherent limitations in studying domestic biogas transitions.

Firstly, while the MLP provided conceptual guidance, it created theoretical lock-in, complicating analysis and potentially masking findings (Binz *et al.*, 2020). The MLP struggles to account for the multi-scalar, socio-political, and geographical factors inherent to decentralised transitions, particularly in rural South Asian contexts. In this study these influential factors were interpreted into the 'landscape' category as they do not belong in the regime or the niche, but they significantly impact transitions more than distant landscape factors. The MLP, primarily developed for national-scale, industrialised context transitions, does not accommodate for socio-political and geographical diversity at multiple scales (Wieczorek, 2018). The graphic representation exacerbates this issue (Figure 4.2), as the MLP's landscape levels are too distant, failing to depict how strongly national and local socio-political, geographical and economic factors mediate transitions to domestic biogas, even within the same programmes and regimes.

Secondly, the MLP directs analysis towards a containerised approach that falls short in studying transitions. Domestic biogas is a niche solution in the energy, sanitation, agriculture, and waste management regimes. Its successful integration into these regimes varies, based on the usage of the technology and products. For instance, it might thrive in the energy regime if users utilise biogas, but fail in the agricultural sector if slurry is discarded. While such multi-sector complexity is not inherent in all sustainable transitions, circular economy practices are crucial for sustainability (Moya, Sakrabani and Parker, 2019; Mallory *et al.*, 2020; Judge *et al.*, 2021). Thus, evaluating transitions to these practices, including waste-to-energy technologies, is critical and requires frameworks that can effectively manage multi-sector and multi-scalarity aspects. As the MLP is a significant tool in sustainability transitions, its limitations need wider recognition.

Upon reflection, a more flexible approach could have been taken —potentially without a specific framework. I could have considered household biogas technology as a global socio-technical niche solution, part of broader multi-scalar energy, waste management, agricultural and sanitation regimes (Miörner and Binz, 2021). This viewpoint would have shifted our inquiry towards understanding the varied success rates of implementing this niche technology in diverse local contexts, even under similar multi-scalar regime structures. Without the MLP, local socio-cultural and political norms would have been interpreted as the backdrop, actively shaping the transition to domestic biogas on multiple levels, not distant landscape factors. I could have then delved into how the socio-cultural context shapes niche development in various geographical contexts under similar multi-scalar regimes. The regime would have been interpreted as one regime that had multi-scalar (global, national and regional) components (Binz and Truffer, 2017; Miörner and Binz, 2021), removing the need for the added sub-regime, which made the analysis quite complicated. Using the

MLP for our analysis and adhering to traditional boundary definitions was made in an attempt to stay consistent with standard categorisations in transition studies.

Rather than adapting the MLP to overcome these challenges, I would suggest that the use of the framework to study similar transitions is foregone. I believe it brings too much bias and working without the MLP will facilitate opportunities for new ways of interpreting transitions to emerge. Following more empirical investigations a new framework or frameworks could be developed that better facilitates the investigation of transitions to household technologies in diverse societies like South Asia.

In spite of the shortcomings of the MLP, this study provides valuable contributions to a growing body of literature aiming to better understand how sustainability transitions emerge in different contexts, with specific focus on the impact of scale and spatiality in shaping transitions (Köhler *et al.*, 2019; Binz *et al.*, 2020; Miörner and Binz, 2021). Notably, the research underscores the significance of multi-scalarity in transitions, challenging the traditional view of transitions as being 'containerised' into national or local levels, advocating instead for a more fluid, multi-scalar interpretation (Miörner and Binz, 2021).

4.7 Discussion and recommendations

4.7.1 Key themes – how multi-levels of actions influence success or failure of biogas programmes

4.7.1.1 Top-down and horizontal governance of biogas programmes

This research suggests that a top-down centrally managed biogas programme, with horizontal governance at the level of implementation, can successfully and sustainably promote domestic biogas. A centralised and top-down approach to policy creation and programme design means that the responsibility of the programme is with a small number of specialised actors knowledgeable about all areas of biogas. To be successful domestic biogas must be promoted over long time periods to potential users, interest rarely comes from the bottom-up or market led. Top-down governance works well to ensure biogas is promoted and peripheral activities such as promotion, training, demonstration digesters, maintenance and regulation are available before users have interest. Top-down programmes must ensure all actors have the expertise and the agency to manage and design a biogas programme for all its energy, agricultural and sanitation benefits and that policies are designed to be adaptable to local contexts. Decentralising a biogas programme to local governance means there are many more actors playing important roles in biogas governance (Brisbois, 2020). The inclusion of more actors can make it harder to identify where decisions are being taken and who is responsible (Brisbois, 2020). This can lead to poor programme outcomes especially if all actors are not adequately trained. Further research is needed to understand how to effectively transfer biogas programmes management to local governance while maintaining efficiency and impact (Brisbois, 2020).

At the level of implementation, how well the policies meet their objectives is strongly dependent on local contexts and processes. Thus, the inclusion of horizontal governance for implementation activities means knowledge does not only follow top-down hierarchical pathways. Knowledge of how grassroots process work and what is required for biogas to succeed in various contexts can travel upwards and impact the design of policies (Huttunen, Kivimaa and Virkamäki, 2014; Kosow *et al.*, 2022). The horizontal governance approach encourages coordination between many different stakeholders so that the top-down policies can be better adapted to local contexts and succeed in practice. However, despite these advantages, programmes that incorporate horizontal governance, like Nepal, still focus on policies that reach large demographics but not minority or vulnerable groups. They also repeatedly fail to reach the poor (Damgaard, McCauley and Long, 2017; Das, Goswami and Hazarika, 2017; Bhattarai, Somanathan and Nepal, 2018). Further effort must be given to improving central design of policies in consultation with grassroots actors and low-income users.

4.7.1.2 Multi-regime coordination and policy coherence

Effective biogas programmes require multi-regime coordination, which combines resources and expertise from various sectors, offering coordinated policy options instead of competing solutions (Gustafsson and Anderberg, 2021). Biogas governance is commonly the responsibility of one regime, most often energy. Multi-regime coordination can overcome the limitations one regime will have in trying to implement biogas that crosses the sectoral boundaries of sanitation, agriculture, energy as well as potentially waste management and social and rural development (Gustafsson and Anderberg, 2021). Combined subsidies from different regimes could mean the total subsidy available is higher giving biogas an additional edge if it is competing with many other subsidised alternatives such as toilets and LPG. Multi-regime coordination is particularly important for promoting toilet connections, which benefits from combined subsidies and expertise from the sanitation regime for working with localised socio-cultural norms and sanitation practices.

Additionally, a multi-regime approach will prevent biogas being promoted and installed in households that do not have the correct motivations or needs for biogas and who are likely to refuse it, abandon biogas or not use it fully. For instance, households who are offered TLADs who have an existing sanitation solution provided by another government scheme lack incentive to adopt a TLAD and overcome potential socio-cultural resistance towards TLADs. There is a need for better understanding of how multi-regime policies diffuse into diverse socio-cultural niche contexts and if and how they interact to affect multiple programme objectives.

To create effective multi-regime policies, a bottom-up approach involving grassroots actors should be implemented, ensuring coherent policy mixes are developed that achieve intended goals in diverse niche environments (Huttunen, Kivimaa and Virkamäki, 2014). Further research should aim to develop practical guides for better integrating multi-regime policy mixes that relate to

domestic biogas programmes, considering local socio-cultural norms, user behaviour, and motivations.

4.7.1.3 Dedicated implementation agency or actors

A dedicated implementation agency could be key to ensuring policies meet their intended outcomes. A biogas programme that is implemented by a government department relies on individual actors, whose primary responsibility may not be biogas implementation and who may lack relevant expertise. Government actors could overlook important policies they do not have the capacity or agency to implement or personally do not agree with, such as toilet connections (Mallory *et al.*, 2020). Government actors in one sector will likely not have the expertise in all sectors that biogas crosses and will lack expertise in developing multi-sector policies. A dedicated implementation agency might be better suited to ensuring multiple government departments from the energy, sanitation and agricultural regimes coordinate so biogas policies are coherent across multiple regimes. If a dedicated implementation agency is not feasible then a biogas programme should at least be run by long-term employees knowledgeable on biogas implementation.

4.7.1.4 Regulation and incentives for innovation

Regulation of domestic biogas construction provides accountability, which is a precondition for, and outcome of, good governance (Brisbois, 2020). Thus, regulation or lack of regulation is tied to programme success or failure because the market has proved ineffective in creating sufficient competition. This means that biogas construction companies are not adequately incentivised to provide well-built biogas and follow-up services. The state or a regulatory body must regulate the market, making sure biogas is constructed to legal standards as well as incentivise innovation that responds to changing landscape factors and user's needs. For instance there are many alternative biogas designs on the market, such as prefabricated biogas digesters made from reinforced plastic (Cheng, Li, Mang, Huba, *et al.*, 2014). They work well with food and toilet waste feedstock (Estoppey, 2010) and do not require masons to build them and thus could respond to declining cattle dung feedstock and labour in rural areas. However, the market alone does not seem to be successfully disseminating these alternative models to rural low-income areas. The in-country regime might have to play a bigger role in bringing these designs to rural areas through subsidising as well as creating incentives for innovation and in-country entrepreneurship rather than relying on imported designs and materials.

4.7.1.5 The negative power of the overarching global development culture and economic system

Despite knowledge to the contrary, biogas programmes are continually implemented without adequate supportive activities such as training, maintenance and regulation (Ortiz, Terrapon-Pfaff and Dienst, 2017a; Xie *et al.*, 2021; Kalina, Ogwang and Tilley, 2022). The continued failure to

incorporate this evidence demonstrates the inertia caused by a technologically focussed global development culture (Wieczorek, 2018; Abdelnour, Pemberton-pigott and Deichmann, 2020). Actors working within the two biogas programmes understand that supportive activities are essential but they work against opposing socio-technical regimes (Goldthau, 2014). This inertia could be addressed by globally reimagining what development is, how it should be measured as well as potentially shielding transitions from the influence of powerful global regimes (Miörner, Heiberg and Binz, 2022). International organisations and donors should rethink their ways of supporting low-income countries. Governments should design policies that better account for the interplay of global forces on local transitions (Wieczorek, 2018).

4.8 Conclusions

This study aimed to investigate the root-causes of domestic biogas programme failures and to better understand why success rates vary, even within similar contexts or under the same programme. These findings are critical considering the ongoing investments in biogas, despite its high failure rates and an insufficient understanding of why these failures are being repeated (Kalina, Ogwang and Tilley, 2022). While prior research has identified general challenges, a comprehensive exploration of the multi-level factors behind varied domestic biogas programme success is lacking.

This study set out to do this by comparing the biogas programmes of Nepal and India, two comparable contexts that have had intermittent success with domestic biogas. Through applying the MLP framework this study set out to identify the multi-level and multi-sector factors influencing a successful household transition to domestic biogas, factoring in the unique socio-cultural, political, and geographical contexts within each country. We examined two local areas in each country to understand how national, regional, and local factors collectively impact the ground-level success of these programmes.

Our study has revealed that local socio-cultural resistance, previously thought to be the main non-technical barrier to the uptake of domestic biogas technology, especially with toilet-connections is only one small part of the reason why biogas so often fails. Previous investigations have insufficiently investigated the whole transition picture resulting in too much emphasis being placed on local socio-cultural norms. This study revealed that the success or failure of biogas programmes primarily hinges on higher-level national and regional factors, as well as how well localised contexts are understood and accounted for within the biogas programme. The governance style of the biogas programme plays a pivotal role in success. A centralised top-down programme design is more efficient at the higher levels of management and policy design, which relies on specialised knowledge and expertise. Over-decentralisation of all programme management means programme efficacy relies on the agency of more individual actors who must have expertise on all aspect of biogas and how it interacts across the sectors of energy, sanitation and agriculture. Horizontal governance at the implementation level is essential for the successful deployment of policies in diverse local contexts.

Having dedicated implementation agencies, as opposed to government departments, can lead to more successful outcomes as an implementation agency has dedicated, trained staff carrying out the biogas programme. Furthermore, multi-sector coordination and policy coherence are vital for a successful programme. Effective cross-sector coordination could ensure that households are not offered a number of competing household solutions inclusive of biogas and that households with the correct needs motivations are identified by the biogas programme as potential adopters. Additionally multi-sector coordination leverages the expertise and resources of other sectors that can support biogas promotion. Funding for biogas programmes, irrespective of the source, must prioritise crucial peripheral activities like training and regulation.

This study advances our understanding of reasons for the success and failure of biogas programmes in varying spatial contexts, marking an important starting point for further research. Future investigations should aim to develop practical, replicable evidence to guide successful biogas programme implementation, and importantly, indicate when domestic biogas might not be an appropriate local solution. I recommend that future research aims to gather empirical evidence as to when different governance arrangements and policy designs work best, and in which contexts. Research should specifically investigate multi-sector coordination, to determine how best to foster it, develop it and execute it in practice to promote successful biogas programmes. This should begin to develop how-to governance and multi-sector coordination methods for domestic biogas programmes with knowledge of when to employ which methods depending on the specific context characteristics.

Chapter 5: Energy literacy, public opinion, and Government accountability in the UK energy crisis

J. Dickie supervised the project. N. Boyd Williams designed the data collection tools with support from J. Dickie. N. Boyd Williams managed the data collection with an online survey provider, Qualtrics. N. Boyd Williams analysed and interpreted the data with consultation support from M. Werther. N. Boyd Williams produced the manuscript.

See Appendix 3 for the survey questions utilised for this Chapter.

Abstract

Since 2022 the United Kingdom (UK) is facing an energy crisis and with UK households paying some of the highest rates for electricity in Europe. This was largely due to the surging global price of gas driving up costs of household electricity bills. Despite this the UK Government has responded with policies aiming to increase extraction and use of domestic gas from the North Sea for UK consumption. This study, through a survey of 999 participants from Scotland and England in 2023, aims to assess how understanding of electricity pricing impacts public opinion on energy policies. The findings indicate a moderate to weak understanding of electricity pricing and market mechanisms amongst most respondents. Over half (56%) incorrectly believe that increased use of domestic gas for electricity production will reduce household electricity bills. The energy crisis appears to have triggered increased public support for domestic energy as survey respondents displayed similar support for increased investments in domestic renewable energy technologies (RETs) and domestic gas extraction for electricity generation. A small portion of respondents with high understanding of the electricity market and pricing demonstrated greater support for RETs than gas suggesting improved public knowledge could increase support for a renewable energy (RE) transition. The research also identifies an opportunity for more extensive implementation of RETs within the UK, with 54% of respondents indicating an increased support for RETs being constructed near to where they live since the energy crisis. A significant proportion of respondents (58%) expressed a lack of sufficient knowledge about energy policies, and 49% indicated they consider other policies to be of higher importance when voting. This suggests that the government may not be held to account adequately for their energy policies. Recommendations are proposed for enhancing public engagement around electricity pricing which could then escalate support for a RE transition and enable more informed public voting.

5.1 Introduction

The energy crisis that began in 2022 in the United Kingdom (UK) saw a surge in domestic electricity and gas prices, with UK households paying some of the highest rates for electricity in Europe (Gill,

2023; National Energy Action, 2024). The sharp increase in energy prices is estimated to have resulted in 6.6 million UK households facing fuel poverty, up from 4.5 million in 2021 (4.5 million) (National Energy Action, 2023). Generally defined as the necessity to allocate a disproportionately high segment of household income to maintain a comfortably warm home, fuel poverty varies in its specifics across the UK (National Energy Action, 2022; Hinson and Bolton, 2023). In 2022, in an attempt to stem the crisis the UK Government announced a two-year plan to cap the cost of each unit of gas and electricity that suppliers can charge households. Under this plan, the average annual energy bill would be limited to £2,500 per household—dependent on consumption levels (United Kingdom Government, 2022). However, £2,500 still represents a 100% increase in energy bills since 2021 (National Energy Action, 2023). The energy crisis, coupled with soaring inflation and wage stagnation, has led to a cost of living crisis in the UK (Atkins, 2022).

While the headline causes of the energy crisis are the increased demand for energy after the Covid-19 pandemic and the Russian War on Ukraine (Mcculloch, 2023), the price of energy in the UK has been rising on average for nearly two decades (United Kingdom Government, 2013; Stewart and Bolton, 2022; Gill, 2023). Fuel poverty has also been an ever-increasing and long-term concern (Bridgen and Robinson, 2023). The steady rise in energy bills in the UK that culminated in the recent energy crisis is due to a long-term accumulation of many factors. Three large contributing factors are the UKs liberalised energy system as well as long-term reliance on fossil fuels, and an unstable global fossil fuel market. In liberalised electricity markets the price of electricity is tied to the price of gas, which is the most expensive means to generate electricity in the UK (Zakeri, Staffell, *et al.*, 2022). The price per kWh of electricity sold on the wholesale market is based on the unit that was needed to make up the nationwide demand. Cheaper renewables and nuclear are used to meet electricity demand first, and gas, is used to make up the demand the cheaper sources cannot supply. Thus, gas sets the price of all electricity on the market (Zakeri, Staffell, *et al.*, 2022). As long as gas-fired electricity contributes anything to the electricity mix, household bills will reflect the price of gas (Guan *et al.*, 2023). The UK Continental Shelf (UKCS) is licenced to private companies who are not obligated to sell the extracted gas to the UK, though they do pay the government revenues (Garavini, 2022). It is sold to UK refineries at the global gas price. Thus, household electricity bills are tied to the global gas price whether the gas used is domestic or imported.

The UK Government's recent energy policies aim to increase investments in renewable energy technologies (RETs) and nuclear sources of energy to fully decarbonise the power sector by 2035 (Department for Energy Security and Net Zero, 2023). The policies also suggest boosting UKCS gas extraction and investing in the UK's fossil fuel industry to ensure energy independence during its reliance on gas. This approach risks deepening the UK's fossil fuel dependency and exposes households to potential energy crises due to volatile global fossil fuel markets (Mitchell, 2012; Guan *et al.*, 2023). Renewable energy (RE) sources, such as wind and solar, are weather-dependent and can be inconsistent in power output. When renewables fall short and storage is inadequate, natural gas is used to meet the UK's demand, owing to the rapid activation of gas-fired plants. The Climate

Change Committee advises that, under current plans, the UK will still require substantial natural gas for the foreseeable future (Committee on Climate Change, 2023b, 2023a).

Historically, the UK public has generally favoured a national shift to RE, with a preference for less visible technologies like offshore wind (Department for Business Energy and Industrial Strategy, 2021). Community engagement and local ownership of RETs can boost public approval for their proximity to residential areas (Roth *et al.*, 2018). From 2019 to 2022, support for UKCS gas extraction declined, aligning with climate change concerns, but it increased in 2022 during the energy crisis (Demski, Pidgeon and Spence, 2013; Department for Business Energy and Industrial Strategy, 2021; Evensen *et al.*, 2023). While the UK public shows awareness of energy supply and transition costs (Devine-Wright, Devine-Wright and Sherry-Brennan, 2010) (Becker *et al.*, 2019), some have expressed confusion about the reasons behind why they pay what they pay for energy (Demski *et al.*, 2017; Becker *et al.*, 2019). There is a research gap in understanding the public's knowledge of the energy market, especially the relationship between gas prices and wholesale electricity prices. Previous research has examined the UK public's views on a RE transition but neglected to investigate the depth of the UK public's understanding of the energy market and pricing, and therefore their ability to evaluate government energy policies, and cast informed votes (Umit and Schaffer, 2022). Informed citizens are crucial for governmental accountability (Fraile, 2007), and lack of political knowledge on energy issues could affect voting behaviour and democratic engagement (Haidt, 2012; Reeves, McKee and Stuckler, 2016; Atkins, 2022).

This study specifically aims to investigate the UK public's understanding of the electricity market and pricing and if and how this knowledge is linked to their opinions on how the UK should invest in the future of its electricity system. The focus of this study is on the electricity market due to its complexity in pricing mechanisms. The research objectives are to:

1. Determine the extent of the UK public's understanding of electricity pricing mechanisms, including the impact of gas prices.
2. Assess public perceptions of future investments to ensure affordable electricity, particularly the impact of future investments in renewables versus fossil fuels.
3. Evaluate whether the energy crisis has increased or decreased public support for renewable and decentralised energy solutions.
4. Assess if participant understanding of electricity pricing mechanisms impacts perceptions of future investments and support for renewable and decentralised energy solutions.
5. Gauge the significance of energy policies in influencing the UK public's voting decisions during general elections.

This research investigation aims to identify areas where public education is needed to foster informed support and voting. This work intends to guide UK energy policy towards achieving Net-Zero, while being mindful of public concerns about affordability. Furthermore, it is hoped that the findings will provide a foundation for pro-renewable groups, political parties, and community energy groups to better engage with the public by understanding their foundational knowledge on these topics.

5.2 UK electricity market structure and historical energy policies

This section examines the UK's energy policy landscape, shaped by decades of policy evolution and historical events. It discusses the private electricity market's structure, the motivations and outcomes of privatisation, and historical policies regarding electricity generation from gas and renewables. This background provides context for understanding the current state of the UK's electricity system.

5.2.1 Britain’s Electricity System: How It Works

5.2.1.1 Privatisation and the effects

The UK's energy system was privatised in the 80s and 90s by the Conservative Government (Garavini, 2022). The aim was to increase competitiveness, innovation and open up the industry to more investments (Garavini, 2022; Valenzuela and Rhys, 2022). After liberalisation the average household electricity bill fell, but this was due to complex factors like falling coal prices. Household bills rose again when the global oil prices rose in the 2000s. Upon liberalisation the government failed to introduce adequate market competition, allowing only a few energy suppliers to dominate the market. As a consequence, UK households were not offered competitive prices and remained vulnerable to price spikes (Valenzuela and Rhys, 2022). To protect households from high prices and to prevent energy companies from amassing excessive profits, the government has had to regulate the market. They have also had to incentivise and pressure private energy companies to invest in RE sources (Pearson and Watson, 2012; Pollitt, 2012; Valenzuela and Rhys, 2022).

5.2.1.2 Private extraction to supply

For gas-fired electricity the first step is extraction from the UKCS which is licensed to private and state-backed companies, both UK and foreign owned. Once these companies extract the gas they can sell it, based on the global gas price, to the UK or choose to export it (Department for Business Energy and Industrial Strategy, 2022b; Common Wealth, 2023; Dunne, 2023).

After extraction and processing of domestic and imported gas, electricity is generated in gas-fired power stations. Electricity is also generated through nuclear and RE sources such as wind and solar. All electricity is then sold to suppliers on the wholesale market. As long as gas is needed to make up the UK daily demand the wholesale price for electricity is set by the price of gas. Although gas accounts for around 40% of the UK's total electricity generation, in 2019, it determined the wholesale price 84% of the time. This is notably high compared to the EU average of 40% in the same year (Zakeri, Staffell, *et al.*, 2022).

After purchasing electricity from traders and generators, suppliers must transmit and distribute it to consumers (Tam and Walker, 2023). The infrastructure for this process is owned and managed by various private corporations. Electricity suppliers set tariffs reflecting costs at each step of the supply chain, while also ensuring firms at each stage can make profits. The Office of Gas and Electricity Markets (Ofgem) regulates the prices per kWh charged to consumers via a price cap, a

strategy aimed at balancing the needs of consumers and the viability of suppliers. However, as gas prices and electricity producers are not capped, Ofgem had to raise the electricity price cap during the energy crisis. This was due to supply companies needing to increase their rates to remain profitable amid the rising costs of energy procurement and distribution. To help suppliers weather this energy crisis, the cap was raised by 80%. In response, the Government introduced the Energy Price Guarantee in 2022, which limited charges to households, ensuring supplier losses were compensated from public funds (Gross *et al.*, 2022; Ofgem, 2023). An illustration of the privatised electricity system in the UK can be found in Figure 5.1.

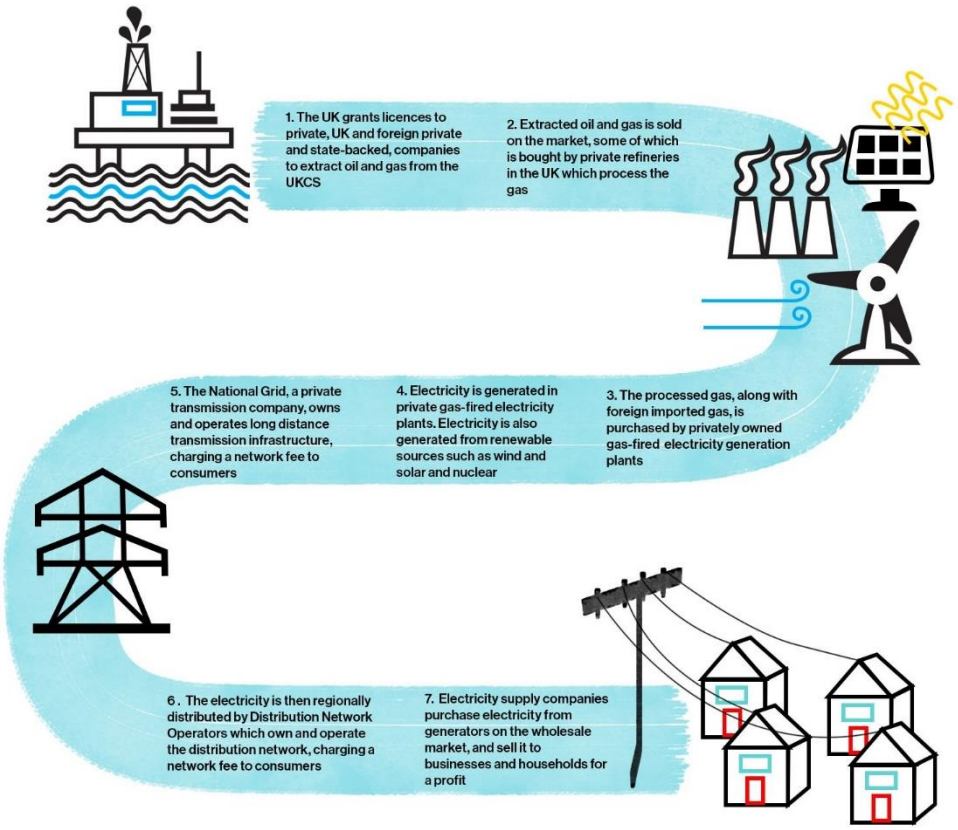

Figure 5.1: *Illustration of how the liberalised electricity system in the UK generates and supplies electricity to UK households and the actors involved adapted from Common Wealth, (2023).*

5.2.2 History of policies and subsidies for electricity

5.2.2.1 Extraction and use of gas

The UK's energy policy has been shaped by its evolution into an oil-producing nation since the discovery of oil and gas in the UKCS in the 1970s (Garavini, 2022). During this time the UK did not import any gas from abroad. The country's infrastructure investments have led to a significant reliance on gas, currently used for 74% of domestic heating and 40% of electricity supply (Gross *et al.*, 2021; Martin, 2023). With the decline in UKCS production and increase in demand, gas imports began again in the early 2000s and now account for half of the UK's gas consumption (Pearson and Watson, 2012; Bradshaw, 2018). The reliance on gas makes the UK susceptible to fluctuations in the global gas market. Despite efforts to reduce fossil fuel dependence, the UK continues to rely on gas

for electricity, especially to cover demand surges or RE fluctuations. The current UK system cannot offer domestic households price security and past policies have been largely ineffective in mitigating this risk for UK residents (Bradshaw, 2018).

5.2.2.2 Strategies for Advancing Nuclear and Renewable Energy Growth and Promoting Decentralisation

In 1990, the UK government introduced the Non-Fossil Fuels Obligation (NFFO) to encourage electricity sourcing from non-fossil fuels. The NFFO mainly aimed at promoting nuclear power, resulted in just a 1% increase in renewable electricity (Pearson and Watson, 2012). The NFFO was funded by the Fossil Fuel Levy, contributed to by both fossil fuel electricity suppliers and household consumers. In 2002, the NFFO was replaced by Renewable Energy Obligations (REOs), mandating electricity suppliers to partially source from RE (Pearson and Watson, 2012). April 2010 saw the introduction of the Feed-in Tariff (FiT) scheme by the Labour Government, promoting small-scale decentralised RE generation (Pearson and Watson, 2012; Mirzania *et al.*, 2019). This scheme, guaranteeing long-term payments to small suppliers for grid electricity, notably boosted the solar voltaic industry and community renewable energy (CRE) projects' financial viability (Pearson and Watson, 2012; Mirzania *et al.*, 2019). In 2013, the Contract for Difference (CfD) mechanism was launched, offering investment incentives in both small and large-scale private RE projects, by shielding investors and consumers from market cost fluctuations.

5.2.2.3 Removal of support – beginning of conservative austerity

In 2016, the Conservative Government reduced and then removed the FiT scheme by 2019, citing a preference for market-driven growth over subsidies (Department for Business Energy and Industrial Strategy, 2018). This significantly impacted the RE sector, particularly CRE projects (Mirzania *et al.*, 2019). Comparatively during the same period, CRE in countries like Germany, with sustained FiT support, thrived (Mirzania *et al.*, 2019). The Smart Export Guarantee, which was introduced to replace the FiT in 2020, requires UK energy suppliers to buy electricity from local producers but without a minimum price guarantee or long-term contracts. This made small-scale RE investments riskier than under FiTs (Community Energy England, 2023). Additionally, solar power was excluded from the CfD in 2015, followed by onshore wind in 2016 (Mirzania *et al.*, 2019), and the REOs were closed to new capacity in 2017 (Ofgem, 2017).

5.2.2.4 Reinvestment – though not as much as before

Following the Covid pandemic, the UK Government issued the 'Energy White Paper: Powering our Net Zero Future' and 'The Ten Point Plan for a Green Industrial Revolution'. These documents outlined strategies for economic recovery and achieving Net-Zero emissions by 2050, focusing on rebuilding and levelling up the economy (Department for Business Energy and Industrial Strategy,

2020a, 2020b; Valenzuela and Rhys, 2022). In 2021, the Government included onshore wind and solar power in the CfD scheme once again. Additionally, the UK is investing in electricity connections with Europe to enhance electricity trade and address supply security concerns (Gross *et al.*, 2022). However, the plans also aim to develop the UKCS as a 'net zero basin' by 2050, encouraging more exploration and offering tax reductions for carbon capture and storage and renewable electricity use in extraction processes. These initiatives, while reducing carbon emissions, require substantial infrastructure investment that will not reduce gas prices to household consumers.

5.2.3 Response to the energy crisis

The UK Government, instead of reinvesting in CfD, REOs, and FiT schemes that would work to decouple electricity prices from gas, chose the Energy Price Guarantee, funded by windfall levies on oil and gas extraction, and electricity generation. Gross *et al.*, (2022) suggest this approach only temporarily eases energy bill increases without directly lowering electricity prices, as reliance on gas-fired electricity persists. Critics of windfall taxes argue levies deter energy companies from investing in infrastructure (Economist, 2022). To offset this, the government offered a 90% tax relief for new UKCS investments. This balance of taxes and tax reliefs allowed some major oil firms to pay minimal windfall tax, despite making record profits and the huge pay-outs they have made to shareholders (Güçeri, 2022; Partridge and Jolly, 2022). The Government also imposed a levy on low-carbon electricity generators, including renewables and nuclear. This has drawn criticism from the renewable sector, claiming it impedes investment and the UK's Net-Zero goals (Lempriere, 2022). The Government justifies this by stating low-carbon generators benefit from gas-set electricity prices without incurring gas costs (UK Government, 2022). Gas electricity generators, despite substantial profits, are exempt from this levy due to their role in providing flexible capacity when RE is insufficient (Pratley, 2022).

5.2.4 Summary and future outlook

The UK's energy strategy aims to offer Europe's lowest wholesale electricity prices by 2035. They also aim to achieve decarbonisation through expanded nuclear and RE, alongside increased UKCS oil and gas extraction (Department for Business Energy and Industrial Strategy, 2022a; Department for Energy Security and Net Zero, 2023). This strategy sparks concern about ongoing fossil fuel reliance and household vulnerability and exposure to gas prices. Current strategies do not fully address how to protect households and decouple their bills from fluctuating gas prices as investment in oil and gas continues (Tam and Walker, 2023). Despite the UK's Climate Change Act of 2008 committing to net-zero emissions by 2050, it's uncertain if current policies prioritise public interest or can meet their targets.

5.3 Methodology

5.3.1 Survey development and administration

To gather data on a sample of the UK public's energy literacy and perspectives regarding the UK's energy transition, an online survey was conducted targeting residents in Scotland and England. Energy literacy is a broad term but specifically for this study it is used to refer to comprehension of the UK's wholesale electricity market and pricing dynamics.

5.3.1.1 Sampling

Scotland and England were chosen based on budgetary constraints, which limited the sample size. These two largest UK countries also offer compelling contrasts for study: Scotland, rich in RE resources, particularly onshore and offshore wind, is also proximate to the UKCS and has a significant oil and gas industry. Despite these resources, 25% of Scottish households experience fuel poverty, a stark contrast to the 13% in England (Hinson and Bolton, 2023).

Participants were solicited through the Qualtrics online panel (www.qualtrics.com/uk/), a platform comprising adult residents in the UK. Inclusion criteria for the study stipulated adult participants living in Scotland and England whose demographic composition matched the average age distribution reported in the latest UK census. Age was selected as an important demographic to control for as various investigations have concluded that energy literacy is related to age, with older participants generally more energy literate (Devine-Wright, Devine-Wright and Sherry-Brennan, 2010; van den Broek, 2019). The target sample size was set at 1000 respondents, with the data collection period running from the 8th to the 12th of June, 2023.

5.3.1.2 Survey quality control criteria

Qualtrics removed respondents that answered the survey in under 4 minutes, had no response variability, and who answered incorrectly to the included two attention check questions. The survey was sent out until 999 responses were collected that passed quality checks.

The survey instrument underwent quantitative pre-testing through a pilot survey, which collected 50 responses via the Qualtrics online panel. The first pilot-survey returned with poor participant interaction. Some 54% of respondents had to be removed because they selected answers that contradicted another of their answers or had low response variability. The first survey instrument was not adequately breaking the complex content down so that it could be properly completed by participants. Subsequently, the survey was redesigned and sent out for second pilot-survey to an additional 50 participants. The responses to the second pilot-survey were improved and so the survey was sent to collect 999 responses.

The language of the survey was kept necessarily neutral. The questions were designed to reflect both a pro-renewable and pro-fossil fuel opinions to not make the survey appear biased or to sway responses either way.

5.3.2 Measure and analyses

5.3.2.1 Survey structure

Participants answered eight demographic questions covering their residence (England or Scotland), age, ethnic origin, education level, living situation, and gender. Additionally, they were asked to reveal their primary UK news source to evaluate its impact on their perceptions of the UK electricity market. News sources, which often have with political leanings, can significantly influence public understanding of topics like energy (Jaspal and Nerlich, 2014).

The survey, after gathering demographic information, concentrated on evaluating participants' understanding of the UK's liberalised wholesale electricity market, its pricing mechanisms, governance, and the influence of gas on electricity prices, thereby determining participant understanding around why households pay specific rates for electricity. Given the unique focus of this study it was necessary to develop a new energy literacy measurement tool. Existing energy literacy assessment tools, upon review, were found to focus mainly on general knowledge of energy production and supply, as well as attitudes, without addressing the specificities and complexities of the liberalised electricity market, particularly the UK's liberalised electricity market (van den Broek, 2019). It has been noted in literature that there exists a wide variety of definitions and approaches characterise the energy literacy and this makes comparisons and generalisability of the findings challenging. While recognising this I argue that existing energy literacy measurement tools are not sufficient for this investigation and the development of a new measurement tool was necessary.

In order to assess the public's comprehension of the UK electricity market, the research process meticulously identified several key areas of understanding. These areas were crucial for a comprehensive grasp of the subject and included the organisation and governance of the UK electricity market, the mechanisms determining household electricity prices, the impact of UKCS gas on these prices, and the broader implications of international events like the Ukraine war on gas imports. Given the scarcity of academic literature exploring public understanding of the liberalised electricity market, the development of the survey tool required referencing a range of media articles. These articles aimed to demystify the electricity market for the general UK public (Comon Wealth, 2021; Clinton, 2022; Common Wealth, 2023; Lawson, 2023). The objective was to create a survey instrument that could effectively gauge participants' awareness of key issues, such as variations in household electricity pricing across different tariffs and the role of UKCS gas in the national energy mix. The tool was designed within the constraints of survey length and cost considerations. It comprised a concise set of questions formulated to determine a participant's level of understanding of the UK's liberalised electricity market (refer to Appendix 3 for the survey questions). The primary aim of this methodology was not to develop an exhaustive energy literacy tool but to design specific, targeted questions that could reveal the public's understanding of particular elements of electricity market dynamics and their direct impact on household energy bills. This focused approach was

pivotal in gathering data that was directly relevant to the study's research questions. The methodology employed in the development of this tool thus reflects a rigorous, context-specific approach to understanding public knowledge and perceptions within the energy sector.

Subsequently, participants were asked to share their opinions on future electricity system investments and their stance on constructing decentralised RETs in the UK. To provide a tangible context for decentralised RETs, wind farms were used as an example in the survey questions - these are substantial installations that have often met considerable public resistance (Jones and Richard Eiser, 2010). The survey also explored attitudes towards nearby privately or locally-owned wind farms. The final questions examined how energy policies influence participants' voting decisions in UK elections.

5.3.2.2 Analysis – descriptive statistics

The analysis commenced with demographic assessments of participants, who were then categorised into four energy literacy groups. Grouping was based on the number of correct answers participants gave to the energy literacy questions: Group 1 (7-9/9 correct answers), Group 2 (4-6/9), Group 3 (1-3/9), and Group 4 (0/9). Correlations between these groups' energy literacy levels and their opinions on electricity system investments and decentralised RETs was explored. Grouping, a common survey analysis technique, helps investigate relationships between a group of people sharing a common characteristic, such as demographics or political orientation and news source, and a dependent variable such as perceptions (Corner *et al.*, 2011; Demski, Poortinga and Pidgeon, 2014; Evensen *et al.*, 2023). This study employs a pioneering methodology, creating a specific set of questions to assess participants' energy literacy, particularly regarding the UK's wholesale electricity market. It then uses grouping to examine the link between energy literacy and public opinion.

5.3.3 Consent

Ethical approval was received from the University of Stirling. As the participants were obtained from a Qualtrics survey panel participants would have been asked consent from Qualtrics to participate. The survey included an additional consent question to verify participants' agreement to their data being used after being informed about the survey's purpose. Participants were also given the contact details of the lead researcher if they wished to follow up after they have completed the survey and or if they want to see the published results.

5.3.4 Limitations

The complexity of the topics in the online survey might prevent multiple-choice responses from fully capturing participants' opinions (Dowler *et al.*, 2006). As a pioneering study in this area, selecting a survey instrument as an initial method aimed to gauge public understanding and assess the need for further, more in-depth investigation in this pioneering area of study. Ideally, a more detailed follow-up using qualitative methods like focus groups or interviews would offer nuanced insights (Dowler

et al., 2006), but this was outside the scope of the study. Focusing on England and Scotland limits the broader applicability of the results across the UK yet provides valuable insights into public opinion in its two largest countries. Creating a new energy literacy measurement scale presents methodological challenges, particularly in terms of validation and comparability with existing studies. Given the lack of an existing scale that specifically measures public understanding of electricity market functions and pricing, developing a new scale was a necessary step for this research. If future research investigates this topic further more work should be invested in methodologically developing the energy literacy tool.

5.4 Results

5.4.1 Demographics

The sample is broadly representative of the population of England and Scotland in terms of age, ethnicity, education and home ownership (Figure 5.2) (National Records of Scotland, 2011; Office for National Statistics, 2021). There was an over-representation of females at 67% whereas the female population of England and Scotland is 49% and 51% respectively (National Records of Scotland, 2011; Office for National Statistics, 2021). The sample was representative of the population of Scotland compared to England.

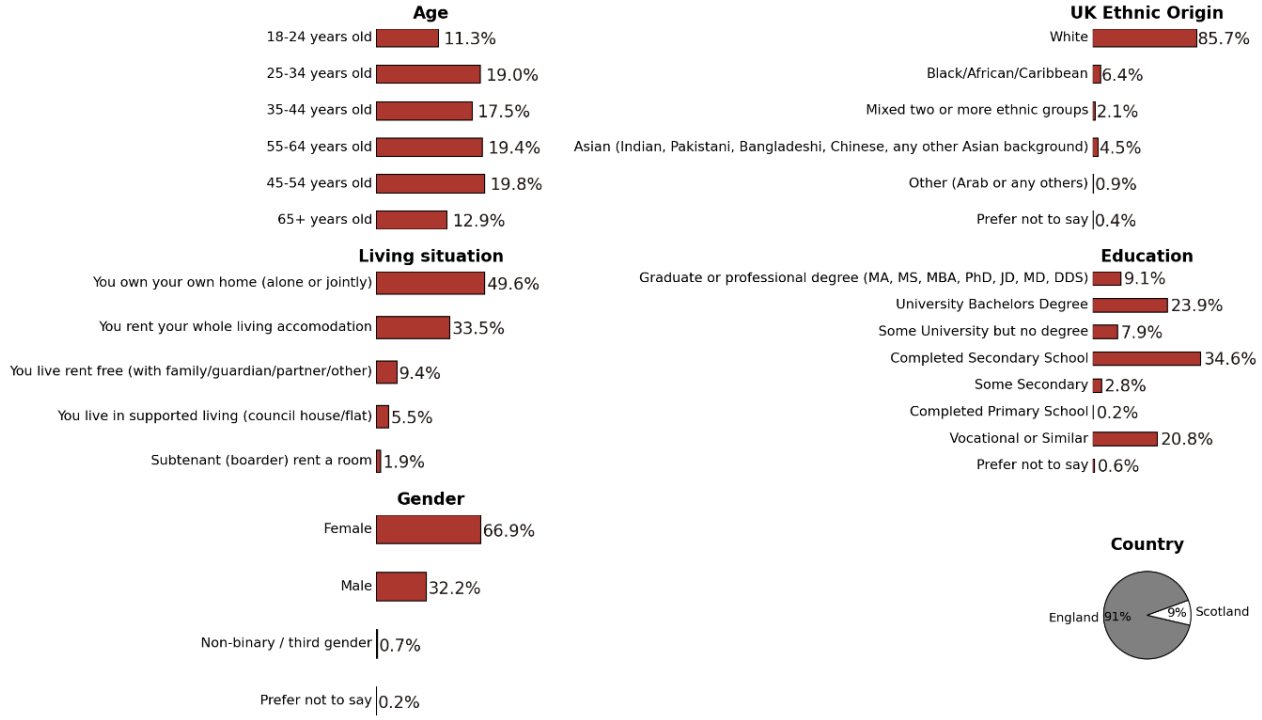

Figure 5.2: *Overall demographics of the 999 survey participants (age, gender, education, ethnicity, living situation, country of origin)*

5.4.2 Energy literacy: electricity pricing mechanisms

To assess the survey participants' energy literacy, they were presented with a series of statements and asked to determine whether each was true or false (Figure 5.3 A-I). The statements pertained to the UK's electricity system, electricity pricing and the contribution of UKCS to the UK's gas demand. Figure 5.3 illustrates the percentage of respondents who answered 'true', 'false', or 'not sure' to each statement, while Figure 5.4 specifically indicates which of these responses were correct or incorrect. Over half of the respondents demonstrated a good understanding of simpler supply and generation costs, as well as certain governance aspects, correctly answering questions about the presence of electricity cables, Ofgem's role, and the cost-effectiveness of RETs compared to gas (Figure 5.4 A, B, and F). However, they performed poorly on questions related to the functioning of the wholesale electricity market, the role of the UKCS, and the pricing of nuclear electricity (Figure 5.4 C, D, E, G, H, and I). There were notable misconceptions among respondents regarding the cost of generating electricity from gas, nuclear, and RETs. While 42% correctly identified that electricity from gas is more expensive than that from RETs (Figure 5.3B), 45% incorrectly believed nuclear to be the cheapest source, despite solar and wind being less costly (Figure 5.3C) (IRNEA, 2022; Zakeri, Staffell, *et al.*, 2022). Furthermore, nearly half (43%) mistakenly thought that households supplied exclusively with RETs electricity pay less per kWh compared to standard tariffs (Figure 5.4D), whereas only 29% were aware that households are charged the same rate per kWh, the wholesale electricity price, regardless of the electricity source (Figure 5.4E).

Respondents displayed a limited understanding of both the governance of gas from the UKCS and its contribution to domestic gas supply. Approximately 36% overestimated the UKCS's contribution, believing it provides more than 75% of the UK's gas, when it's actually around 50% (Figure 5.3G) (Office for National Statistics, 2022). Additionally, 43% were unsure whether the UKCS meets over 75% of the UK's gas demand. Regarding gas governance, 19% incorrectly thought that UKCS gas, licensed to private companies, could only be exported if not needed in the UK, with 55% uncertain about this (Figure 5.3I). Only 26% know that these companies are not obligated to sell their UKCS-extracted gas to the UK. Furthermore, 60% mistakenly believed that a significant portion of the UK's gas was imported from Russia prior to the Ukraine war (Figure 5.3H), whereas only 4% of the UK's 2021 gas supply was from Russia, with the majority (over 70%), then and now, sourced from Norway (Mettrick and Ying, 2022; Office for National Statistics, 2022).

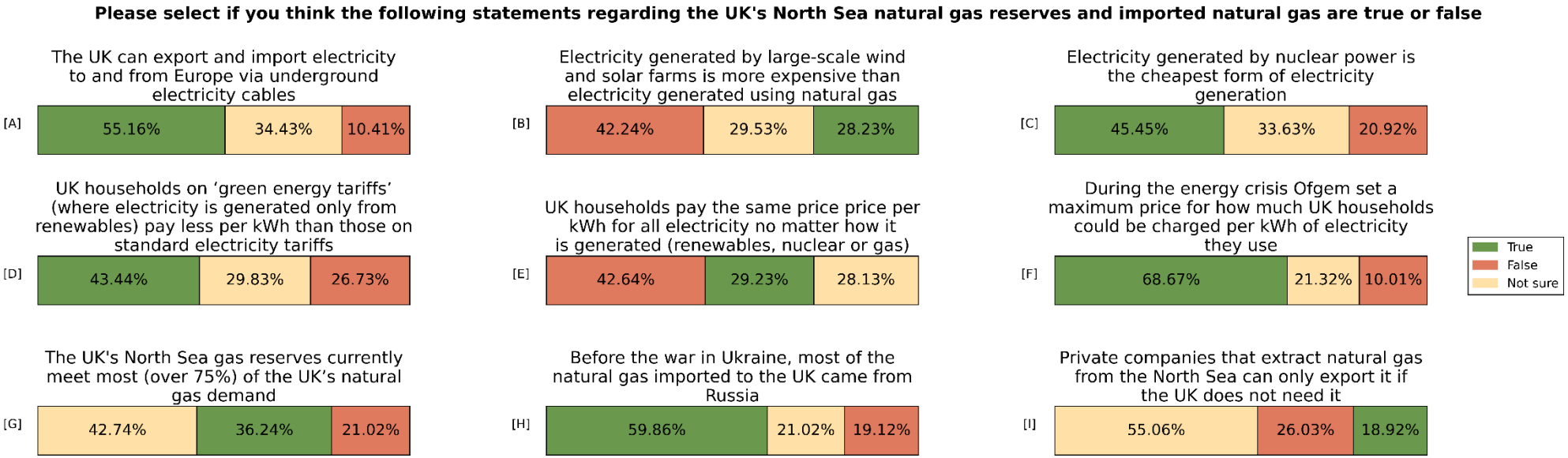

Figure 5.3: *Energy literacy statements presented to the survey respondents, along with how many of the respondents believed them to be true, false or if they were not sure*

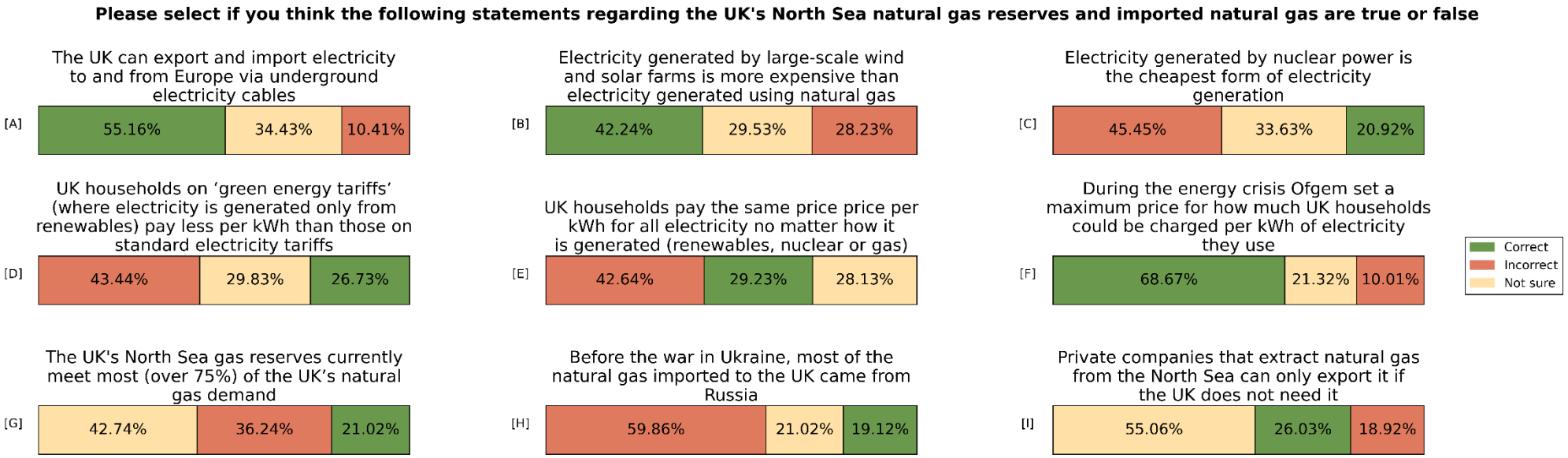

Figure 5.4: *Energy literacy statements mapped from the true/false answer in the survey to the factual correct-/incorrectness of each statement.*

5.4.2.1 Grouping analysis by energy literacy

Respondents were sorted into four energy literacy groups based on their accuracy in answering the energy literacy statements. The division into these groups enabled an in-depth comparison across diverse knowledge levels, with the specific groupings based on the spread of correct answers. Notably, there were more respondents who answered 0/9 questions correctly than those scoring 8/9 or 9/9, leading to a broader range of correct answers defining the higher knowledge group compared to the lower one.

Table 5.1: *Energy literacy classes and counts of respondents*

Group	Energy literacy description	Number of correctly answered questions	Number of respondents
Group 1	High	7-9	42
Group 2	Moderate	4-6	340
Group 3	Weak	1-3	544
Group 4	Poor	0	73
		Total count	999

The majority of respondents are moderately (Group 2) and weakly (Group 3) energy literate, at least regarding the subject topics they were asked about in this survey.

There was some demographic variation between Groups 1 – 4. Group 3's demographics closely mirror the average demographics of the entire sample, and as the largest among the four groups, it suggests that the average energy literacy level in the UK may align with Group 3's weak energy literacy. Group 1 consisted largely of white male homeowners who are older than 45. Respondents from Scotland also make up 19% of Group 1 which is disproportionally high as they represent only 9.2% of the total sample. Group 1 had an above average number of males (69%) considering that the average survey sample was 32% males.

Groups 2 and 3 exhibit broader age distributions than Group 1, which is made up predominantly of people over 45. Younger individuals (18-24 years old) are increasingly represented in lower energy literacy groups. Although older people exhibit the highest energy literacy, all age groups are represented among lower energy literacy levels. The age distribution in Groups 2-4 is generally even, except for a notably low percentage of respondents aged 65+ in Group 4.

The correlation between the highest level of education and energy literacy is not straightforward across the groups. In Group 1, 38% have a university bachelor's degree or equivalent, yet 26% completed secondary education. Conversely, in Group 4, while 41% attained secondary education as their highest level, 17% hold a bachelor's degree or equivalent. Interestingly, individuals with education beyond a bachelor's degree are found in all groups, indicating that higher formal

education does not correspond to greater energy literacy. Higher education could be linked to home ownership, which is then linked to energy literacy.

Respondents were also asked where they obtain the majority of UK news. The BBC (radio/TV and online) is the main sources of news for respondents in all Groups. However, secondary news sources vary. The second and third main source of news for Group 1 are the Guardian (26.%) and ITV news (21%), for Group 2 they are Social media (29%) and ITV News (25%), for Group 3 they are Social Media (34%) and ITV News (34%) and for Group 4 they are Social media (32%) and friends and family (24%). The Sun and The Daily Mail specifically are read by more people in Group 3 and 4 compared to Groups 1 and 2. Social media is quite similar between groups 2, 3 and 4 but is much lower in Group 1.

Table 5.2: *Demographic description of the four energy literacy groups*

Group	Demographic description (% rounded up or down)
Group 1	White **(97%)** Male **(69%)** Homeowners **(81%)**, renters **(19%)** 65+ **(26%)**, 55-64 **(36%)** 45-54 **(19%)** ~ most people over 45 **(81%)** **Highest education received:** University bachelor's **(38%)** Graduate or professional degree **(5%)** Completed secondary school **(26%)**
Group 2	White **(87%)** Female **(60%)** Homeowners **(59%)**, renters **(31%)** Even distribution of people over 25, 18-24 year olds **(9%)** **Highest education received:** University bachelor's degree **(26%)** Graduate or professional degree **(12%)** Completed secondary school **(33%)**
Group 3	White **(84%)** Female **(73%)** Homeowners **(43%)**, renters **(36%)**, rent free **(12%)**, supported living **(7%)** Age ~ representative of total sample **Highest education received:** University bachelor's degree **(22%)** Graduate or professional degree **(8%)** Completed secondary school **(36%)**
Group 4	White **(84.5%)** Female **(74%)** Homeowners **(34%)**, renters **(40%)**, rent free **(16%)**, supported living **(8%)** Very few people over 65+ **(4%)** and similar representation from all other groups **Highest education received:** University bachelor's degree **(18%)** Graduate or professional degree **(5%)** Completed secondary school **(41%)**

5.4.3 UK public's future outlook for energy policy

5.4.3.1 Future investments: gas or renewables

Approximately 56% of respondents believe that using more gas from the UKCS to generate electricity would bring down household electricity bills. Moreover 31% are not sure if this is true (Figure 5.5 A). Almost 65% of respondents support increased UKCS gas extraction for the use of

electricity generation. Nearly half of respondents disagreed that investments in RETs are the main cause for the rise in household bills over the last two years (Figure 5.5 C). Additionally 60% believe that the future reduction of household electricity bills hinges on investments in RETs and halting gas-based electricity generation (Figure 5.5D). This view contradicts the fact that 56% of the survey takers believe household bills will decrease if more gas from the UKCS is used for electricity generation. Notably, irrespective of whether participants support investments in RETs or gas, there is a high level of support (63%) for the nationalisation of the energy sector (Figure 5.5 E).

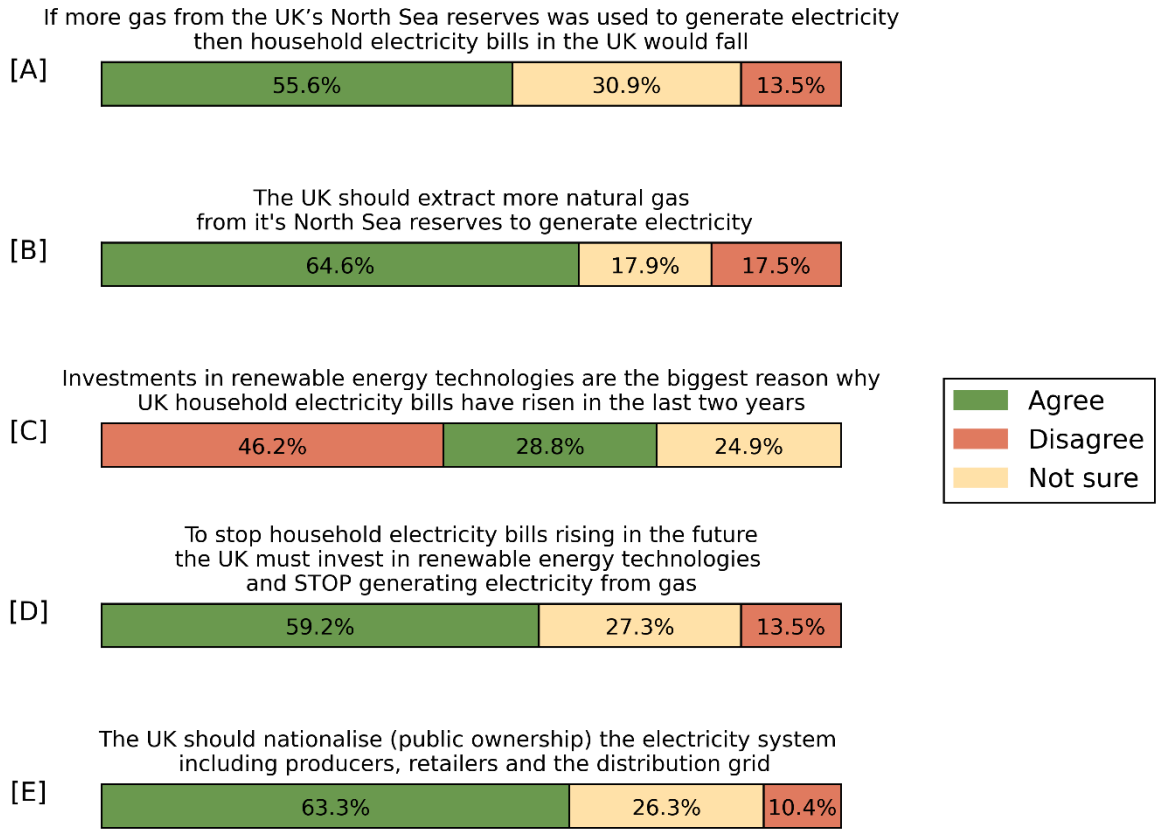

Figure 5.5: *Average responses from the whole survey group, agreeing or disagreeing with directions for the UK's future energy transition*

The survey suggests that the less energy literate someone is the more likely they are to select 'not sure' about their opinion (Figure 5.6 Group 4). Respondents in Group 1 have less support for increased use of gas for electricity generation and greater support for RETs than all other groups. Furthermore, more people in Group 1 (38%) disagree that increased use of gas from the UKCS to generate electricity will bring down electricity prices compared to Group 2 (18%). These answers suggest higher energy literacy is related to greater support for RE and less for gas. There is little difference in people's opinions in Groups 2 and 3 where respondents display similar support for gas and RETs. The survey responses imply that the average UK population akin to Groups 2 and 3 supports gas and RETs similarly.

***Figure 5.6**: Responses to five future energy transition actions the UK could take by energy literacy groups 1 – 4. [A] If more gas from the UK's North Sea reserves was used to generate electricity then household electricity bills in the UK would fall, [B] The UK should extract more natural gas from its North Sea reserves to generate electricity, [C] Investments in renewable energy technologies are the biggest reason why UK household electricity bills have risen in the last two years, [D] To stop household electricity bills rising in the future the UK must invest in renewable energy technologies and STOP generating electricity from gas, [E] The UK should nationalise (public ownership) the electricity system - including producers, retailers and the distribution grid.*

5.4.3.2 Influence of the proximity to renewable energy technologies on levels of support

Overall, there is reasonably high support for the construction of RETs built close to where people live, whether privately-owned (52%) or locally-owned (61%) (Figure 5.7 A and C). Participants demonstrate slightly more support for (+9%) and less opposition towards (-7%) a locally-owned wind farm being built close to where people live compared to privately-owned one. Sixty three percent of respondents believe locally-owned energy to be a good solution to the energy crisis after reading a short statement explaining what it is. However, 32% were not sure if it is a good solution or not. The energy crisis resulted in many people becoming somewhat more (34%) and much more (20%) supportive of the siting of RETs close to where they live. It has also had the converse effect on a smaller number of people, resulting in them becoming more opposed (7%) of the siting of RETs and for a third of respondents their perceptions did not change.

Support for the siting of RETs in the UK landscape is related to energy literacy (Figure 5.8). Gradually fewer people indicated they would support or strongly support RETs as energy literacy decreases as shown in Figure 5.8A and 5.8B. However, opposition increases only moderately as energy literacy decreases. Most people with lower energy literacy are ambivalent rather than become more opposing. The more energy literate someone is the more likely they are to think that locally-owned energy is a good solution to the energy crisis. As energy literacy decreases people do not become more inclined to think locally-owned energy is a bad solution, but they become unsure.

While the energy crisis resulted in 50% of people from Groups 2 and 3 becoming more supportive of the siting of RETs near to where they live, the energy crisis did not change the opinion of the majority of people in Groups 1 and 4 (Figure 5.8).

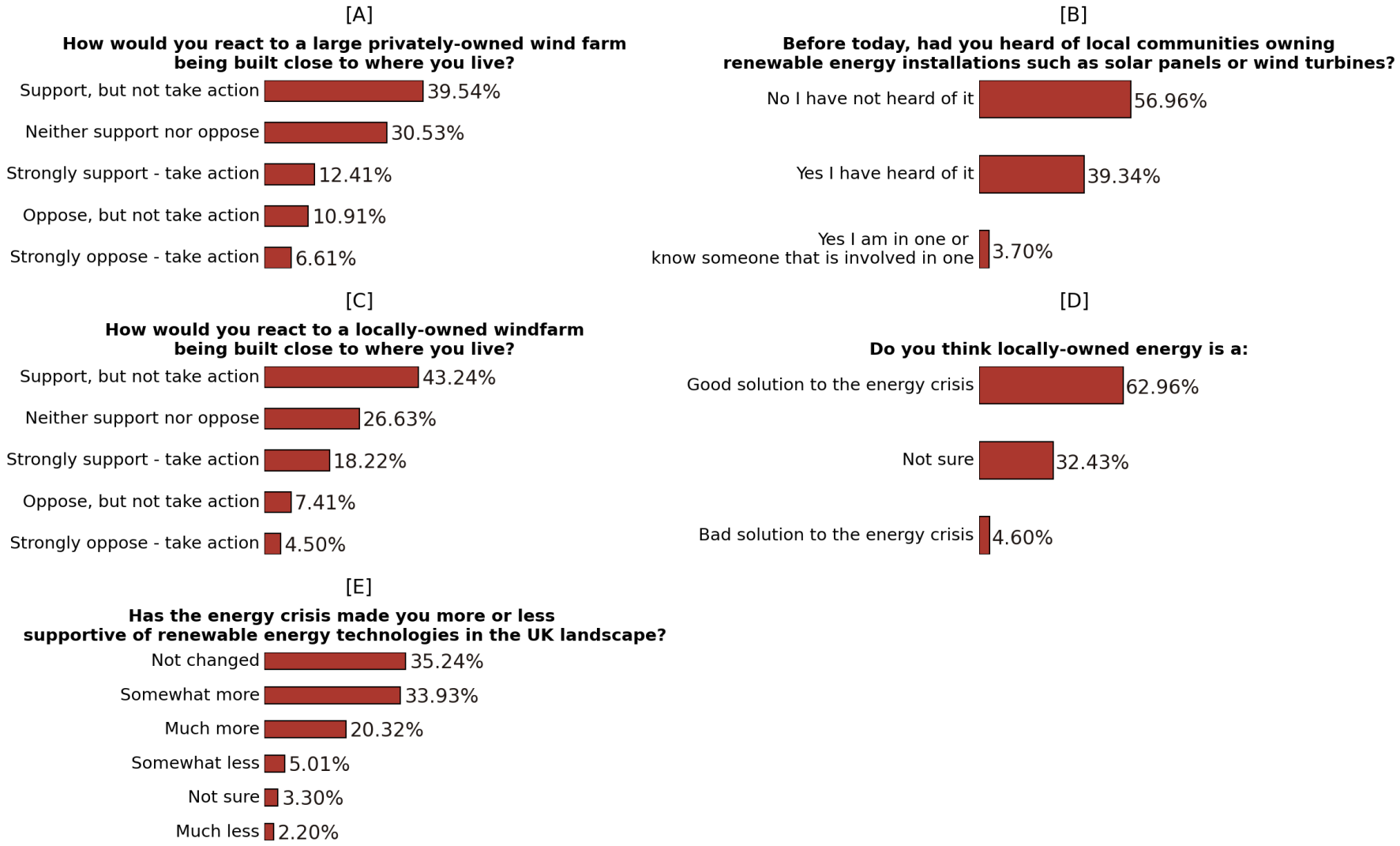

Figure 5.7: *Overall responses to questions on the sitting of locally- and privately-owned renewable energy technologies (RETs) in the UK landscape, if it is a good or bad solution to the energy crisis and if the energy crisis has resulted in increased or decreased support for the sitting of RETs in the UK landscape*

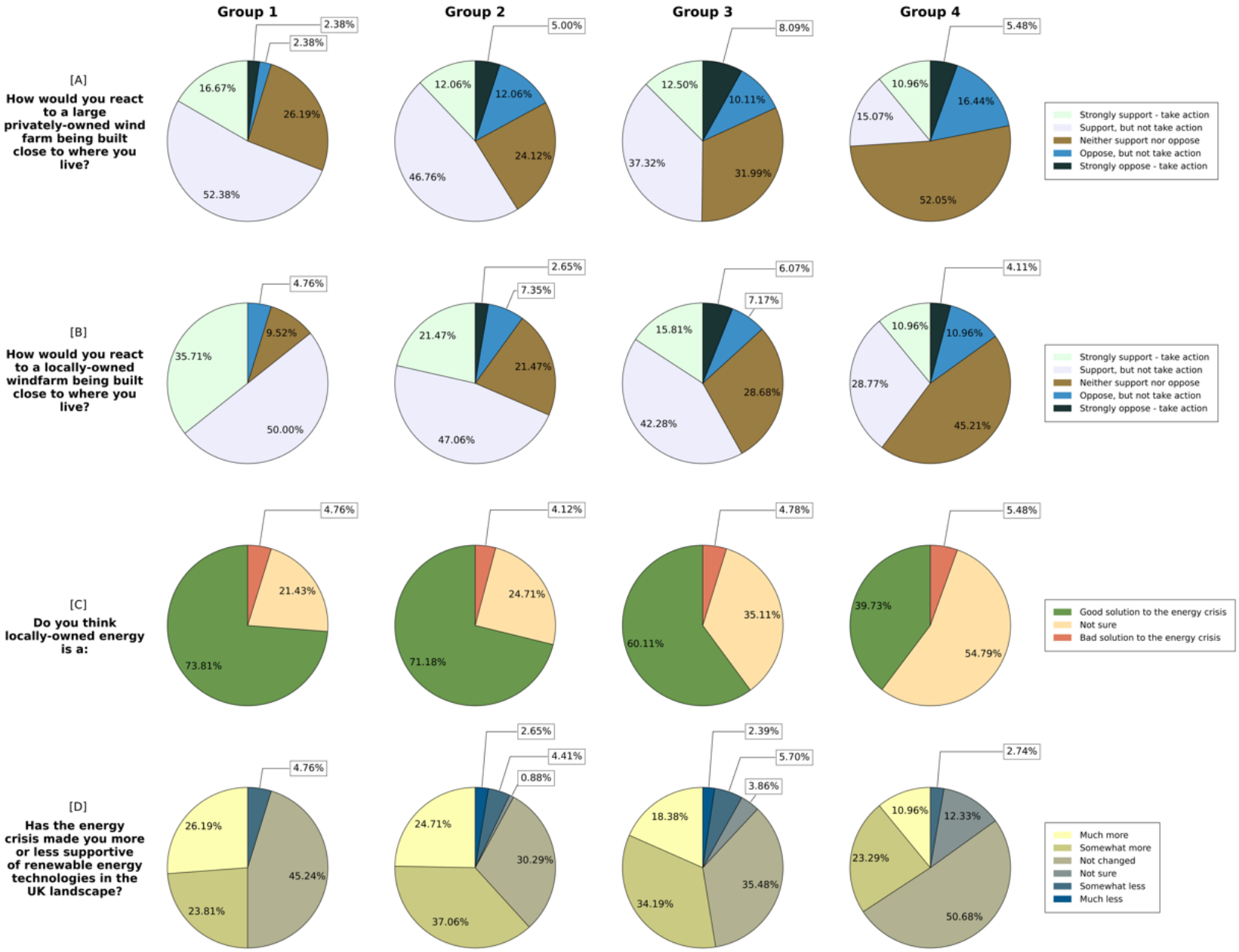
Group 1
Group 2
Group 3
Group 4
[A]
How would you react to a large privately-owned wind farm being built close to where you live?
16.67%
2.38%
2.38%
26.19%
52.38%
12.06%
5.00%
12.06%
24.12%
46.76%
12.50%
8.09%
10.11%
31.99%
37.32%
10.96%
5.48%
15.07%
16.44%
52.05%
Strongly support - take action
Support, but not take action
Neither support nor oppose
Oppose, but not take action
Strongly oppose - take action
[B]
How would you react to a locally-owned windfarm being built close to where you live?
35.71%
4.76%
9.52%
50.00%
21.47%
2.65%
7.35%
21.47%
47.06%
15.81%
6.07%
7.17%
28.68%
42.28%
10.96%
4.11%
10.96%
28.77%
45.21%
Strongly support - take action
Support, but not take action
Neither support nor oppose
Oppose, but not take action
Strongly oppose - take action
[C]
Do you think locally-owned energy is a:
73.81%
4.76%
21.43%
71.18%
4.12%
24.71%
60.11%
4.78%
35.11%
39.73%
5.48%
54.79%
Good solution to the energy crisis
Not sure
Bad solution to the energy crisis
[D]
Has the energy crisis made you more or less supportive of renewable energy technologies in the UK landscape?
26.19%
4.76%
23.81%
45.24%
24.71%
2.65%
4.41%
0.88%
37.06%
30.29%
18.38%
2.39%
5.70%
3.86%
34.19%
35.48%
10.96%
2.74%
12.33%
23.29%
50.68%
Much more
Somewhat more
Not changed
Not sure
Somewhat less
Much less

Figure 5.8: *Responses to questions on the sitting of renewable energy technologies in the UK landscape for each energy literacy group. For the first two questions 'strongly support - take action' means: (attend meetings/contact officials) to help move forward a nearby large privately-owned/locally-owned wind farm and 'Strongly oppose - take action' means: (attend meetings/protests/contact officials) against a nearby large privately-owned or locally-owned wind farm. As was written in the survey questions.*

5.4.3.3 Energy behaviour and perceptions since the energy crisis

Respondents in all energy literacy groups have become more aware of the personal implications of the energy crisis (Figure 5.9). Over half of respondents in all groups reported increased awareness of electricity costs, reduced electricity usage, and heightened stress about paying bills, with the exception of Group 1 where fewer people (38%) are experiencing more stress than all other groups. However, the impact the energy crisis has had on increasing people's awareness of the UK's energy landscape more broadly varies across groups. Approximately 28-33% of Groups 1-2 reported becoming more aware of the sources of electricity and government energy policies, compared to only 10-24% in Groups 3-4. Therefore, while the crisis has led to an overall increase in awareness of the costs of electricity, it has not significantly enhanced the understanding of the determinants of electricity costs among those with lower energy literacy.

Those with lower energy literacy, particularly in Group 4, are more likely to express disinterest in learning more about the electricity system. While 31-35% of people in Groups 1-3 showed interest in learning more, only 19% in Group 4 did (Figure 5.9 Groups 1-4). Moreover, as we progress from Group 1 to 3, there's an increasing proportion of respondents expressing uncertainty about where to find information on the electricity system. This suggests that lower energy literacy is also linked to poorer access to information.

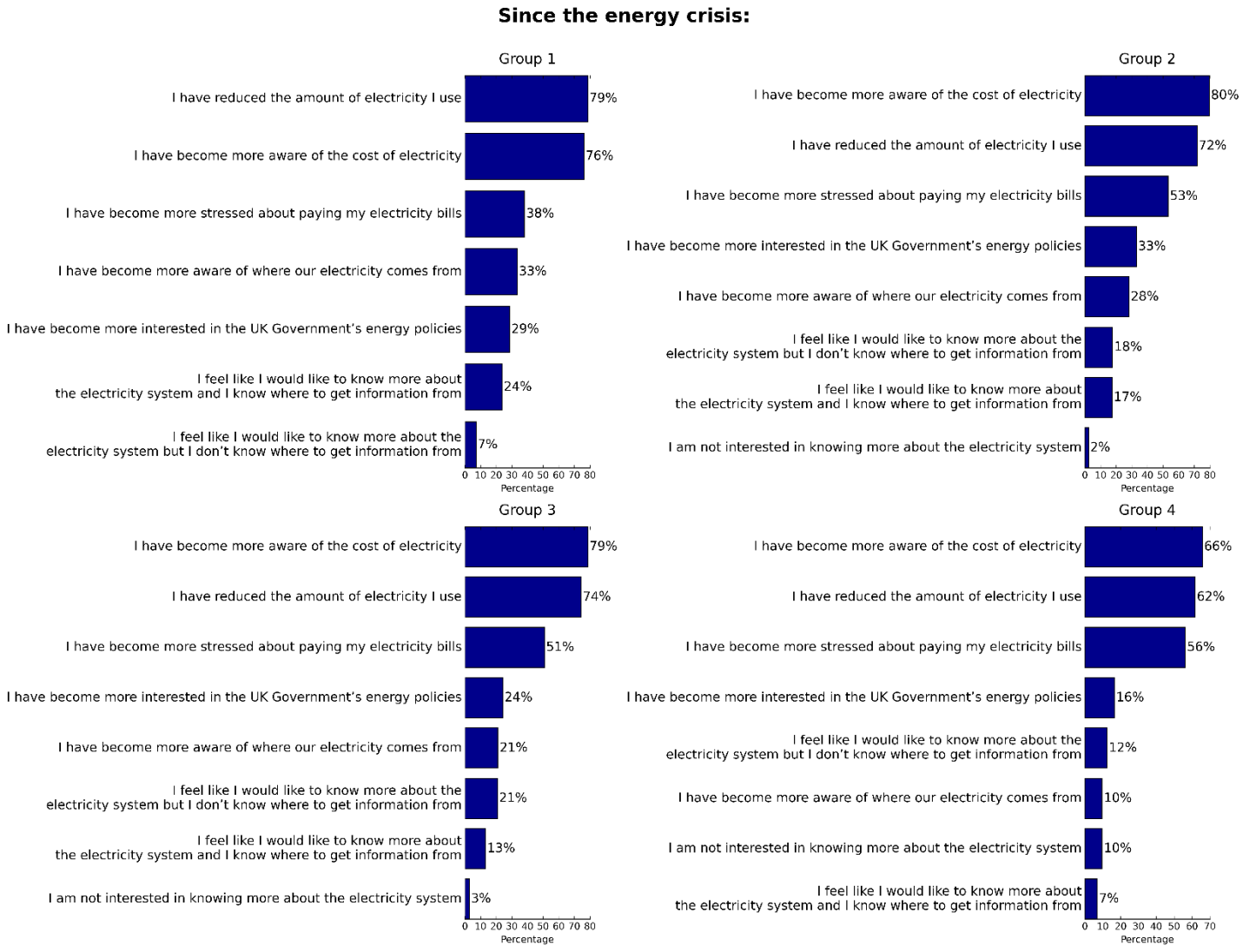

Figure 5.9: *How the energy crisis has influenced personal experience and awareness of energy in the UK.*

5.4.4 Energy policies and voting

The majority of respondents believe that energy is a political issue in the UK. Almost 70% of respondents believe the Government's energy policies have contributed to the energy crisis (Figure 5.10 A). Additionally, nearly 40% consider energy policies when voting (Figure 5.10 B). However, 58% also believe that they do not know enough about the energy policies of different political parties to affect their vote (Figure 5.10 C), and 49% believe that other policies are more important to consider when voting (Figure 5.10 E). Even if some of the public think energy policies are important, for the majority, energy policies do not play a large role in influencing voting patterns. Although, almost 65% indicated that they are interested in energy policies suggesting there is potential for energy policies to become more of an interest and an influencing factor.

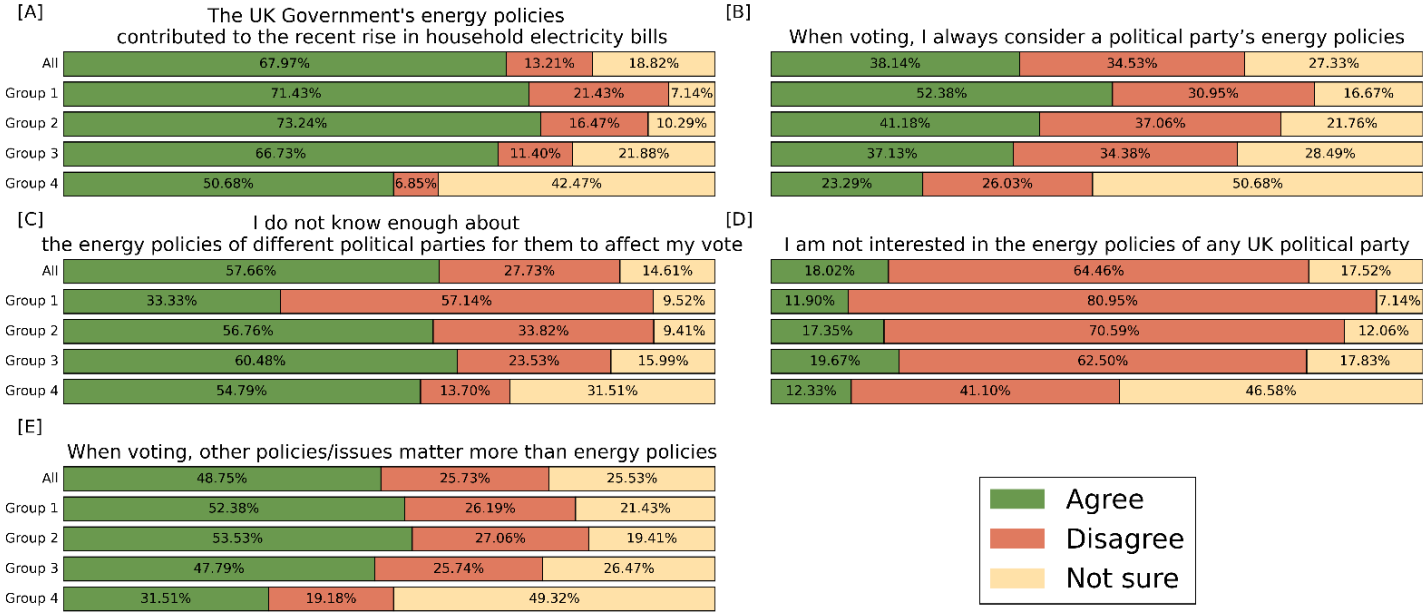

Figure 5.10: *Statements about the energy policies, Government responsibility and voting decisions that respondents selected agree, disagree or not sure to. Responses are shown for each statement for the overall survey, as well as broken down into responses by the energy literacy Groups 1 – 4.*

Responses to these statements on energy policies did not vary considerably with energy literacy. Respondents in Group 1 believe themselves to know more about energy policies than lower energy literate groups with only 33% believing they do not know enough to affect their vote compared to 57% of Group 2 and 60% of Group 3 (Figure 5.10 C). Fifty two percent of Group 1 also indicate they always consider the energy policies of a political party when voting compared to 41% of Group 2, 37% of Group 3 (Figure 5.10 B). However, a similar percentage of people in Group 1 (52%) say they think other policies are more important when voting, to Group 2 (53%) and Group 3 (48%) (Figure 5.10 E).

5.5 Discussion

5.5.1 Energy literacy and public opinion on a RE energy transition

The results indicate that only a small proportion of the population in Scotland and England understand the determinants of electricity pricing, potentially comprehending the correlation between gas prices and wholesale electricity costs. Participants in the highest energy literacy group favour greater investment in RETs over increased gas usage for electricity generation, more so than all other energy literacy groups. This suggests that enhancing the UK public's energy literacy, particularly regarding electricity pricing, could increase public support for a RE transition. Therefore, organisations engaged in RE advocacy, like Greenpeace, Extinction Rebellion, and Just Stop Oil, might consider integrating targeted energy literacy enhancement into their strategies, emphasising the issues of energy affordability and justice, rather than primarily rallying support around climate change (Chilvers *et al.*, 2023).

5.5.2 Increased support for domestic energy

The survey indicates the energy crisis has raised public support for increased use of domestic RETs and UKCS gas for electricity generation. This increased support for domestic energy sources may stem from longstanding public concerns about energy security and the UK's reliance on foreign imports with the energy crisis increasing these sentiments of self-reliance (Demski, Poortinga and Pidgeon, 2014). The results suggest this could be an opportune time for both privately and locally-owned decentralised RE growth. Public support for privately-owned (52%) and locally-owned (61%) RETs near homes was fairly similar with a slightly higher acceptance for locally-owned as found in other literature (Upham and Shackley, 2006; Rogers *et al.*, 2008; Warren and McFadyen, 2010; Međugorac and Schuitema, 2023). Respondents in Groups 1 – 3 generally saw locally-owned energy as a positive response to the energy crisis, suggesting the need for further qualitative research on leveraging the energy crisis to boost government and public support for locally-owned energy initiatives.

It is worth noting that the growth of CRE in the 90s was not a passive result of the oil crisis of the 1970s. In liberalised economies in Europe a path for CRE growth from the 90s was a direct result of government policy intervention as CREs need support to enter the market (Hewitt *et al.*, 2019). The most recent energy crisis of 2022 has not created an automatic window for CRE growth, or other locally-owned RET business models. It has created potential for greater public support and engagement with them, but it will require government action and intervention to grow (Törnberg, 2018; Mirzania *et al.*, 2019). CRE groups across the UK could drive societal change for more decentralised democratic RE transitions, if they can leverage more public support, and thus demand government support for their movement in this time of opportunity. Improved public energy literacy could be the catalyst for increased public support for a RE transition and engagement in the politics of energy.

5.5.3 Who is energy literate and where are they obtaining their knowledge from

The correlation between educational attainment and comprehension of the UK's liberalised electricity markets appears to be moderate. Postgraduate degree holders are uniformly distributed across all energy literacy groups. Group 1 has 20% more individuals with a bachelor's degree as their highest educational attainment compared to Group 4. However, Group 1 predominantly consists of older individuals, who are also more likely to have attained higher education and own a home. Although the survey data implies that formal education doesn't markedly enhance electricity pricing comprehension, the findings suggest a nuanced relationship among age, living situation, education, and energy literacy. Political education in UK schools has already been found to be severely lacking (Uberoi and Johnston, 2021; Weinberg, 2021). Efforts to improve this should include specific education on the liberalised electricity market and government energy policies. Homeownership, gender, and race more strongly correlate with energy literacy, with male, white homeowners generally more knowledgeable. This indicates an access disparity in energy knowledge. While it was beyond the scope of this study, future studies could explore the impact of demographic factors on energy literacy to enhance public engagement approaches.

Populist media and some UK politicians are pushing for increased UKCS gas extraction, promoting it as a path to energy independence, economic growth, and reduced household bills. This stance gains traction as government communications, including the 'Energy White Paper' and 'The Ten Point Plan for a Green Industrial Revolution,' mainly blame the energy crisis on heightened post-COVID-19 demand and the Russia-Ukraine conflict. These headline narratives overlook the critical issue of how the liberalised wholesale electricity market ties household bills to the price of gas, even when gas comes from the UKCS, and how the proposed energy policies fail to address this issue (Department for Business Energy and Industrial Strategy, 2022a). The survey indicates that such narratives could be swaying public opinion, reflected in the low energy literacy and widespread support for increased UKCS gas extraction. This finding is echoed by Evensen *et al.,* (2023) who observed a surge in public support for UKCS gas extraction in 2022, despite its role in escalating energy bills. It suggests the public are misinformed and populous narratives are filling in the gaps.

The majority of participants within all energy literacy groups obtain their UK news from the BBC, ITV News and Sky News suggesting these outlets may not adequately cover energy issues, critique populous narratives or government statements. The Guardian was read by more people classed as highly energy literate and with greater support of RETs. Lower energy literacy and unsure opinions were associated with increased readership of social media and the Daily Mirror and The Sun, indicating a significant lack of comprehensive energy coverage in these outlets and that they could be promoting populous pro-gas narratives, a prediction supported by other studies (Reeves, McKee and Stuckler, 2016; Evensen *et al.,* 2023).

Interestingly, the overrepresentation of respondents residing in Scotland in Group 1 warrants deeper investigation. The context of Scotland's abundant energy resources, pervasive fuel poverty, and critical media on UK government policies may inform this pattern (Robertson, 2023). It could

also be contextual, with higher energy literacy being related to proximity to energy resources and industry and the high levels of energy poverty in Scotland. This should be investigated in more detail.

5.5.4 Political engagement and voting

The survey results suggest that energy policies are not ranked highly for many people when voting. While 50% suggest they do consider energy policies when voting more do not know enough to use them as a vote decider (58%) and many think that other policies are more important when voting (49%). Findings suggest that government accountability for energy policies during general elections is lacking. To rectify this, public participation mechanisms and educational campaigns should be expanded to highlight the impact of energy policies on daily life, emphasising why they are of importance to everyone. Energy education campaigns must include specific education on the politics of energy as this survey suggests that higher energy literacy does not automatically mean that people consider energy policies when voting and prioritise them over other nationwide issues (Figure 5.10).

5.5.5 A wider look at a RE transition in the UK

The UK's highly institutionalised energy landscape setting and low public energy literacy will hinder bottom-up change in the RE transition. Despite the energy crisis potentially boosting support for RE implementation and investment, the transition, especially decoupling from fossil fuels, remains challenging for a fossil fuel-producing state (Mitchell, 2012; Wright, 2022; Mcculloch, 2023). The presence of domestic gas reserves means there are many parties with an interest in increasing gas extraction and use and promoting their agenda. Lacking accurate knowledge on electricity pricing, UK public opinion seems to align with pro-gas narratives or general support for domestic energy inclusive of increased UKCS gas extraction and use (Atkins, 2022). Furthermore, in the liberalised energy market, the economic advantages of RE transition are obscured as long household electricity bills are influenced by gas prices, and investments in RE infrastructure add to household costs (Aklin, 2021).

Interestingly, this survey indicates broad public support for the re-nationalisation of the UK's electricity system across all energy literacy groups. This is likely because of a perceived unfairness in how much the UK public pay compared to the profits the energy companies are making instead of reinvesting money into improving the electricity system (Demski *et al.*, 2017, 2019; Becker *et al.*, 2019). This discontent is not reserved only to energy, with calls to re-nationalise or operate not-for profit water companies following Thames Water going bust, record level sewage discharges in the UK despite profits accrued by water utilities every year (Branston and Tomlinson, 2023). There is public dissatisfaction with the current profit-driven systems in the UK which hints at potential opportunities for reform.

5.5.6 Limitations and further research

Notably, 10% of respondents (93 individuals) simultaneously agreed that green energy tariffs result in lower household payments and that all households pay the same rate per kWh (Figure 5.3 C and D). This confusion may arise from complexities such as variable peak time tariffs or fixed rate options. However, the fixed daily rate of the wholesale electricity price remains constant (Ofgem, 2016). The contradicting answers suggest that the survey questions might have lost some clarity while trying to be simplified or the respondents' energy literacy, particularly regarding wholesale electricity market pricing mechanisms, was low. Additionally, conflicting responses were observed in Figure 5 A and D, where 60% believe reducing household electricity bills depends on investing in RETs and ceasing gas-based generation, yet 56% think bills will decrease with increased UKCS gas use for electricity. This discrepancy could stem from the question phrasing, a lack of distinction between domestic and imported gas, or unclear respondent opinions. Despite this, support for both increased RET investment and UKCS gas extraction is similar, suggesting that knowledge of UK electricity pricing's link to gas prices does not strongly influence most people's opinions. Due to the limitations of a survey, it is recommend that qualitative methods such as focus groups and interviews are used to follow up on this research investigation (Dowler *et al.*, 2006).

This survey included only a small cohort of highly energy-literate individuals (n=43). To conclusively ascertain whether higher energy literacy correlates with greater support for RETs and less support for gas, as well as increased involvement in energy policies during voting, larger-scale studies are required. These studies should explore whether increased RET support among the highly literate is driven by an understanding of the electricity market and pricing or a heightened awareness and concern about climate change. This insight is crucial for evaluating the impact of targeted energy literacy campaigns in the UK. Additionally, the survey did not clarify whether support for increased UKCS gas usage in electricity generation stems from a misunderstanding of the global gas price's impact on wholesale electricity prices or a belief that UKCS gas is independent of global pricing. Future research should delve deeper into these aspects to pinpoint the source of misconceptions.

5.6 Conclusions

The objective of this study was to assess public understanding of the UK electricity market and pricing and explore how this knowledge influences opinions on the country’s energy transition. An online survey of 999 residents from Scotland and England gathered data on public comprehension of the electricity market, perspectives on future energy investments, and the impact of the energy crisis on support for renewable and decentralised energy solutions and voting behaviours.

The findings reveal a moderate to weak grasp of electricity pricing and market mechanisms among most participants. The survey suggests that the majority of the English and Scottish public could be moderately to weakly energy literate. Over half of the respondents demonstrated a good understanding of simpler supply and generation costs, as well as certain governance aspects, correctly answering questions about the presence of electricity cables, Ofgem's role, and the cost-effectiveness

of Renewable Energy Technologies (RETs) compared to gas (Figure 5.4 A, B, and F). However, they performed poorly on questions related to the functioning of the wholesale electricity market, how much gas used domestically is supplied from the UKCS and how the gas is governed, and the pricing of nuclear electricity (Figure 5.4 C, D, E, G, H, and I). The survey indicates that a large majority of the public do not understand why they pay what they pay for electricity nor understand that gas from the UKCS does not belong to the UK and that it is sold to the UK for the global gas price.

Participants in the highest energy literacy group favour greater investment in RETs over increased gas usage for electricity generation, more so than all lower energy literacy groups. Educational initiatives aimed at increasing the UK public's energy literacy, particularly regarding electricity pricing, could indirectly increase public support for a RE transition.

The survey results suggest that government accountability for energy policies during general elections is lacking. Energy policies, while considered important, are probably not vote deciders for the majority of people due to a lack of understanding and prioritisation of other matters (Fraile, 2007; Haidt, 2012). This is perhaps enabling policy and industry decisions that are not prioritising UK household energy bill affordability. Echoing sentiments from literature, the UK should enhance engagement with energy justice in practice, aiming to improve equity, knowledge, inclusion, and participation of the public in energy matters (Jenkins *et al.*, 2016; Jenkins and Santos, 2023).

Energy literacy was only weakly related to formal education suggesting that the formal education system is not adequately covering the determinants of electricity pricing. Educational campaigns on electricity pricing should be targeted towards public groups of all education levels. Energy literacy was related to newspaper source. People who are highly energy literate had higher readership of The Guardian and those with lower energy literacy increasingly obtaining news from The Sun, The Daily Mail and social media (Jaspal and Nerlich, 2014). The majority of people from all groups indicated they obtained some news from the BBC and ITV suggesting these outlets are not engaging in accurate reporting of electricity and gas market pricing and mechanisms. Homeownership, gender, and race significantly correlate with energy literacy, suggesting male, white homeowners are more informed about energy costs and systems, revealing a knowledge access gap and bias. Energy literacy also varies with age, predominantly higher among those over 45. Further research is needed to understand these demographic influences better and tailor educational efforts.

The state of public knowledge of the UK electricity market is poor and this suggests that the majority of the public are not able to make informed democratic decisions about energy policies in the UK. Public education and engagement in energy, which affects all aspects of people's lives, must be improved. It is recommend that the UK energy policy engages more practically with energy justice theories to improve equity, knowledge, inclusion and participation in energy matters (Jenkins *et al.*, 2016; Jenkins and Santos, 2023).

Chapter 6: Synthesis and key findings

6.1 Introduction

The objectives of this thesis were:

4. To deepen our understanding of local socio-cultural resistance towards household toilet-linked anaerobic digesters (TLADs), to evaluate its influence on TLAD adoption, and to understand how it shapes the realisation of policy goals tied to TLAD deployment;
5. To identify the reasons for the success or failure of domestic biogas programmes, especially regarding the implementation TLADs and to more broadly understand the multi-scalar and spatial factors that impact programme success;
6. To evaluate the level of understanding the UK public has about electricity pricing in the UK, and to ascertain if this knowledge shapes their opinions on the future trajectory of the UK's RE transition.

This discussion section synthesises the contributions of each data chapter towards fulfilling the research objectives, summarising their impact on both scientific and practical knowledge domains. It proceeds to articulate the broader contributions of this thesis to the understanding of decentralised renewable energy (RE) transitions, leveraging insights from across all case studies. By doing so, it underscores the thesis's wider academic contributions that surpass the specified research objectives, illustrating its significance to both the scientific literature and theoretical developments in the field.

6.2 Research objective 1: Socio-cultural resistance towards toilet-linked anaerobic digesters and possible pathways to adoption

6.2.1 Summary of main scientific contributions

This thesis significantly advances our understanding of socio-cultural resistance towards TLADs through its detailed investigations in Chapters 2 and 3. It provides detailed insights into the pathways to TLAD adoption, illustrating how socio-cultural norms influence the use of biogas and slurry derived from human excreta (HE), and consequently, how cultural norms mediate the achievement of biogas programme policy goals. This research stands as the most comprehensive study on household transitions to TLADs to date, providing insights not only into TLAD adoption but also offering implications for the broader use of HE-derived products. This contribution is crucial for both scientific understanding and policy formulation.

Chapters 2 and 3 offer comparative case studies from Nepal and India, focusing on the socio-cultural norms that influence the adoption of TLADs. In Province 4 of Nepal, despite widespread initial hesitation, socio-cultural norms have been renegotiated, leading to widespread adoption of TLADs. In contrast, in Assam, India, socio-cultural norms opposing TLADs have not been renegotiated and there are no known TLADs in the state. This variance between two geographically

and culturally relatable contexts underscores that the renegotiation of socio-cultural norms and the subsequent adoption of TLADs depend on a multitude of factors beyond only socio-cultural norms, which is most often quoted in literature as the biggest barrier to adoption (Raha, Mahanta and Clarke, 2014; Mittal, Ahlgren and Shukla, 2018).

The exploration of socio-cultural norms in relation to TLAD adoption revealed a high degree of diversity across households within both case studies. A pivotal finding is that the degree of opposition towards TLADs is influenced by the degree of religiosity or engagement with purity and pollution practices by individuals. Socio-cultural resistance to TLAD adoption is not uniform across or within religious groups, challenging the assumption that entire countries, regions, or communities would both uniformly reject TLADs due to opposing socio-cultural norms (Raha, Mahanta and Clarke, 2014; Mittal, Ahlgren and Shukla, 2018) and uniformly overcome them (Muralidharan, 2017). Furthermore, socio-cultural resistance was found to be dynamic rather than static, highlighting that initial resistance to TLADs can evolve over time (Andersson, 2015). Demonstrations and other engagement strategies in Nepal catalysed households into renegotiating socio-cultural norms overtime, leading to the adoption of TLADs. This finding critically undermines the notion that initial opposition is permanent, a finding echoed in other studies (Andersson, 2015).

This thesis identifies key factors influencing the adoption of TLADs beyond socio-cultural norms, such as user needs, motivations, and the presence of contextual catalysts that facilitate socio-cultural renegotiation. Users of TLADs in Nepal adopted TLADs and renegotiated socio-cultural norms because they perceived a need for improved sanitation facilities and the additional benefits of energy, sanitation, fertiliser, and waste management that TLADs offer. This was driven by both the immediate needs of the households and their motivation to adopt a multifunctional solution. Conversely, in Assam, the potential for TLAD adoption was hampered by the availability of existing sanitation solutions and access to affordable energy alternatives such as Liquefied Petroleum Gas (LPG), resulting in a lack of motivation to adopt TLADs. The successful adoption of TLADs in Nepal was further supported by conducive conditions that facilitated socio-cultural renegotiation: households had opportunities to observe and trial TLADs through community demonstration projects, promotions targeted households with a genuine need and motivation over extended periods to allow for the gradual acceptance of TLADs. Additionally, efforts focused on embedding TLADs within the social norms of entire communities, rather than targeting individual households in isolation (Rogers, 2003; Andersson, 2015). Opportunities to trial or observe a TLAD were key to catalysing adoption and renegotiation of socio-cultural norms. These opportunities allowed people to learn, first hand, the benefits that TLADs can provide them with and that many of the negative socio-technical imaginations they have, such as the kitchen smelling like a toilet are, in fact, not true (Andersson, 2015; Roxburgh *et al.*, 2020). Such strategic approaches were absent in Assam, where households were not provided with similar opportunities to engage with and understand the potential benefits of TLAD adoption. Households lacking the chance to discover the benefits of a TLAD or envision one in their home led to prevailing negative socio-technical imaginaries. Many were left

imagining undesirable scenarios, such as agricultural fields smelling like toilets (Boyd Williams, Quilliam, Campbell, Raha, *et al.*, 2022).

Analysis and comparison of the interview data collected in Chapters 2 and 3 suggest that similar pathways to adoption of TLADs may happen in different contexts. A small number of people will be 'risk-takers'. These individuals either did, in the case of Nepal, or indicated they might, in the case of India, adopt a TLAD before the rest of their communities approved. This meant they risked or would risk some negative social consequences. Risk-takers in Nepal experienced their communities speaking or gossiping about them after they first adopted a TLAD, or other members of their household being initially opposed to it causing some household tensions. The majority of other adopters or potential adopters require opportunities to trial or observe a TLAD provided either through the programme or by a 'risk-taker' household. The findings of this thesis align with established theories on the diffusion of innovations, such as those proposed by Rogers, (2003). Rogers theorises that innovations spread through a population in a specific pattern, involving key player categories: early adopters, early majority, late majority, and laggards. In the context of TLADs, the 'risk takers' align with Rogers's early adopter group and the majority of other adopters will fall under his other categories. These insights are consistent with other studies examining similar taboo adoption patterns across various technologies and practices (Andersson, 2015; Roxburgh *et al.*, 2020). This pattern of adoption highlights the critical role of demonstration and trial in encouraging broader acceptance and integration of new technologies like TLADs into communities.

The research uncovers the intricate ways socio-cultural norms influence the utilisation of biogas and slurry from TLADs, extending beyond the initial decision to adopt. Households face numerous decisions regarding the use of these products, with socio-cultural norms significantly guiding these choices. In Nepal, for example, despite long-term ownership of TLADs, many households refrain from using biogas for cooking during ceremonial occasions or for guests who prefer not to use it. This nuanced understanding, marking the first detailed examination into the post-adoption use of biogas and slurry from TLADs, provides valuable insights for policy formulation. It underscores the need for biogas programmes promoting digesters with and without toilet connections, to recognise that households may use the technologies and their products differently. Such distinctions are crucial for accurately assessing the impact of these programmes on replacing alternative energy and fertiliser sources.

Overall this study demonstrates that the adoption or rejection of TLADs is not merely a matter of socio-cultural acceptance or opposition, but hinges on the perceived need and motivation of households and if the programmatic environment has created opportunities for socio-cultural renegotiation to occur (Andersson, 2015). I believe the research findings strongly suggest that in instances where socio-cultural resistance appears to be a barrier, further investigation is crucial to determine whether TLADs are in fact unnecessary or unsuitable for the context, or if a programme fails to facilitate exploration and renegotiation of socio-cultural norms. It is crucial for future research to avoid oversimplifying socio-cultural resistance as the primary reason for TLAD adoption

challenges (Andersson, 2015; Mittal, Ahlgren and Shukla, 2018). Socio-cultural resistance varies significantly across individual experiences and often reflects broader programmatic shortcomings or a genuine lack of need for TLADs.

6.3 Research objective 2: To identify why biogas succeeds in one place and not another, even in seemingly similar contexts

6.3.1 Summary of main scientific contributions

This thesis, through investigations in Chapter 4, has made significant contributions in expanding understanding within academic literature on the root-causes of biogas programme failure, as well as, more specifically failure to promote and implement TLADs. Chapter 4 also extensively expanded on Chapter 2 and 3 to suggest why some programmes have succeeded in implementing TLADs in areas with existing socio-cultural opposition where others have not. Unresolved socio-cultural opposition towards TLADs, despite promotion of the technology, can be seen as a symptom of various multi-scalar programmatic failures that result in poor targeting and limited or no opportunities for households to trial or observe a TLAD.

Contemporary biogas literature highlights that biogas programmes face widespread challenges such as those highlighted in Table 1.1. These challenges however, are interpreted as the reasons for failure and there is a lack of critical policy-focussed literature that investigates what causes these repeated challenges within biogas programmes. Through findings in Chapter 4, this thesis suggests these challenges are actually symptoms of deeper systemic failures, rooted in unsupportive regulatory frameworks across global, national, and local energy regimes. A main critical oversight is the centralised, one-size-fits-all approach to biogas policy, which fails to account for local diversity (Crewe, 1997; Abdelnour, Pemberton-pigott and Deichmann, 2020; Bharadwaj *et al.*, 2022). Interviews conducted for Chapter 4 reveal a consensus among experts on the necessity for locally adapted policies and better policy coordination across sectors and government departments. The prevailing regulatory and governance culture within biogas programmes resists such changes and programmes are unable to engage with and adapt to local diversity. This pattern is not reserved to biogas but reflects a broader trend in development where many development programmes overlook local socio-cultural and political dynamics, favouring uniform technological solutions (Crewe, 1997; Abdelnour and Saeed, 2014; Boamah and Rothfuß, 2018; Abdelnour, Pemberton-pigott and Deichmann, 2020). The simplified implementation of technological solutions under uniform programmatic approaches has led to prolific programme failure (Ruiz-Mercado *et al.*, 2011; Wieczorek, 2018; Abdelnour, Pemberton-pigott and Deichmann, 2020; Ha and Kumar, 2021).

Chapter 4 of this thesis reinforces the findings from Chapters 2 and 3 regarding TLAD dissemination and adoption. It highlights that socio-cultural resistance, often cited as a primary barrier to TLAD adoption, is more accurately a symptom of programmatic failures. This insight shifts the narrative from a focus on user resistance, to understanding it as a result of ineffective programme

strategies. Stakeholder interviews in Chapter 4 confirm the patterns of TLAD adoption observed in the earlier chapters. In Nepal, programme implementers strategically targeted progressive farmers as early adopters of TLADs. These pioneers served as demonstrations for entire communities, showcasing TLADs' benefits, ultimately leading to wider community adoption. Furthermore, the interviews underscored the significance of multi-sector policy coordination. Stakeholders from Nepal's biogas programme emphasised the combined efforts of sanitation and biogas programmes, including joint subsidies and marketing strategies, as key to their success. In contrast, a stakeholder from India discussed how they believe the lack of such coordination significantly hindered TLAD dissemination in India. These findings from Chapter 4 provide a deeper understanding of the mechanisms behind TLAD adoption. They highlight the need for well-coordinated, multi-sector approaches and underscore the importance of selecting and supporting early adopters to facilitate broader community acceptance.

To enhance biogas programmes, a deeper understanding and integration of local diversity into policy design and governance are essential. The prevailing centralised, one-size-fits-all approach, lacking cross-sector coordination, is proving ineffective. The success of biogas programmes remains constrained as long as they operate within rigid, dominant regimes that do not support decentralised RE. This thesis advocates for a fundamental shift in biogas research focus, urging a move from focussing on understanding household decision-making and identification of common high-level challenges to critically examining governance and policy designs. Such a shift necessitates investigating how centralised policies are applied in diverse local settings and devising strategies for improving programme effectiveness. Echoing Kalina, Ogwang and Tilley (2022), this thesis highlights the need for in-depth case study investigations to understand how national biogas programmes integrate into local contexts. Chapter 4 demonstrates the value of examining governance and policy mechanisms in diverse settings to decipher the complex dynamics influencing biogas transitions. This work offers significant empirical insights and methodological innovations, laying the groundwork for future research that prioritizes governance and policy effectiveness in facilitating biogas transitions, thus steering biogas research towards more context-sensitive approaches.

6.4 Summary of practical recommendations for improved domestic biogas programmes

The outcomes of this thesis strongly suggest the need for localised promotion and implementation strategies over a centralised one-size-fits-all approach in biogas programmes (Goldthau, 2014). However, for practicality some generalisations must be made. The research in this thesis has led to a number of recommendations that could facilitate more successful biogas programmes, and specifically more successful adoption of TLADs. Adoption of biogas technology should only be encouraged if the biogas programme has the means to support biogas adopters over the lifetime of the biogas plants with training and maintenance services and if the biogas programme can be held

accountable for failures and grievances be followed up (Zuzhang, 2013; Mittal, Ahlgren and Shukla, 2018). Without these provisions I believe it would be unethical to use the following recommendations to improve promotion and adoption of domestic biogas:

6.4.1 General recommendations to improve biogas programmes:

1. Adapt central policies to fit diverse local contexts, recognising that one-size-fits-all policies have limited success.
2. Adopt a user-informed, bottom-up policy design approach.
3. Customise needs assessments to the local context when targeting biogas adopter households, considering geographical and cultural diversity, livestock rearing patterns and available feedstock, and potential user needs and motivations.
4. Promote and implement domestic biogas only in households with suitable needs and motivations
5. Promote the benefits of biogas technology beyond energy production, including waste management, sanitation, and agricultural advantages.
6. Avoid confining biogas programme management to energy-focused government departments. If unavoidable, ensure interdepartmental coordination for holistic biogas promotion.
7. Integrate biogas programmes at the national or regional level with other energy, sanitation, and agricultural initiatives. High-level coordination can provide households with targeted policy options instead of competing policies.
8. Ensure biogas programmes coordinate with other initiatives to avoid proposing conflicting energy/agricultural/sanitation solutions.
9. Adopt modes of governance that suit different programme scales. We suggest that a top-down centralised governance for programme design (that is locally adaptable) and horizontal governance at the level of implementation could be effective. This must be investigated more.
10. Facilitate local actor involvement, such as dairy cooperatives and other local organisations, in biogas programmes for community outreach and programme success

6.4.2 Recommendations to specifically improve the successful promotion, adoption and use of TLADs:

11. Adopt a strong top-down promotional approach for TLADs, providing information, time, and demonstration opportunities for users to renegotiate socio-cultural resistance.
12. Facilitate opportunities to trial and observe TLADs to encourage adoption, as most users (except early adopters or risk-takers) need such exposure.
13. Install TLADs in early adopter or risk-taker households for demonstration to others.

14. Encourage biogas adopters to install an additional pipe for the toilet connection. This will remove technological barriers if they decide to connect a toilet later.
15. Educate biogas programme participants about TLAD benefits.
16. Cooperate with cultural groups and religious leaders during TLAD promotions to facilitate community acceptance of HE as a resource.
17. Advocate for top-down, national government-led cross-sector coordination. Coordination with the sanitation sector is specifically recommended to aid promotion and the correct identification of households in need a sanitation facility.
18. Promote and implement TLADs only in households with suitable needs and motivations

6.5 Research objective 3: public understanding of electricity pricing in the UK, and how knowledge is linked to their opinions on the RE transition

6.5.1 Summary of main scientific contributions

Chapter 5 enriches understanding of the English and Scottish public's perspective on the UK's RE transition, linking their opinions with their knowledge of the electricity system. It proposes that strategic energy literacy education could help sway public opinion towards a RE transition. By examining the UK's energy landscape alongside the survey results, it provides insights into the UK's struggle to move away from fossil fuels. The institutionalisation of the UK's centralised energy system forms a considerable obstacle to the success of decentralised renewable energy technologies (RETs). While the energy crisis may have amplified public support for domestic energy, encompassing locally built RETs and local-ownership models, the feasibility of replacing the entrenched, fossil fuel-focused and centralised system with a decentralised RE transition remains challenging (Bauwens, Gotchev and Holstenkamp, 2016).

The chapter reveals that the majority of the English and Scottish public may have only moderate to weak knowledge of electricity pricing. Respondents with the highest understanding of the electricity market showed the most support for increasing the use of RE and expressed reduced support for using gas for electricity generation. Elevating public energy literacy could play a pivotal role in shifting public sentiment towards a RE transition. This is not an endorsement of the criticised knowledge deficit model in science communication, which attempts to sway public opinion through enhanced one-way scientific learning (Simis *et al.*, 2016). Instead, increased public engagement, particularly regarding the electricity market, is advocated for. The goal of energy literacy campaigns should not be to push an agenda, but to empower individuals with insight into the electricity system they are already participating in, and the processes affecting their bills. This informed understanding boosts their democratic capacity to make beneficial decisions for themselves and others based on facts (Wahlund and Palm, 2022).

The UK's historical ties to the fossil fuel industry as a fossil fuel producer pose significant challenges to the RE transition (Bauwens, Gotchev and Holstenkamp, 2016). Fossil fuel production

and use is deeply ingrained in national identity, and has been leveraged by the Government and media to foster public support for increased gas extraction from the UK Continental Shelf (UKCS) (Atkins, 2022; Department for Business Energy and Industrial Strategy, 2022a). The survey revealed that over half of the respondents have misconceptions about UKCS gas pricing and governance, incorrectly believing that increasing UKCS gas usage for electricity production would lower household bills. This misconception may underpin the reason that almost 65% endorsed increased use of UKCS gas for electricity generation. Furthermore, it could also explain why the recent energy crisis has resulted in public support for domestic energy overall, rather than boosting support specifically for RE.

Respondents in the survey largely thought locally-owned energy could be a good solution to the energy crisis. While there is a niche demand for locally-owned energy initiatives (Community Energy England, Community Energy Wales and Community Energy Scotland, 2021; Community Energy England, 2023), their integration into the UK's energy system has proven challenging. For them to become viable they need top-down policy support from the Government to be viable in the regulatory environment favourable to big utilities (Bauwens, Gotchev and Holstenkamp, 2016; Mirzania *et al.*, 2019). The Government took a top-down centralised 'one-size fits all' approach to decentralised local energy policy. Against public consultation, the Feed-in Tariff (FiT) was removed all over the UK (DECC, 2015). As an alternative to removing it entirely, the Government could have retained it in some remote rural areas where locally-owned energy is more suited, due to existing social cohesion, and needed, due to high levels of energy poverty (Bauwens, Gotchev and Holstenkamp, 2016; Mirzania *et al.*, 2019). A lack of existing social cohesion in the UK is speculated potential reason for slow CRE growth compared to other European countries such as Germany and Denmark, which have had much more success with locally-owned energy (Bauwens, Gotchev and Holstenkamp, 2016). The blanket approach to policy overlooks regional differences in the UK. Bottom-up designed policies that recognise diverse local needs, could lead to a more inclusive energy system.

In the absence of top-down support, bottom-up action can drive change. The survey suggests that there could be significant challenges in initiating bottom-up changes to the energy landscape in the UK. Public understanding of the electricity system and pricing appears to be weak, preventing informed public decision-making. While over 60% of survey respondents saw locally-owned energy as a potentially good solution to the energy crisis, just under 40% had heard of it before the survey, and only 4% were connected to such an initiative. This suggests a lack of public knowledge on alternatives to the dominant centralised and privatised energy model. Further, the data implies that over half the public might lack sufficient knowledge on energy policies to factor them into their voting decisions, with almost half likely prioritising other policies. This deficit of understanding concerning pricing, alternatives, and the low impact of energy policies on voting, indicates a scarcity of energy democracy in the UK (Szulecki, 2018). For a just transition, it's imperative to enhance public engagement with energy issues and their potential options (Jenkins, Sovacool and McCauley, 2018; Thomas, Demski and Pidgeon, 2020).

6.5.2 Summary of practical implications for policy

This survey was administered to a small sub-section of the UK public from England and Scotland and more research is needed to confirm some of the findings and how representative they are of the whole UK. I also recognise that my interpretation of the public as one public rather than various publics was a narrow interpretation, and that if investigations focus on specific groups of the public, people's knowledge of, and engagement in, energy might be much different compared to this sample (Chilvers *et al.*, 2023). However, this study has some practical implications and recommendations for the UK government or any group wishing to increase public support and engagement in the RE transition:

1. Enhance public energy literacy. Implement public energy literacy campaigns, specifically providing comprehensive information about energy pricing, energy sourcing, and the effects of different types of energy on household bills.
2. Improve energy education in formal education to promote a deeper understanding of energy issues from an early age, thus raising energy-literate citizens.
3. Encourage public participation in energy decision making and develop better mechanisms for public involvement in energy policy decisions, enhancing governmental accountability and encouraging democratic involvement.
4. Promote locally-owned RETs so the public become more aware they are an option to both reduce carbon emissions but also better distribute more of the benefits of RE transitions.
5. Counteract misinformation and work with media outlets to ensure accurate coverage of energy matters, counteracting populist narratives that might skew public opinion and decision-making.
6. Advocate for greater transparency in energy pricing and demand that the government be more transparent in their communication about gas and electricity pricing, as well as their strategies to manage the effects of global gas price fluctuations.
7. Promote energy justice as a benefit of a RE transition.
8. Conduct research to understand why energy policies do not significantly influence voting behaviour and develop strategies to underscore their importance to the public.

6.6 Synthesis

In addition to answering the research objectives, the findings from each data chapter in this thesis have provided insights more generally into how transitions to decentralised RETs emerge in diverse contexts, and why they fail. This section will highlight the key headline findings from the case studies and how they contribute to expanding contemporary scientific knowledge of decentralised RE transitions.

6.6.1 Key findings from across all case studies

6.6.1.1 Socio-cultural or public resistance is not a headline barrier to decentralised energy, it is a symptom of failed governance or policy

By thoroughly situating public decision-making processes within the socio-cultural, political, economic, and geographical contexts of energy transitions in Nepal, India, and the UK, this thesis addresses critical gaps in current research. The findings compellingly argue that what is often interpreted as public resistance to energy transitions is, in reality, a symptom of broader systemic failures in policy and governance. This perspective challenges narratives that position public groups in opposition to energy transitions. It also underscores the necessity of re-evaluating the discourses and language used within energy transitions literature and how important it is to ask critical 'why' questions to investigate deeper more systematic challenges to decentralised energy transitions.

The case studies of Nepal and India challenge the widely held view that socio-cultural norms are a fixed barrier to the adoption of TLADs (Raha, Mahanta and Clarke, 2014; Sovacool, Kryman and Smith, 2015; Mittal, Ahlgren and Shukla, 2018). Findings from Chapters 2 and 3 indicate that while socio-cultural norms will deter some individuals from adopting TLADs, many others could renegotiate these norms when and if there is a perceived need to adopt a TLAD and if the biogas programme has provided them with a supportive environment. This shift in understanding places the responsibility for failed transitions not on individual users but on broader programmatic and systemic failures.

Similarly, the UK case study suggests that public resistance to RETs and / or the support for fossil fuels is indicative of systemic policy and educational shortcomings. The research highlights a pervasive lack of public knowledge about the main drivers of high-energy costs and the energy crisis, especially the impact of gas prices. By focusing narrowly on public opinion, some existing research overly focussed on public opinion overlooks the critical role of policy frameworks and education in shaping these opinions. Thus, the thesis argues that public support for fossil fuels or lack of support for RE is not the barrier to a RE transition that should be focussed on. The more important barrier is an uninformed public and a policy-making process that lacks genuine democratic engagement.

This thesis contributes valuable insights to the evolving discourse on public resistance within energy transition studies, particularly challenging the conventional framing of resistance. It expands upon previous findings that suggest public opposition is not unjustified but stems from factors such as emotional attachments to place, misunderstandings of technology, distrust in developers, and a history of negative experiences (Wolsink, 2006; van der Horst, 2007; Batel and Devine-Wright, 2020; Few *et al.*, 2021). Through empirical evidence from Nepal, India, and the UK, this research illustrates that resistance to RETs, often results from systemic shortcomings in policy, education, and misalignment between technological proposals and community needs. It aligns with scholarly criticisms that blaming communities or individuals unfairly delegitimises local opposition, fails to acknowledge the legitimate concerns and needs of communities and obscures the systemic causes of

failed transition (Edelstein and Kleese, 1995; Wolsink, 2006; van der Horst, 2007; Boso *et al.*, 2020b; Few *et al.*, 2021).

After reflecting on the findings in this thesis and existing literature I would argue that there is a need for more critical examinations of public resistance towards energy technologies, particularly emphasising the need for such scrutiny within Global South contexts. As discussed in Chapter 3, the use of the term NIMBYism (assigning blame to public groups who have Not in My Back Yard attitudes) has been widely challenged for its tendency to oversimplify and unjustly blame the publics in Global North. Scholars have critiqued it and have urged a shift away from its use in both practice and research (Wolsink, 2006; van der Horst, 2007; Wilson and Dyke, 2016).

Similarly to NIMBYism, socio-cultural resistance is frequently cited to explain opposition to technologies in the Global South but critique, while it exists (Agarwal, 1983; Crewe, 1997; Andersson, 2015; Malakar, Greig and van de Fliert, 2018a; Mittal, Ahlgren and Shukla, 2018; Sovacool and Griffiths, 2020), is less ubiquitous. While there is a significant and expanding discourse on energy justice in the Global South, which addresses issues like land rights contestations in RE projects and highlights the frequent overshadowing of local perspectives (Edelstein and Kleese, 1995; Agrawal, 2003; Achiba, 2019), research specifically critiquing the use of the term 'socio-cultural resistance' remains scarce. Specifically, challenging its tendency to 'other' local communities, overlooking their valid concerns and the systemic reasons for transition failures. This could be a research gap beyond the discipline of energy as Andersson (2015) highlights that even though socio-cultural resistance is often identified as key barrier to the use of HE in food production, related norms, attitudes and cultural perceptions have so far been insufficiently explored. Andersson argues against the interpretation of socio-cultural norms as insurmountable barriers and argues that socio-cultural norms can be renegotiated with appropriately tailored programmes and understanding of local processes.

The interpretation of socio-cultural resistance as a barrier to overcome has roots in colonialism and early international aid, which often viewed socio-cultural norms as impediments to technological and economic development (Dubey, 1968; Kothari, 2006; Lopez-claros and Perotti, 2014). Through a Western lens, religion and culture are reserved for the personal realm, not the practical and thus, do not belong in the physical realm (Pfaffenberger, 1992; King, 2011; Viswanath, 2014), Yet, in many cultures, religion and culture are a part of the physical (Douglas, 1966; Bennett, 1983). Socio-cultural norms should be viewed as an inherent part of the local context, shaping the adoption of biogas, not a barrier to be overcome (Andersson, 2015; Few *et al.*, 2021). I argue we need a more integrated approach to domestic biogas investigations that does not frame socio-cultural norms as alien or antagonistic to technological innovation. Even implementation programmes and research investigations that take a socio-technical lens, accounting for local socio-cultural practices, still perpetuate their status as barriers if they are referred to as one, reinforcing the notion of "othering" (Sovacool and Griffiths, 2020; Few *et al.*, 2021). I argue that we need to revaluate the

language and discourse within energy transition research to ensure a more holistic and inclusive understanding of the interplay between socio-technical systems and socio-cultural dynamics.

6.6.1.2 One-size-fits all approach to policy

After reflecting on all Chapters I believe that one of the key overarching findings from the thesis is the negative affect that centralised one-size-fits all policies have on decentralised RE transitions. A generalised approach to policy yields success only in localised contexts that align well with centralised policies. In contrast, local contexts where these policies do not align risk failure. In other words, a centralised one-size-fits all approach leaves success up to chance, dependent on if policies happen to fit to a local context or not.

UK energy policies, which often prioritise large utilities, overlook the unique needs of remote rural communities affected by energy poverty. These rural communities could greatly benefit from locally-owned RE solutions (Bauwens, Gotchev and Holstenkamp, 2016; Mirzania *et al.*, 2019). However, the nationwide removal of the FiT for small-scale RE installations, rather than maintaining it for areas in need of decentralised alternatives, exemplifies a one-size-fits-all policy approach. This centralised policy framework is failing to address the pervasive energy poverty across the UK, underscoring a misalignment between national energy strategies and the specific needs of vulnerable communities.

In India, centralised biogas policies are ill fitted to Assam and households have been poorly targeted by the centralised programme (Raha, Mahanta and Clarke, 2014). The centralised policies overlook that diverse ethnic groups with alternative livestock-rearing patterns could benefit from biogas. They also overlook household socio-economic demographics targeting households with large numbers of cattle who likely have higher incomes than those with less cattle. These households can afford alternatives to biogas like LPG and thus have less need for biogas (Mittal, Ahlgren and Shukla, 2018). Many households that do have biogas in Assam are abandoning it or not using it optimally as they do not have a need for it. The centralised biogas programmes in Nepal and India, despite having additional subsidies for low-income or marginalised households, have repeatedly failed to recognise and provide benefits to the poorest households, perhaps because centralised policies treat the poor as a uniform group (Damgaard, McCauley and Long, 2017; Bhattarai, Somanathan and Nepal, 2018; Mittal, Ahlgren and Shukla, 2018).

These findings and conclusions around biogas are consistent with other studies outside of India and Nepal. In Bolivia, households were found not using their biogas because they prefer the space heating provided by wood fuel. The programmes policies, like in Assam, have not targeted households with the correct needs for biogas. In regions with demands for space heating, biogas might not be the most suitable decentralised RE solution (Martí-Herrero *et al.*, 2015). Additionally, in Ethiopia where approximately 50-60% of a household's cooking requirement is used to bake a traditional bread, a study found that biogas could not fulfil this cooking requirement (Kamp and Bermúdez Forn, 2016). In China, households were found to be unable to afford upkeep and repairs

of their biogas. The uniform approach in China to subsidising only the initial installation instead of the longer term upkeep costs is not working for some households (Salum and Hodes, 2009). I agree with Kalina, Ogwang and Tilley (2022) who highlight that too often researchers and practitioners focus on the potential of biogas, without considering if it is actually a practical solution. It is essential to critically assess whether biogas is the optimal technology for a given context and examine whether policies are adaptive to local environments.

All three case studies provide examples of how decentralised RE transitions are inhibited due to centralised approach to technology dissemination and governance that does not adapt to localised needs (Goldthau, 2014). Of particular significance, it demonstrates the shortcomings in centralised domestic biogas programmes. This thesis offers rich insights into specifically how centralised policies in Nepal and India's biogas programmes, two of the biggest biogas programmes globally, diffuse to succeed or fail in local environments. These insights significantly enrich the domestic biogas literature by addressing a gap in multi-scalar policy evaluation studies, highlighting the need for nuanced policy analyses. The conclusions drawn in this thesis find support in broader research, despite the lack of specific literature within the domestic biogas field. For instance Abdelnour, Pemberton-pigott and Deichmann (2020) highlight the failure of simplified, techno-centric approaches in the clean cooking sector, attributing this to a disregard for the complexities of cooking practices and the varied needs of households. Similarly, Wieczorek (2018) notes that the main reason internationally led development projects fail is the lack of meaningful engagement with place-specific cultures, power relations and infrastructures. These studies underline the importance of contextual considerations in the success of development initiatives.

6.6.1.3 Policy coherence

Another key finding is how the success of decentralised RE transitions hinges on successful multi-sector policy coherence (Bauwens, Gotchev and Holstenkamp, 2016; Kanda *et al.*, 2022).

The UK, even when the FiT was active saw relatively limited uptake of community renewable energy (CRE). Some scholars have attributed this to the relative lack of social cohesion in the UK that does not facilitate the public working in energy cooperatives (Mirzania *et al.*, 2019). A multi-sector approach to this challenge would be to support the FiT indirectly, combining policies to improve social cohesion and facilitate communities coming together to benefit from community energy. Hannon *et al* (2023) suggest that the UK's CRE sector could benefit from policies that are indirectly focused on the CRE sector such as support for entrepreneurial experimentation. Comparatively Germany has experienced much more local engagement in decentralised RE initiatives. This has been theorised to be due the German government's consistent support for local subsidiarity, public benefit values and promotional lending while these factors are lacking in the UK (Mirzania *et al.*, 2019).

The diffusion of biogas in India and Nepal is impeded due to households being offered other, often subsidised, alternatives for fuel, sanitation, and fertiliser. These alternatives make biogas less

competitive to households. In such contexts, biogas may not be a suitable decentralised RE solution when alternatives that require less labour to operate are available. Martí-Herrero *et al* (2015) also find in Bolivia that households that have biogas are also being provided with subsidised LPG and are subsequently not using their biogas optimally. Policy incoherence undermines the efforts and funding put into biogas programmes. Through improving multi-sector policy coherence, biogas could be better targeted to households that are lacking alternatives. In Nepal, TLADs were successful, at least in the case study villages studies in this thesis, because TLADs were promoted to households that needed improved sanitation facilities. The programme also coordinated policies and promotional activities with the sanitation sector so households were approached by unified programmes and technological options, not competing alternatives.

This thesis underscores a critical gap in the literature regarding the influence of multi-sector policy coherence on the success of domestic biogas programmes. While existing research highlights the importance of multi-sector policy alignment for institutional biogas projects, a detailed examination of its impact on domestic biogas initiatives remains unexplored. Studies by Damgaard, McCauley and Long (2017) and Bharadwaj *et al* (2022) link biogas uptake in Nepal to factors like road access, hinting at the role of external policies in shaping biogas distribution. These insights, though valuable, suggest a need for more comprehensive research into how together agricultural, energy, sanitation, and waste management policies collectively affect the outcomes of domestic biogas programmes. Future research should delve deeper into how these cross-sector policies interact, potentially offering competing alternatives or shaping local and national regimes, to fully understand their effects on biogas programme outcomes. This is important line of investigation; many stakeholders discussed how rural development programmes are run separately out of various government departments with little to no integration.

6.6.1.4 Improve energy democracy and public participation

The evidence gathered from the case studies underscores the critical importance of fostering energy democracy and encouraging greater public participation in the energy transition process (Pandey and Sharma, 2021; Wahlund and Palm, 2022).

In both India and Nepal biogas programmes faced challenges due to poor targeting, incoherent policies, and an inability to adapt to local needs. Interviews with biogas users revealed that many users had grievances, suggestions for policy improvements, and issues with biogas system repairs that were going unheard. Increased citizen participation in the programme and or policy consultation and design could greatly help adapt the programme to better fit to, and serve, local populations. Increased accountability and listening to users could greatly improve biogas programme effectiveness. Decentralised RE initiatives that are not accountable for their failings will have poor governance and outcomes (Brisbois, 2020). Without mechanisms for feedback and accountability, there is little means or motivation for programmes to address shortcomings and make necessary improvements. There is a notable gap in research that investigates accountability within domestic

biogas programmes and how a lack of accountability, which is in effect excluding citizens from any decision-making processes, is negatively affecting programme outcomes.

The findings indicate a significant gap in the UK public's understanding of the factors that influence electricity pricing and a general disengagement from energy policy in voting behaviours. This lack of awareness and engagement means the UK government faces little public accountability for its energy policies (Arnold, 2012). Educated and informed citizens are crucial for demanding accountability and advocating for policies that reflect their interests and needs (Arnold, 2012). Enhancing public engagement could foster a more informed populace, aware of the electricity market's intricacies and the potential of alternative energy solutions. This informed populace could better hold the UK government accountable and better demand that policies respond to diverse and localised energy needs in the UK.

These conclusions align with studies that argue that more inclusive citizen participation can lead to fairer transitions, ensuring that the benefits of such transitions are more equitably distributed and that communities have the necessary knowledge to make informed decisions (Bauwens, Gotchev and Holstenkamp, 2016; Jenkins, Sovacool and McCauley, 2018). The findings and conclusions also reinforce the call for integrating energy justice more comprehensively into energy transition policies, debates, and research (Jenkins, Sovacool and McCauley, 2018). Lack of citizen consultation and accountability to citizens for failed policies and programmes is an energy justice issue. The thesis emphasises the critical need for accountability within energy policy debates, to mitigate adverse effects caused by institutional unaccountability. It advocates for further research into democratising energy policies and enhancing justice, ensuring the public is adequately informed and empowered to hold governments accountable for their energy decisions.

6.6.1.5 Technological focus is inhibiting energy transitions and study and understanding of them

The key headline findings so far discussed in this section all converge under one overarching issue: a techno-centric approach to decentralised RE transitions. Such an approach leads to the overemphasis on *socio-cultural resistance*, perceived as oppositional to technological advancement due to its 'othering' from the physical realm of technology use. *Policies* are thus designed with a one-size-fits-all mentality, overlooking the need to interact with and embrace cultural and regional diversity. P*olicy coherence* also suffers as policies are not designed around universal energy access or rural development aims but are designed individually around top-down implemented technological solutions. A techno-centric approach also results in a lack of *democratic participation*, as energy transitions are viewed as a technological solution rather than a societal evolution, diminishing the role and involvement of communities in the process.

This observation aligns with the critical perspectives of scholars like Boamah and Rothfuß (2018), who argue against the prevailing techno-centric focus of energy transitions, emphasising that societal adaptation issues fade into the background when energy is regarded merely as technology.

This view is further supported by scholars critical of the clean cooking sector, within which biogas serves as one clean cooking solution. Despite a wealth of studies, Bharadwaj *et al* (2022) draw attention to the absence of comprehensive studies in the clean cooking sector that investigate failure while accounting for high-level factors such as governance and policy. Instead studies to date have over focussed on household decision making around technological solutions. Abdelnour, Pemberton-pigott and Deichmann (2020) similarly critique techno-centric approaches to clean cooking project implementation that neglect the specific needs and practices of users, resulting in high failure. This is a sentiment echoed in Abdelnour and Saeed's (2014) critique of clean cook stoves being marketed as a simplistic solution to complex societal issues such as gender-based violence. This tendency to oversimplify and impose technologically centred "solutions" without addressing the underlying societal challenges is a recurring theme. Wieczorek (2018) extends this critique more broadly to energy transitions in the Global South, observing that the failure of projects led by international organisations often stems from their technological focus and a disconnect from the local cultural context, power dynamics, and infrastructural realities. These insights collectively underscore the need for energy transition research and initiatives to move beyond technology-centric approaches and to engage more deeply with the societal, cultural, and governance aspects that critically shape their success or failure.

These conclusions lead us to ask ourselves as researchers, important questions and to challenge our positionality: Why is context so often overlooked when studying user decision-making? Why are high-level factors in the clean cooking sector failure under-researched? Why is the inclusion of users in the design processes rare, despite long-standing recommendations (Agarwal, 1983; Crewe, 1997)? Why are improvements in deliverables, processes, and outcomes not the focus of donor-directed monitoring and evaluation (Abdelnour, Pemberton-pigott and Deichmann, 2020)? Further investigations into the failure of biogas programmes, and other decentralised RE transitions, should turn their attention to these questions. Improvements in individual programmes will only have limited impact as long as the clean cooking and energy sector as a whole, continues to operate in a way that hinders achieving real impact (Ha and Kumar, 2021).

6.6.1.6 Overall contribution to sustainability transition literature, dialogue and framework analytical refinement

This thesis offers a few notable contributions to the field of sustainability transitions:

Firstly, recently identified research gaps in the field of sustainability transitions are: a need for more research investigations that explore how and why transitions occur in various geographical contexts, more cross country comparisons and more research that explores transitions within countries in the Global South (Köhler *et al.,* 2019). This thesis contributes to filling all of these identified research gaps and contributes rich data for discussion.

Secondly, this thesis not only aligns with current research emphasising the importance of multi-scalar considerations in understanding energy transitions within the Global South (Hansen *et*

al., 2018; Wieczorek, 2018; Köhler *et al.*, 2019), but also significantly extends this discourse by introducing the critical need for multi-sector analysis. While existing studies have stressed the variability and complexity of governance regimes across different levels—from national to local—this research uniquely highlights the intersectionality of various sectors, such as energy, agriculture, sanitation, and waste management, essential for the effective dissemination of domestic biogas technologies (Huttunen, Kivimaa and Virkamäki, 2014; Kanda *et al.*, 2022). It argues that a holistic understanding of biogas transitions requires not just an appreciation of the scalar dimensions of governance but also an integrated approach that considers how these technologies straddle and impact multiple sectors (Gustafsson and Anderberg, 2021; Kanda *et al.*, 2022).

Thirdly, this thesis highlights a pervasive issue in energy transitions, not just limited to individual cases of international aid but indicative of a broader global regime influencing development practices. Wieczorek (2018) points out that classical technology transfer mechanisms implemented by international organisations often fail due to a lack of engagement with local cultures, power dynamics, and infrastructures. This thesis suggests that this issue extends beyond specific instances of donor aid to influence nationally funded and implemented development programmes. Domestic programmes are failing for similar reasons as internationally funded ones. The techno-centric aid model has embedded itself within the global regime, affecting national policies and their implementation across diverse geographies, irrespective of direct international aid involvement. This widespread influence calls for a deeper examination of the global energy regime and its foundational principles, as well as its impact on national and local processes in various contexts (Fuenfschilling and Binz, 2018; Miörner, Heiberg and Binz, 2022).

Fourthly, I believe my engagement with the Multi-Level Perspective (MLP) framework raises crucial discussions on its relevance and adaptability for studying decentralised RE transitions to household technologies in Global South contexts. The MLP has been developed and so far, predominantly applied to studying transitions in Global North contexts. The increasing application of the MLP to analyse transitions in Global South contexts necessitates a critical examination of its capabilities, limitations, and potential biases (Hansen *et al.*, 2018; Wieczorek, 2018). Upon reflection, the MLP, while insightful for mapping transition processes over time, appears limited in addressing the broader socio-political forces and the nuanced dynamics of energy transitions across various contexts. A primary critique is its inability to fully integrate the rich socio-cultural, economic, geographical, and political diversities that vary significantly from national to local, and even within village and household levels. These contextual elements, crucial to the transition, are not merely peripheral landscape factors but are central to understanding the complexities of energy transitions. Additionally, the MLP struggles with the non-linear nature of household transitions. The mere adoption of domestic biogas doesn't imply its integration into the broader energy or agricultural regimes. The real test of penetration lies in households' consistent use of biogas and slurry, which is subject to change over time. This dynamic aspect of transition, where adaptation and usage evolve,

challenges the MLP's ability to capture the full spectrum of transition dynamics at the household level.

My reflections are aligned with scholars who critique the MLP for its failure to adequately incorporate actor agency and its insensitivity to spatial, agency, power, and political dimensions (Geels, 2011; Wieczorek, 2018). However, the MLP is robustly defended by many within the academic community, including Geels, (2010, 2011), who argue for its flexibility and broad applicability in studying sustainable transitions, suggesting that its effectiveness largely depends on how it is applied by the researcher. Nevertheless, there is a pressing need for scholars, particularly those examining the MLP's application in the Global South, to undertake a more critical examination of its suitability. The academic studies that I used to inform my approach and use of the MLP, while they applied the MLP in Global South contexts, did not delve deeply into a critical review of the framework and its limitations (Kamp and Bermúdez Forn, 2016; Yadav, Malakar and Davies, 2019; Pilloni, Hamed and Joyce, 2020). This thesis champions the establishment of a culture of critical reflection on the use of the MLP in new contexts, promoting discussions on its potential refinement or the exploration of alternative frameworks that can more accurately encapsulate the complexities of decentralised energy transitions in the Global South. The collected data from this thesis provides rich data through which to study transitions to a decentralised RE technology in Global South contexts and to test the applicability of frameworks like the MLP. I would share this data, anonymised, for further academic exploration with different frameworks or models, aiming to enrich discussions and contribute to the field's development.

Lastly, this thesis has broadened the scope of measuring and analysing energy literacy within the study of energy transitions. In their review, van den Broek (2019) identifies existing energy literacy tools as largely confined to aspects of physical energy production, supply knowledge, and personal energy attitudes and values. By contrast, Chapter 5 pioneers a scale and methodology for assessing energy literacy with an emphasis on knowledge of energy markets and policies. This research illuminates the impact of energy literacy on public support for energy policies and voting behaviour, establishing a direct link between individuals' understanding of energy policies and markets and their opinions. It underscores the significance of incorporating knowledge of policies and markets into energy literacy, advocating for the development and refinement of tools to assess this crucial dimension effectively. These findings challenge the adequacy of existing tools in capturing the full spectrum of energy literacy factors influencing energy transitions. The creation of an energy literacy scale, as detailed in Chapter 5, marks a pivotal advancement by incorporating political dimensions into energy literacy assessments. This novel scale serves as a foundation for integrating more politically-oriented inquiries into energy literacy tools. Future research should focus on adapting this scale for broader international use, given its current UK-specific design. Expanding its applicability through cross-country comparisons would significantly increase the scale's utility and relevance across diverse geopolitical landscapes.

6.7 Concluding remarks

6.7.1 Overall

This thesis aimed to explore how decentralised RE transitions emerge in different contexts and to better understand the reasons for success and failure. To investigate how decentralised RE transitions are shaped by diverse space and place characteristics this thesis utilised case studies from Nepal, India, and the UK. The primary focus of the thesis was to better understand transitions to domestic biogas in rural Nepal and India, probing the long-term question of why domestic biogas inconsistently succeeds, even in seemingly similar contexts. Particular focus was given to understanding of the role of socio-cultural resistance in TLAD adoption or rejection.

The qualitative findings, derived from in-depth semi-structured interviews with households and stakeholders of the biogas programmes in India and Nepal, illuminate the complexities of household transitions to domestic biogas. These insights underscore the necessity of tailoring biogas programmes to local contexts to enhance their effectiveness and sustainability. Centralised policies, that are not customisable to local needs, can result in inconsistent programme outcomes across diverse localities. To improve domestic biogas programme outcomes this study advocates for the adoption of adaptable, locally tailored policies that incorporate bottom-up input and cross-sector coordination. It specifically identifies and advocates for the necessity of cross-sector coordination, a crucial yet underexplored aspect in domestic biogas literature, essential for understanding the success or failure of biogas initiatives. Biogas technology intersects multiple sectors—at least energy, agriculture, sanitation, and waste management—but is frequently categorised narrowly within renewable energy departments. However, its effectiveness and adoption are significantly influenced by broader policies and subsidies related to alternative cooking fuels like LPG, as well as chemical fertilisers, and other sanitation solutions. Available and affordable energy, agricultural and sanitation alternatives impact a households' decisions regarding biogas adoption and the long-term use of biogas. To fully understand household decision making and biogas programme success or failure it is crucial to analyse the biogas programme within the broader policy context, considering alternatives and competing solutions from different sectors. This comprehensive analysis and understanding is also vital for identifying households that are ideal candidates for biogas, taking into account the alternative products and services available to them that will drive their needs and motivations for biogas.

The reductive attribution of socio-cultural resistance as a blanket explanation for the failed adoption of TLADs, particularly in India, has resulted in the oversimplification of local perspectives, framing communities as inherently resistant to technological change while masking governance and programmatic failures at higher levels (Pawan K., 2014; Raha, Mahanta and Clarke, 2014; Muralidharan, 2017; Mittal, Ahlgren and Shukla, 2018). This thesis urges a paradigm shift in the global energy and international aid sectors, moving beyond techno-centric models of rural development that often misconstrue socio-cultural norms as obstacles (Andersson, 2015; Boamah and Rothfuß, 2018). Socio-cultural norms must be interpreted as an inherent component of the whole

transition and viewed in the context of the wider landscape and policy environment that is shaping household decision making (Pfaffenberger, 1992; Few *et al.*, 2021; Bharadwaj *et al.*, 2022). In Assam, while socio-cultural opposition to TLADs was a genuine issue for some households, the larger barrier was the lack of necessity; most people already had existing sanitation and energy solutions and thus no motivation to challenge socio-cultural norms. Stakeholders within the biogas programme in Assam, who attribute the absence of TLADs in the state solely to socio-cultural resistance (Raha, Mahanta and Clarke, 2014), overlook critical aspects of programme delivery. These include effectively marketing TLADs, providing opportunities for households to trial or observe TLADs, and coordinating the biogas programme with existing sanitation initiatives. The failure to integrate and tailor the programme to local needs reveals a broader issue of misaligned programme strategies rather than mere socio-cultural opposition.

The secondary aim of the thesis was to examine public energy literacy in the UK, particularly how literacy influences public opinion on the UK's energy transition following the energy crisis. The findings, encompassing survey data from a section of the public in England and Scotland, suggests that enhanced public understanding of electricity pricing could shift support away from gas and towards RE, inclusive of decentralised RE. The energy crisis seems to have raised public awareness of energy costs and support for domestic energy, including local RETs. Limited understanding of electricity systems and market pricing could explain why most participants support both increased UKCS gas extraction and RE for electricity generation. Without comprehensive energy system knowledge, the public may lack the resources necessary to make informed decisions or to hold institutions accountable. The energy crisis, by increasing public awareness of energy costs, presents an opportunity to leverage education about electricity pricing to boost support for RET investment and development.

Each chapter of this study provided valuable insights into transitions towards decentralised RE in specific geographical contexts, yet collectively, they highlight broader, globalised challenges facing successful transitions to decentralised RE. The global energy regime, characterised by its techno-centric and centralised approach to governance, has been identified as a significant barrier to the decentralised RE transitions explored in this thesis's case studies. This regime's reliance on technology-driven solutions emerges as a dominant theme, influencing energy transitions in various critical ways (Boamah and Rothfuß, 2018), as evidenced across the investigated scenarios. It leads to an overemphasis on socio-cultural resistance, framing it as oppositional to technological advancement due to its separation from the technological realm. Policies are consequentially often designed with a one-size-fits-all mentality, failing to account for cultural and regional diversity and specific needs, because they are seen as separate from technology. Policy coherence is also compromised as policies are typically designed around specific technologies rather than broader aims like universal energy access or rural development. Subsequently, decentralised RETs are promoted alongside competing alternatives, often in contexts unfavourable to decentralised RE solutions due to lack of support from wider indirect policies. These wider policies could otherwise facilitate social

innovation, cohesion, and stronger local decentralised governance. Additionally, the techno-centric approach limits democratic participation in energy transitions. By viewing transitions primarily as technological solutions, the role and involvement of communities are diminished, overlooking the societal aspects of these transitions.

The case studies of Nepal, India, and the UK showcase how centralised, and particularly in the UK, privatised energy governance hinders the pursuit of a democratic, decentralised energy future. The thesis argues for a paradigm shift in how energy transitions are both approached and researched. Further academic investigation must better situate individual case studies or individual, household and public decision making within the broader, multi-sector, and multi-scalar context of a RE transition. The findings from this thesis demonstrate how analysing findings from localised studies in isolation from the broader context overlooks systematic policy and governance issues, offering limited actionable insights for policy improvement. It further demonstrates how situating individual, household and public decision making within the broader context of an energy transition, and asking critical why questions, can facilitate the obtainment of research findings that identify root-causes of transition failure, previously overlooked.

6.7.2 A final remark on transitions to domestic biogas

Domestic biogas can offer households many holistic benefits and has the potential to transform rural communities, aligning environmental objectives with livelihood improvements (Bajgain and Shakya, 2005; Fulford, 2015). However, recommendations for biogas programme improvements drawn from this study should be applied with discretion. Biogas technology spans across the sectors of energy, sanitation, waste management, and agriculture, and it deeply interacts with the local socio-cultural, political, and geographical contexts where it is implemented (Bhat, Chanakya and Ravindranath, 2001; Cheng *et al.*, 2011; Pawan K., 2014; Raha, Mahanta and Clarke, 2014; Ortiz, Terrapon-Pfaff and Dienst, 2017b; Kalina, Ogwang and Tilley, 2022). There is no one-size-fits-all approach to implementation that can be reapplied in multiple contexts (Abdelnour, Pemberton-pigott and Deichmann, 2020). Successful implementation demands robust governance and regulatory capacity, capable of managing the complexities associated with a biogas programme (Gustafsson and Anderberg, 2021). Unless these conditions are met and the factors leading to prior biogas programme failures are thoroughly studied and understood to avoid repetition, the implementation of biogas technology might need to be re-evaluated (Kalina, Ogwang and Tilley, 2022). While the findings in this study are novel, offering many valuable recommendations for programme improvement, the overarching regimes within which biogas operates are currently too unsupportive to continue recommending its continued deployment.

There have been numerous documented global biogas programme failures and until the insights from this study are expanded upon, we should exercise caution in disseminating more domestic biogas digesters. My hope is that the work from this thesis will instigate more in-depth conversations and comprehension about the recurring issues with domestic biogas, as well as the

shortcomings of the current aid sector model and global energy framework in deploying decentralised solutions like biogas. The ultimate goal should be to reshape global energy governance, facilitating an environment in which decentralised renewable energy solutions, including biogas, have a higher probability of succeeding.

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Appendices

Appendix 1: Nepal, Province 4 interview schedules

1. **How long have you had your TLAD?**
2. **Who decided to get it and where to put it?**
3. **What were your reasons for getting a TLAD?**
4. **What do you like about having a TLAD?**
5. **What do you dislike about using and maintaining a TLAD?**
6. **Compared to the wood fire cooking with biogas is there difference in your feelings/ family life?**
7. **Is your life more comfortable in any way since getting biogas?** (less labour)
8. **Have there been any unexpected benefits or challenges?**
9. **What do you do if it needs a new part or breaks/ gas reduces?**
10. **How do you empty the TLAD and how often? How is this different to emptying out a latrine?**
11. **What do you feed your TLAD?**
12. **What do you use the biogas for?**
13. **What can you not use the biogas for?** (What jobs is it not suitable for and why)
14. **Does everyone want to use the biogas in the same way? Who decides what it is used for and do women get a say?**
15. **Has there been changes in the way biogas is used across generations?** (has acceptance increased over generations?)
16. **Are you aware of the fertilising potential of faeces and urine?**
17. **What do you use the fertiliser for and why?**
18. What **do you not use the fertiliser for and why?**
19. **Do you believe TLAD to be a modern household technology that people should use in the future ?**
20. **Do you know anything about community biogas projects?**
21. **How do you feel about community biogas projects compared to domestic?**
22. **Would you prefer another fuel or technology instead of TLAD?** Which one if yes and why if no or yes?
23. **Some of the main challenges around TLADs is because other people don't like them. Why do you think people don't like them? Do you have an example of a negotiations around use in your household please?** For example some people in Nepal have used cow dung to purify the human excreta to make the biogas acceptable for use. Any other examples like this?

Appendix 2: India, Assam state interview schedules

India, Assam semi-structured household interview schedule for participants with domestic biogas (was adapted for households that did not have domestic biogas)

TLBD = toilet-linked biogas digester

Gobar Gas = anaerobic digester without toilet connection (mostly fed on cow dung)

1. **When was your Gobar Gas built and is it still working?**
2. **Has your experience been positive or negative?** *Please explain*
3. **What do use the biogas for?** Cooking, animal food, heating water
4. **Do you get enough biogas for all your needs?** *Are they happy if it only supplies half and they fulfil the rest with other fuels.*
5. **If you only have limited cow dung do you apply it to soil or use it in the Gobar Gas?**
6. **What do you use the gobar gas fertiliser for?** *The liquid slurry*
7. **Is there anything you don't like using the fertiliser for?**
8. **What do you do to the digestate before applying it to soil?**
9. **Does it help with crop growth or health?** *Explain effects*
10. **How does it compare to other fertilisers (potash, chemical NPK, cow dung, other)?**
11. **What do you feed your gobar gas?** Do they only put in cow dung or do they put in crop residue, food waste, weeds, goat dung, rice water?
12. **Do you think the work you need to do to maintain the gobar gas is okay?** Is it too hard, unpleasant, too long, dirty….
13. **If you have a problem with your gobar gas do you feel like there is support locally to help you fix it or get advice and support?**
14. **Did you receive training and would you like more training?**
15. **Do you know what toilet-linked gobar gas is?** *Explain if no*

Interviewer: Get picture out of a TLBD and ask if it is ok to ask them questions around their opinions and feelings about TLBD. We do not have an agenda and there are no right or wrong answers we would just like to know local people's feelings.

In Nepal people with TLBDs preferred them to other toilets because they smell less, they contain the excreta so it doesn't soak into ground water and they don't need to have their toilets emptied. They make the toilet waste less smelly and they get value from the fertiliser which they apply directly to soil or compost first. They use the biogas for some cooking along with LPG and wood fuels, which a lot of people use for ritual cooking.

16. **Can you see any advantage in a TLBD instead of just gobar gas?** Make it clear toilet it connected, cow dung/ food waste etc would still be used.
17. **Is there anything you think you would dislike about connecting a toilet?**
18. **Would it be unacceptable for you to cook all of your food/tea on TLBD biogas or is there somethings you couldn't?** Would it be ok to cook ritual, celebration foods?
19. **Do you think the cow dung mixing in the toilet linked gobar gas could purify the human excreta and make using the biogas more acceptable?**
20. **Do you know human excreta contains plant nutrients?**
21. **Do you think connecting a toilet to your gobar gas would improve the fertiliser?**

22. **What crops would you fertilise with the TLBD fertiliser and is there any you would not want it on?** In Nepal people didn't use it for salads, root veg but did for most other things
23. **Would you be okay handling and touching it?**
24. **What if it could be set up so the liquid digestate directly went to a compost pile so you would only have to handle the compost?**
25. **Do you think a TLBD toilet would be better than the toilet you have now?**
26. **Do you think TLBD would help to control diseases?**
27. **Do you think there is any difference between how LPG and TLBD biogas is made?**
28. **What if sweepers stopped cleaning toilet? Or do you thinking emptying a TLBD might be better work for them than cleaning toilets?**

Can we now ask you a question about menstruation and TLBDs?

29. **OPTIONAL – if interviewer feels they can ask participant. Women are sometimes restricted from cooking or entering the kitchen on their period. Would gas made from menstrual blood be an additional restriction to using TLBD biogas in the kitchen? Would women have to use a different toilet?**

30. **Do you think your family and neighbours would be supportive if you connected a toilet to your gobar gas?** Would they stop coming to your house or stop talking to you?
31. **How would you react if someone you knew got one?** *Would you eat at their home?*
32. **Do you think anyone you know would get a TLBD?**
33. **If you got a TLBD do you think social problems could be resolved or people would get used to it over time?**
34. **Would you be interested in learning more about connecting a toilet to your gobar gas?**
35. **What would have to change in your circumstances for you to want or need to connect a toilet to your gobar gas?** What if LPG price increased or subsidy was taken away? What fuel would you use?
36. **Did you know the Indian Government offers subsidies for gobar gas and extra subsidies for connecting a toilet to it?**
37. **Do you think biogas is a modern fuel that future generations will use? Or are more convenient fuels like LPG and electric more likely to be used?** Maintaining biogas can be quite hard work

OR If they don't think TLBD would be good for them ask them:

38. **Please can you describe the type of household that would be most likely to use a TLBD and get the most benefits from it?** (people that live in rural areas far from LPG, towns, different religions, incomes etc.

Appendix 3: Survey questions for England and Scotland public energy literacy and opinions on the UK's RE energy transition for Chapter 5

I give my consent to proceed with the survey and for the University of Stirling to use my responses.

- ○ Yes (1)
- ○ No (2)

Please read - Important definitions for the survey

UK households purchase electricity from supply companies such as Scottish Power, E-on, EDF Energy, and SSE Npower.

The electricity that households buy is generated on a large-scale, by privately owned companies, from the following sources:

- **Natural gas** (burnt in gas-fired power stations to generate electricity)
- **Nuclear** power plants
- **Large scale renewables: for example** Onshore and offshore wind farms and solar farms)

Electricity can also be generated on a small-scale through:

- **Locally-owned renewable energy:** small scale wind turbines or solar panels that are owned by local people. The community benefits from any profits made generating and selling electricity
- **Household renewables for example h**ousehold size solar panels on roofs that generate electricity

Demographic Questions:
Q1 In the United Kingdom which country do you reside in?

- ○ England (1)
- ○ Scotland (2)
- ○ Wales (3)
- ○ Northern Ireland (4)

Skip To: End of Block If In the United Kingdom which country do you reside in? = Wales

Skip To: End of Block If In the United Kingdom which country do you reside in? = Northern Ireland

Q2 How old are you?

- ○ Under 18 (1)
- ○ 18-24 years old (2)
- ○ 25-34 years old (3)
- ○ 35-44 years old (4)
- ○ 45-54 years old (5)
- ○ 55-64 years old (6)
- ○ 65+ years old (7)

Q3 What best describes your ethnic origin?

- ☐ White (1)
- ☐ Black/African/Caribbean (2)
- ☐ Asian (Indian, Pakistani, Bangladeshi, Chinese, any other Asian background) (3)
- ☐ Mixed two or more ethnic groups (4)
- ☐ Other (Arab or any others) (5)
- ☐ Prefer not to say (6)

Q4 What is the highest level of education you have completed?

- ○ Some Primary (1)
- ○ Completed Primary School (2)
- ○ Some Secondary (3)
- ○ Completed Secondary School (4)
- ○ Vocational or Similar (5)
- ○ Some University but no degree (6)
- ○ University Bachelors Degree (7)
- ○ Graduate or professional degree (MA, MS, MBA, PhD, JD, MD, DDS) (8)
- ○ Prefer not to say (9)

Q5 Please select the option that best describes your living situation

- ○ You own your own home (alone or jointly) (1)
- ○ You rent your whole living accomodation (2)
- ○ Subtenant (boarder) rent a room (3)
- ○ You live rent free (with family/guardian/partner/other) (4)
- ○ You live in supported living (council house/flat) (5)

Q6 What is your gender

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary / third gender (3)
- ○ Prefer not to say (4)

Q7 What is your main source of UK news

- ☐ The Times (1)

- [ ] The Daily Mail (2)
- [ ] The Daily Express (3)
- [ ] The Daily Mirror (4)
- [ ] The Telegraph (5)
- [ ] The Sun (6)
- [ ] The Evening Standard (7)
- [ ] The Daily Star (8)
- [ ] The Metro (9)
- [ ] The Guardian (10)
- [ ] The BBC (all channels) (television/online/radio) (11)
- [ ] Sky News (12)
- [ ] ITV News (13)
- [ ] Channel 4 news (14)
- [ ] Channel 5 news (15)
- [ ] GB News (16)
- [ ] The Independent (17)
- [ ] The Mail Online (18)
- [ ] Radio (national or regional) (19)
- [ ] Social media (Twitter, Youtube, Facebook, TikTok, other) (20)
- [ ] Podcasts (21)
- [ ] Friends and family (22)
- [ ] Other (23)

Survey questions:

Q1 How much have you read or heard about the following topics?

	Nothing at all	I have heard of it, but know nothing else about it	A little	A fair amount	A great deal
The UK electricity system (generation & distribution of electricity)					
The role of Ofgem (Office of Gas and Electricity Markets)					
The way in which household electricity prices are calculated in the UK.					
The role of natural gas in influencing the cost of household electricity.					

Q2 Please indicate if you think the following statements about UK's electricity system and household electricity bills are true or false

	True	False	Not sure
The UK can export and import electricity to and from Europe via underground electricity cables			
Electricity generated by large onshore wind and solar farms is more expensive than electricity generated using coal and natural gas			
Electricity generated by nuclear power is the cheapest form of electricity generation			
UK households on 'green energy tariffs' (where electricity is generated only from renewables) pay less per kWh than those on standard electricity tariffs			
UK households pay the same price price per kWh for all electricity no matter how it is generated (renewables, nuclear or gas)			
During the energy crisis Ofgem set a maximum price for how much UK households could be charged per kWh of electricity they use			
Please select "False" for this option			

Q3 Please select if you think the following statements regarding the UK's North Sea natural gas reserves and imported natural gas are true or false

	True	False	Not sure
The UK's North Sea gas reserves currently meet most (over 75%) of the UK's natural gas demand			
Before the war in Ukraine, most of the natural gas imported to the UK came from Russia			
Private companies that extract natural gas from the North Sea can only export it if the UK does not need it			

Q4 If more gas from the UK's North Sea reserves was used to generate electricity then household electricity bills in the UK would fall

- ○ Agree (1)
- ○ Disagree (2)
- ○ Not sure (3)

Q5 The UK should extract more natural gas from it's North Sea reserves to generate electricity

- ○ Agree (1)
- ○ Disagree (2)
- ○ Not sure (3)

Q6 Investments in renewable energy technologies are the biggest reason why UK household electricity bills have risen in the last two years

- ○ Agree (1)
- ○ Disagree (2)
- ○ Not sure (3)

Q7 To stop household electricity bills rising in the future the UK must invest in renewable energy technologies and **STOP generating electricity from gas**

- ○ Agree (1)
- ○ Disagree (2)
- ○ Not sure (3)

Q8 The UK should nationalise (public ownership) the electricity system - including producers, retailers and the distribution grid

- ○ Agree (1)
- ○ Disagree (2)
- ○ Not sure (3)

Q9 How would you react to a large **privately-owned** wind farm being built close to where you live?

- ○ Strongly support – Take action (attend meetings/contact officials) to help move forward a nearby large privately-owned wind farm (1)
- ○ Support, but not take action (2)
- ○ Neither support nor oppose (3)
- ○ Oppose, but not take action (4)
- ○ Strongly oppose – Take action (attend meetings/protests/contact officials) against a nearby large privately-owned wind farm (5)

Q10 Renewable energy technologies can be owned by private companies, but can also be **owned and managed by local communities**. These communities are local people that would benefit from the generated electricity and profits.

Before today, had you heard of local communities owning renewable energy installations (such as solar panels or wind turbines)?

- ○ Yes I have heard of it (1)
- ○ Yes I am in one/ know someone that is involved in one (2)
- ○ No I have not heard of it (3)

Q11 How would you react to a **locally-owned** windfarm being built close to where you live?

- ○ Strongly support – Take action (attend meetings/contact officials) to help move forward a nearby locally-owned wind farm (1)
- ○ Support, but not take action (2)
- ○ Neither support nor oppose (3)
- ○ Oppose, but not take action (4)
- ○ Strongly oppose – Take action (attend meetings/protests/contact officials) against a nearby locally-owned wind farm (5)

Q12 Do you think locally-owned energy is a:

- ○ Bad solution to the energy crisis (1)
- ○ Good solution to the energy crisis (2)
- ○ Not sure (3)

Q13 Please explain why you responded as you did to the previous question OPTIONAL

_____

Q14 Has the energy crisis made you more or less supportive of renewable energy technologies in the UK landscape? for example wind or solar farms built close to where you live

- ○ Much less (1)
- ○ Somewhat less (2)
- ○ Not changed (3)
- ○ Somewhat more (4)
- ○ Much more (5)
- ○ Not sure (6)

Q15 How likely is it that you would personally invest in technology to generate your own renewable electricity (e.g. household solar roof panels) if it saved you money in the long term?

- ○ Very likely (1)
- ○ Likely (2)
- ○ Neither likely or unlikely (8)
- ○ Unlikely (3)
- ○ Extremely unlikely (4)
- ○ Not sure (5)

Q16 How likely is it that you would you personally invest money into a locally-owned renewable energy project to be built near you (for example a community-owned wind turbine) where you and your community would benefit from the profits?

- ○ Very likely (1)
- ○ Likely (2)
- ○ Neither likely or unlikely (6)
- ○ Unlikely (3)
- ○ Extremely unlikely (4)
- ○ Not sure (5)

Q17 Since the energy crisis:

YOU CAN SELECT ALL ANSWERS THAT APPLY TO YOU

- ☐ I have become more interested in the UK Government's energy policies (4)
- ☐ I have become more aware of the cost of electricity (1)
- ☐ I have become more aware of where our electricity comes from (2)
- ☐ I have reduced the amount of electricity I use (3)
- ☐ I have become more stressed about paying my electricity bills (5)

☐ I feel like I would like to know more about the electricity system and **I know where to get information from** (6)

☐ I feel like I would like to know more about the electricity system but I **don't know where to get information from** (7)

☐ I am not interested in knowing more about the electricity system (8)

Q18 Please indicate how much you agree or disagree with the following statements about energy policies in the UK

	Agree	Disagree	Not sure
The UK Government's energy policies contributed to the recent rise in household electricity bills (1)			
When voting, I always consider a political party's energy policies (3)			
I do not know enough about the energy policies of different political parties for them to affect my vote (4)			
I am not interested in the energy policies of any UK political party (5)			
When voting, other policies/issues matter more than energy policies (6)			
Please select "Agree" for this option (7)			
Please select "False" for this option			