The Governance of Anaerobic Digestion in the United Kingdom: Insights from England and Scotland

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Abstract

The role of governance has received considerable attention within the academic literature on sustainability transitions. However, extant theory in this respect has focused on managing and steering sustainability transitions, while referring mainly to the national level of government, so it has yet to account for the role of local authorities.

This thesis seeks to address that deficiency by identifying a set of explanatory factors to explore the reasons why there are differences in the deployment of waste-fed Anaerobic Digestion (AD) in England and Scotland. Specifically, it addresses how cross-sectorial stakeholders from different government levels and with different jurisdictions coordinate together. By doing so, the research contributes to the literature on governing sustainability transitions by discussing insights on environmental governance from the literature on multi-level governance, network governance, policy networks approach and urban climate governance. The exploration of these literatures leads to the adoption of an analytical framework on governance effectiveness, which includes governance, economic and geographical factors.

England and Scotland are chosen for a comparative study to assess their governance effectiveness on the deployment of waste-fed AD. Compared to England, Scotland has been proactive in providing financial and regulatory support. The comparison also involved three local authorities in each nation, with diverse characteristics in food waste management and local governance arrangements. The research provides useful insights on reasons for the differences between the waste-fed AD deployment rates of the two nations. The key contribution of the thesis lies in its revelations about the processes of coordination and learning between national and local levels of government, along with the factors of local capacity, market, and geography. If the sustainability transitions literature is useful in explaining the waste-fed AD deployment in this regard – as it claims to be – then it needs to consider the role of local government.

‘Two roads diverged in a wood and I –

took the one less travelled by,

And that has made all the difference.’

– *Robert Frost, 1915*.

This thesis is dedicated to my mother Stamatia, my farther Theodoros, my aunt Marina who supported my personal and professional development endlessly.

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Author’s declaration

I declare that all the material contained in this thesis is my own work.

Anna Kaxira

List of abbreviations

Acronym	Description
AD	Anaerobic Digestion
ADBA	Anaerobic Digestion Bioresources Association
BEIS	Department for Business, Energy & Industrial Strategy
CIWM	Chartered Institution of Waste Management
COSLA	Convention of Scottish Local Authorities
DEFRA	Department for Environment, Food and Rural Affairs
DESNZ	Department for Energy Strategy and Net Zero
DfT	Department for Transport
EA	Environment Agency
EU	European Union
FiT	Feed in Tariff
GHGs	Greenhouse Gases
GWh	Gigawatt hours
IVC	In-Vessel Composting
LAs	Local Authorities
MLP	Multi-Level Perspective
Mt	Megatonnes
NGOs	Non-Governmental Organisations
NNFCC	National Non-Food Crops Centre
REA	Renewable Energy Association
RHI	Renewable Heat Incentive
SEPA	Scottish Environment Protection Agency
TIS	Technological Innovation Systems

TM	Transition Management
TWh	Terrawatt hours
UK	United Kingdom
WAMITAB	Waste Management Industry Training & Advisory Board
WRAP	Waste and Resources Action Plan

Chapter 1 Introduction

1.1 Research Purpose, Goal and Objectives

Sustainable development is an intergenerational, intragenerational, multi-scalar and multi-actor concept. Achievement of sustainable development is a complex, challenging, and long-term goal, which calls for the initiation, adoption, and support of transitions in our society. Governance is instrumental in achieving the long-term objective of integrating technology for sustainable development. Waste-fed Anaerobic Digestion (AD) is a technology which decomposes organic waste, while producing biofertiliser and bioenergy. Specifically, it is presented as a case of sustainability transition in the United Kingdom. Differences in the governance of Scotland and England result in the different deployment rates of waste-fed AD in the two devolved nations. However, the dynamics of these differences at the devolved level and their influence on the uptake of an environmental technology at the local level have not been researched so far. This research aims to compare the deployment of AD in England and Scotland as well as to explore the reasons for any differences. Apart from the importance of the national level, the role of English and Scottish Local Authorities (LAs) is also explored in the use of AD plants for food waste management and renewable energy production. Exploring the literature on environmental governance is useful to identify these reasons, along with the interaction of the national and local level, because it explains the theoretical foundations of how sustainability and governance are interconnected.

AD technology has been used for sewage sludge treatment in the UK for more than hundred years (POST, 2011). However, its specific usage of food waste disposal by LAs is relatively recent and still growing in the UK. AD technology involves numerous actors and affects the sectors of environment, energy, food, water, and waste within different scales. In the UK, there are different policies and regulations, devolved administrations, various cross-sectorial organisations, involved in the multi-layered governance landscape. Governance involves uncertainty and complexity arising from the interactions of different actors at the national, regional and local levels of government. Further, exploring the role of the state through these levels of governance and their influence on this coordination of stakeholders is essential. By doing so, the research contributes to the literature on governing urban sustainability transitions by discussing the central concepts including the Multi-Level Perspective (MLP) (Geels, 2002, 2012; Smith et al., 2005), Transition Management (TM) (Frantzeskaki et al., 2012; Kemp et al., 2007; Loorbach, 2010; 2007), and Technological Innovation Systems (TIS) (Hekkert et al., 2007; Suurs, 2009; Alkemade et al., 2011; Loorbach et al., 2017).

By addressing the issues of cross-sectorial coordination in the rollout of an environmental technology, the research explores the reasons for the differences in the deployment of waste-fed AD between England and Scotland. To address this aim, the research has the following three objectives. Firstly, it reviews the role of the UK environmental governance on the deployment of waste-fed AD, while exploring key policies and incentives, closely related with waste-fed AD. Secondly, it investigates the impact of the national level of governance on waste-fed AD in the UK and its links with the devolved and local levels. Thirdly, it identifies the core factors describing the success of English and Scottish LAs in the use of AD plants for food waste management and renewable energy production. Contemporary academic literature on environmental governance addresses the resolution of environmental conflicts and problems over resources through coordination, while exploring the role of key actors, through the following literatures: multi-level governance, policy networks, network governance and urban climate governance. These literatures of environmental governance address the role of state and the different levels of government, the interrelationships between public and private sector and the involvement of diverse stakeholders across multiple scales in the pursuit of sustainability.

This introductory chapter aims to provide a clear focus of the research, by highlighting the importance of governance in transitions towards sustainable development, illustrating waste-fed AD as a case of sustainability transition, and exploring the policy development, which influenced the deployment of waste-fed AD, with a focus on the importance of devolved level, when comparing England to Scotland. Key aspects of the different academic literatures of environmental governance are also presented as the foundations of the analytical framework of the research. At the end, the research questions are provided along, with the thesis structure reflecting the content of the following chapters.

1.2 Transitions towards sustainable development: the importance of governance

Demand on natural resources is still increasing, while financial crisis and insecurity is being prolonged, so the need for taking organised action towards climate change becomes more evident than ever before (Sharmina, et al., 2016). Sustainability is an ecological, economic, and social concept, which requires a holistic and interdisciplinary approach to secure the existence and development of humanity in the future. Sustainable development is a process of achieving sustainability through the key dimensions of human activities; economic, social, and environmental. These activities are mutually interdependent, and policymaking decisions in one sector can influence the other. In these activities, there are interdependencies created at different geographical, temporal, and political scales (Cairns et al., 2017), which can influence the progress towards the achievement of sustainable development. Sustainable Development is a complex and long-term process, involving multiple actors with different jurisdictions and power (Meadowcroft, 1997; Loorbach, 2007; Frantzeskaki et al., 2012).

Embedding sustainable development in our lives is challenging and the progress towards sustainable development depends on the effectiveness of governance mechanisms. Governance plays an important role in the achievement of sustainable development (Frantzeskaki et al., 2012; Loorbach, 2007). The pathway to sustainability is non-linear and needs radical socio-technical changes initiated and supported, with the use of environmentally friendly technology and positive response of the society. The literature on sustainability transitions defines these changes as long-term, radical, and multi-actor transformations towards more sustainable modes of production and consumption (Markard et al., 2012). The *'governance of transition processes'* is highlighted in sustainability transitions research (Smith et al., 2005; Markard et al., 2012; Loorbach et al. 2017) for the achievement of long-term goals, which need a broad range of cross-sectorial actors working together. Despite this recognition of the significance of governance, the sustainability transitions research has overlooked the evolution and multi-level dynamics of governance, public policies, regulations, decision-making processes, and coordination (Mourato and Wit, 2022; Loorbach et al. 2017). Specifically, the questions which are rarely addressed in the literature on sustainability transitions are: how stakeholders with different jurisdictions coordinate together and what the influence of governance is on this coordination and on the uptake of an environmental technology. Nevertheless, this research delves into these questions.

There are different angles to approach the question of a large-scale socio-technical change in transitions literature, however the research aims to evaluate the role of governance in the uptake of a specific environmental technology (waste-fed AD). For this reason, it examines key aspects of three theoretical frameworks in the sustainability transitions literature: the Multi-Level Perspective (MLP), Technological Innovation Studies (TIS) and Transition Management (TM). TM is used as a framework for experimental exploration of transition governance, which recognises the role of state on objective setting and niche protection (Loorbach et al., 2017). However, it degrades the importance of other levels of government, the local conditions, the competition, and politics for the progress of sustainability transitions. MLP and TIS are used to evaluate governance in sustainability transitions, while recognising the importance of policy as a key factor for the uptake of innovations and the completion of these transitions (Loorbach et al., 2017; Alkemede et al., 2011; Geels, 2011; 2004; 2002). The MLP is a multi-level framework, which identifies how different stakeholders involved in the three levels of organisations; niche, landscape, and regime, work together to adjust policy to community needs (Geels, 2002; Markantoni, 2016). TIS framework is used to formulate policy interventions for innovation pathways and evaluate transition agendas (Hekkert et al., 2007; Suurs, 2009; Alkemade et al., 2011; Loorbach et al., 2017). MLP is a framework applied in the sustainability transitions of different sectors, such as food, energy, and transport sectors, whereas TIS is mainly used in the studies focusing on the emergence of clean-tech sectors (Bergek et al., 2015). These three frameworks recognise the importance of coordination in the governance of these transitions, in which a variety of actors and institutions need to work together to implement strategies for a climate-resilient future. Despite the usability of these theoretical frameworks, the role of local government and its influence on the uptake of a niche or innovation is not explored in depth by these frameworks as it is illustrated in chapter 2.

1.3 Waste-fed AD: a case of sustainability transition in the UK

The research addresses AD as a technology used to promote ecological sustainability, achieve sustainable development, and address climate change. Overall, the process of AD involves the decomposition of organic matter, such as animal slurry, food waste and energy crops, in the absence of oxygen to produce biogas and a nutrient-rich digestate, which is often used as an organic fertiliser. This cycle of AD involving inputs, processes and outputs is illustrated in Figure 1.1.

After the process of digestion, organic material is produced in both solid and liquid form. This material is the digestate, which can contribute to the improvement of soil structure for crop production and replace fossil-fuel based nitrogen fertilisers in agriculture (Edwards et al., 2015; National Grid, 2016). The produced biogas is a mixture of gases, consisted of approximately two thirds of methane, one third of carbon dioxide and other gases in trace amounts, such as hydrogen sulphide and ammonia (DfT et al., 2012). It can be either sold as an energy fuel (replacing fossil fuels) or combusted on site to produce renewable heat and/or electricity (Bell et al., 2016; Redman, 2010; DfT et al., 2012). An alternative option for the biogas is to be

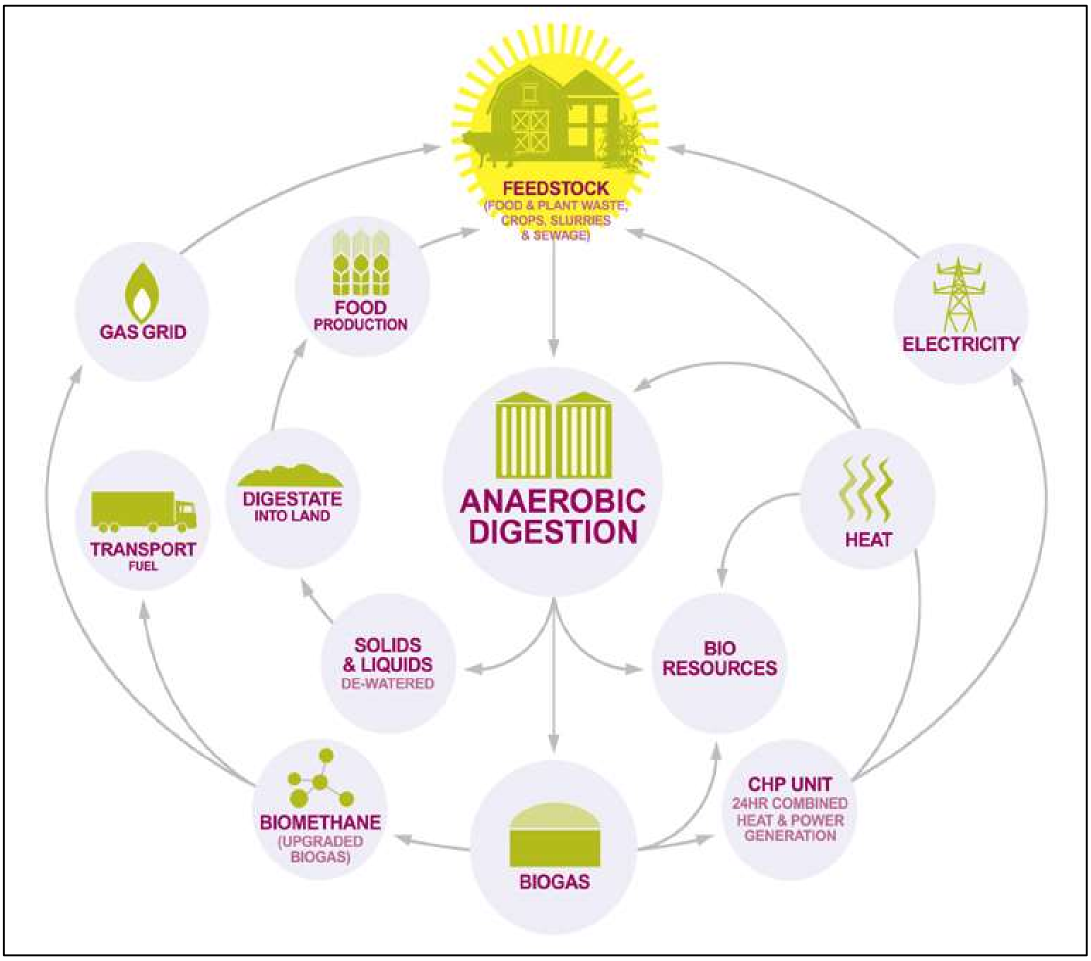

Figure 1.1 The cycle of AD (Source: ADBA, 2020)

upgraded to biomethane by removing the other gases, then it can be injected into the gas distribution network as a replacement for natural gas, or for use as a transport fuel (Lukehurst and Bywater, 2015; DfT et al., 2012; Letcher, 2016). During biogas production and digestate storage, any leakage can lead to harmful emissions of hydrogen sulfide, ammonia, siloxanes, methane, and carbon-dioxide, contributing to the overall GHGs emissions from AD plants (Whiting and Azapagic, 2014; Edwards et al., 2015; Vasco-Correa et al., 2018). The recovery of methane for use in efficient combined heat and power (CHP) units and best practice of digestate application on land are two ways to reduce GHG emissions from AD systems.

The composition and quality of the biogas and digestate depend on the type of feedstock and the efficiency of AD plant (DfT et al., 2012; Redman 2010; Letcher, 2016). There are different types of feedstocks used by AD plants, which have different technological characteristics. The distinction between farm-fed and waste-fed AD plants is based on the amount and type of feedstock they use. Farm-fed AD plants are the installations where more than 50 per cent of the total feedstock comes from agricultural sources, such as manure, slurry, energy crops and crop wastes. Waste-fed AD plants are the installations where more than 50 per cent of the total feedstock used is waste from municipal, commercial, and industrial wastes, such as food waste, green waste, brewery waste and animal processing waste (ISABEL Consortium, 2016). Furthermore, there is the option of on-farm co-digestion of livestock waste with other organic wastes from the local community which is an easy way to manage food waste and recycle nutrients in the farm (Letcher, 2016). Another food waste management option is anaerobic co-digestion with sewage sludge, which is related to water industry operations and is often used to improve digestion efficiency and increase the energy output. Despite the plurality in feedstock options and AD applications, such as wastewater and farm-fed, this research focuses only on the operation of food waste AD plants, because of the dual benefit of renewable energy production and sustainable food waste management. It is also worth-noting that waste-fed AD deployment has attracted limited academic discussion in the field of social sciences, however the technological and biochemical aspects of AD have been the key interest in biochemical and engineering studies.

The inclusion of AD to manage food waste and produce renewable energy is relatively new in an urban setting as the first AD plant treating organic waste in the UK, appeared in 2000 (NNFCC, 2019). The co-existence of waste-fed AD plants with local communities and households in the UK has not been investigated, while taking into consideration the interrelationships with the national and local level of governance. The decade 2010-2020 was critical for the rollout of food waste AD plants which started appearing in more LAs. These also started adopting separate food waste collections, which were directed to the AD facilities. So, in this way we can see a change or transition which brought a new usage of the technology, while engaging the local communities. This socio-technical transition influenced the sustainability strategies of LAs in the UK, along with the important sectorial incentives and policies adopted at the national level. So, the successful deployment of AD brings a social transition embedding the technology and involves actors from the different levels of government, industry, market, and households who coordinate and influence the progress of this sustainability transition. This research investigates the role of the devolved level and its influence on the local level of governance, which adopts this transition with the usage of the waste-fed AD.

The success of AD technology depends on technological, environmental, and economic factors. Technological factors influence the capacity of the waste-fed AD plants, their connection to the electrical grid and the capacity of the network. The use of AD technology can contribute to the creation of a circular economy based on zero waste of resources (Table 1.1). Through waste-fed AD technology, renewable energy and digestate are produced, generating income for AD plant owners, and providing cost-effective nitrogen to farmers, thereby promoting resource efficiency and profitability (Table 1.1). AD brings economic benefits as it can effectively generate income and reduce expenses to AD plant owners (Redman, 2010; Iacovidou, 2012; Gowreesunker and Tassou, 2016; Letcher, 2016; DfT, 2017), but also to the community by helping the wider AD sector to grow and create jobs. Overall, the circular nature of waste-fed AD encourages the synergy, cooperation and sharing of resources among farm businesses, AD plants and waste processing industry.

There are also social and political factors which influence the position and acceptance of AD plants by the public. Waste-fed AD technology offers key social benefits, which can increase its acceptability as the inputs and outputs of AD may not be welcome by the wider community (Table 1.1; Bourdin and Nadou, 2020; Lukehurst and Bywater, 2015). AD also contributes to the UK's renewable energy and carbon reduction targets, supports decentralised electricity and heat provision, aids in achieving waste recycling targets and reduces landfill waste (Letcher, 2016; Röder, 2016; Redman, 2010). The successful use of waste-fed AD prompts discussions on effective policy development, which makes the best use of AD technology for the environment, economy, and society. Unpacking these wider political, economic, and geographical factors, this research aims to investigate how the LAs make the best available use of waste-fed AD for the purposes of energy production and waste management.

Table 1.1 Benefits and Challenges of waste-fed AD in the UK

Benefits	***Challenges***
Environmental	
Renewable Energy production	
Recycling of waste	
Nutrient recycling	Management of digestate
Reduction of water, land & air pollution	
Contribution to more efficient land management	
Reduction of GHGs emissions	Emissions from AD plants
Economic	
Income generation	Access to funding
Reduction of expenses	Cost of AD investment
AD industry expansion	Gate fees
Creation of jobs	Availability of market for biogas and digestate
Social	
Odour reduction	Low understanding and awareness of AD
Production of renewable energy and heat for local use	
Cleaner environment	
Community acceptability	
Political	
Achievement of renewable energy, climate and waste targets	Plethora of state and non-state actors
Decentralisation of electricity and heat provision	Location of AD plants
Addressing the issues of fuel security and land use	Policies and Regulations influencing AD development

Source: Bourdin and Nadou, 2020; Röder, 2016; Gowreesunker and Tassou, 2016; Letcher, 2016; Duruiheoma, 2015; Lukehurst and Bywater, 2015; Iacovidou, 2012; Redman, 2010.

Despite the above benefits of AD, its adoption and deployment face several challenges in the UK (Frith & Gilbert, 2011). Specifically, AD deployment in the UK faces various environmental, economic, social, and political challenges, as presented in Table 1.1. The technology of AD has also faced several challenges and difficulties, which have limited its uptake in the UK (Duruiheoma, 2015), but further exploration of technological challenges is outside the scope of this research. While waste-fed AD offers environmental benefits, it also presents challenges, particularly in managing digestate and GHG emissions (Table 1.1). These two main environmental challenges necessitate careful consideration and the development of best practices, such as covered storage and biofertiliser application, to mitigate environmental impacts and promote wider adoption of AD (Whiting and Azapagic, 2014; Lukehurst and Bywater, 2015; Vasco-Correa et al., 2018). Finance is also a key barrier to AD adoption in the UK, due to the need for funding and market access (Wilkinson, 2011; Duruiheoma, 2015). Whereas incentives mainly supported the investment in large-scale operations of AD, rising costs and feedstock needs still pose risks to viability, and availability of markets for energy and digestate output presents an additional challenge (Duruiheoma, 2015; Hoolohan et al., 2018). The above economic and environmental challenges can be addressed effectively by sufficient understanding and knowledge of its technology, processes, and main by-products (biogas and digestate).

1.4 UK policy development influencing the deployment of waste-fed AD

During the last decade, AD started gaining momentum in the UK policy making as an environmental technology, which can provide a waste management alternative with the production of bioenergy (Voulvoulis, 2015). Generation from AD accounted for 2.7 TWh, which equals to 2.5 per cent on the renewables and 0.8 per cent on total electricity in the UK (BEIS, 2019). In 2020 there were 661 AD sites generating electricity from food waste, agricultural materials, industrial effluents, and sewage in the UK (NNFCC, 2021). Despite the wide use of AD for the stabilisation of sewage sludge, other types of this technology, such as the waste-fed AD and co-digestion of food and farm waste, grew at a slower pace, compared to other European countries (Iacovidou, 2012; Letcher, 2016). In 2018, there were 486 operational AD plants outside of the UK sewage treatment sector (NNFCC, 2019). These were also more farm-fed AD plants (338) than waste-fed AD plants (148) (NNFCC, 2019). Around 40 per cent of them generate capacity which is over 500 kWe (NNFCC, 2019). Almost half of them (215 plants) were completed during 2014-2015, which significantly increased energy generation in the AD sector (NNFCC, 2019; ISABEL Consortium, 2016). Overall, the number of AD plants in the UK seems very small compared to other countries, such as Germany, which is the EU leader in biogas production and has approximately 8000 AD plants (Auer, et al. 2017).

While the number of AD plants is increasing in the UK, feedstock demand (such as food and industrial waste) is also increasing for their operation. Even though demand for feedstock will be increasing in the future, supply of food waste suitable for AD will be unable to meet its demand if accessibility is not improved. Operators of food waste processing plants face the major barrier of feedstock insufficiency, which can threaten the completion of investment and financial viability of their plants (WRAP, 2015). It is a controversy as 17 Mt of organic material are sent to landfill or exported to other countries annually and only 1.8 Mt are currently recycled (WRAP, 2015a). However, if the remaining 17 Mt of organic waste were treated via AD, this can produce 35 TWh of biomethane and 14.5 Mt of digestate, significantly contributing to the UK's energy and waste management (National Grid, 2016). Overall, AD has not yet reached its full potential of operation in the UK, despite the prospects in both the waste and energy sectors. Policy is an influential factor for the deployment of an environmental technology, but it is only one element characterising the landscape of governance. So, it is important to explore the role of governance on the uptake of the waste-fed AD in the UK.

The nature of the technology, the different organisations in decision-making, the multi-layered policymaking and devolved administrations of the UK, the multiple influences stemming from the different policy streams and the particularities of the economic incentives, provided to different groups of the population for different uses and addressing different needs and circumstances – all these create a complex landscape of governance, which affects the deployment of AD. Furthermore, different actors are acting simultaneously in unexpected ways and their interactions and relations are multi-level and multi-phase. The formation of these interrelationships is influenced by the existing (regime) dynamics, niche innovations, power, competition, and politics.

A range of legislation, regulations, policies, and incentives have affected the different stages, types, and projects of AD. The main policy sectors, influencing the uptake of waste-fed AD plants, are climate change, renewable energy, waste, and planning. During the last decade, the introduction of financial incentives and feed-in-tariffs started increasing the number of AD plants and the amount of bioenergy they produce (Whiting and Azapagic, 2014; Vasco-Correa et al., 2018). In the UK renewable energy sector, some influential regulations, and policies, which guided mainly the management of large-scale projects, have also influenced indirectly the development of AD, such as the renewables obligations. There have also been specific regulations and standards to be met for the use of different types of feedstocks and digestion, the quality of digestate and the biogas production (DEFRA, 2011; Voulvoulis, 2015). Furthermore, planning plays a key role in the location of AD facilities and can significantly determine their success as their proximity to their input resources (such as feedstock or organic waste) can create economies of scale and benefit AD plants (Bourdin and Nadou, 2020; Duruiheoma, 2015; Dagnall, 1995).

1.5 The importance of the devolved level: insights from England and Scotland

Apart from the national government, the devolved governments have adopted policies related with the development of AD, while being in coordination with the centre and the EU. In the policy areas of climate change, renewable energy and waste, decision-making expanded from the centre to the peripheries to include multiple levels and actors (Markantoni, 2016), but this also has various impacts at the different levels of the UK Government. One of these impacts can be the different rates of the uptake of certain environmental technologies, such as AD, in the devolved regions of the UK. Policymaking at the devolved level can also be a contributing factor to different deployment rates of AD across Wales, England, Scotland, and Northern Ireland, however it has not been researched. Furthermore, the devolved nations have also formed different relations with the local governments through the years.

The devolved nations have adopted different strategies to manage waste and energy within their own boundaries, while taking into consideration the UK policy objectives. They have the autonomy to take decisions and policies influencing the rollout of waste-fed AD plants at the local level. The development of AD can be characterised by different rates in the four devolved nations, but the reasons for these differences in AD deployment have not been investigated further. Compared to Wales and Northern Ireland, Scotland has a distinct significance in the deployment of AD in the UK. However, Scotland ranks second after England in total numbers of AD plants and has more waste-fed AD plants than Wales (Figure 1.2). Overall, Scotland and England are the two nations of the UK with significant presence of waste-fed AD plants. Furthermore, England has the highest population density and can provide the highest amounts of food waste, which can be used as feedstock for the AD plants. Scotland's population is approximately ten times smaller than England's but concentrated in an area around Glasgow and Edinburgh. Taking into consideration the size of land and population is also important, because then the density of AD plants operating on the ground is higher in Scotland than England. Scotland has achieved a higher rate of waste-fed AD deployment per capita than England.

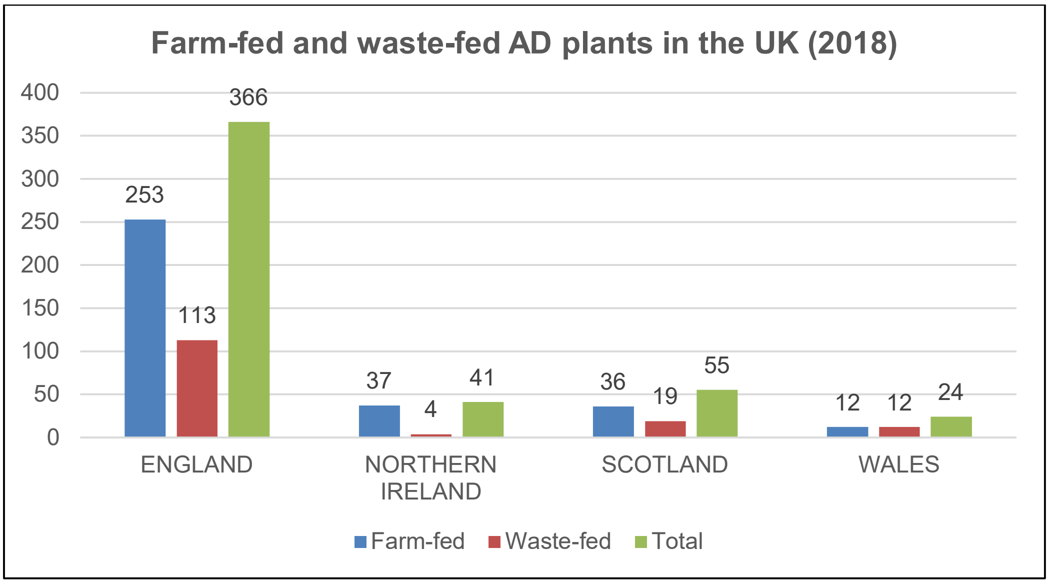

Figure 1.2 Numbers of farm-fed and waste-fed AD plants in the four UK devolved nations (NNFCC, 2019)

Given the fact that there is a potential for difference across the devolved nations in the uptake of waste-fed AD, it is worth exploring both whether differences exist on the ground and, if they do, the reasons behind this variation. Taking into consideration the time and funding restrictions of this research, the focus is on the comparison of the two devolved nations who have the highest uptake of waste-fed AD: Scotland and England. Differences stem from the in-depth analysis of three main factors, influencing AD governance, and these are the following: governance, economic, and geographical factors. The research aims to explore the influence of cross-sectorial stakeholders with different jurisdictions on the successful adoption and usage of waste fed AD plants by certain LAs of the two devolved nations. In this way, actor dynamics will be explored and how they encourage the transition towards the adoption of waste-fed AD by LAs.

1.6 Environmental governance: multi-level, network, and urban climate approaches

There are various theoretical approaches to understand the relationship between governance and sustainability. Environmental governance is associated with the management of resources, decision-making and policymaking, with the aim of achieving sustainability. The dimensions of interaction, coordination and resolution of problems are at the core of environmental governance. Paavola (2008; 2016) defines environmental governance as the resolution of conflicts over resources through the establishment, reaffirmation and change of institutions. According to Stoker (1998, p.18), governance provides an 'organising framework' for the coordination among stakeholders involved in complex and cross-cutting policy challenges and it enables us to understand the change in the processes of governing. Rhodes (1996, p.666) defines governance as the existence of 'self-organising interorganisational networks', with specific refence to explain the changes in the UK Government. Environmental governance involves a diverse set of policy actors, processes of coordination to resolve conflicts and address problems at the different levels of decision-making. Hufty (2011) argues that the goal of environmental governance is to analyse the interactions among stakeholders involved in collective problems (Yi et al., 2019). This research explores the conditions and boundaries within which stakeholder jurisdictions interact.

Identifying the levels of government is the first step to take for the exploration of the impact of these dynamics on the deployment of AD across the different nations of the UK. Environmental governance has multi-level nature, corresponding to the multi-level functionality of environmental phenomena. Multi-level environmental governance has the potential to define and describe the environmental governance in the United Kingdom, where there are vertical (type I) and horizontal (type II) dimensions of governance (Hooghe and Marks, 2003). Type I of multi-level governance focuses on the delegation of governmental functions and power to sub-state units at limited levels. In this type, authority is stable, and the focus is on the structural aspects of non-overlapping governmental arrangements rather than on specific policies. Type II illustrates governance as 'a complex, fluid, patchwork of innumerable, overlapping jurisdictions' (Bache and Flinders, 2004, p.5), where the focus is on the role of 'interest groups' and private actors and their demands for governance change (Bache and Flinders, 2004). However, this typology does not help us to understand the building of power relations and trust within policy networks, and to identify the most influential actors (Smith 2003; Zito 2015; Marquandt 2017; Eckersley 2017; Eckersley, 2018).

This differentiation of the two types of multi-level governance is useful for the comparison of England and Scotland in relation with AD deployment, but it is not sufficient for the in-depth exploration of their differences and the stakeholder interactions. Network governance and policy networks are two inter-related literatures which can provide an additional theoretical element to this exploration as they focus on the existence and governing of networks in policymaking. Network governance refers to the process of public authorities to steer and govern networks in accordance with specific rules and procedures, with the final aim of producing and delivering public services (Sørensen and Torfing, 2009; Molin and Masella, 2016). Rhodes (1996) defines network governance as a web of formal and informal links among governmental and non-governmental actors, all involved in policy design and implementation. Policy network is defined as the representation of the policy-making process in which state agencies, interest groups and representatives of the civil society repeatedly interact to define public policies (Borzel 1998; Klijn and Koppenjan 1995; Marsh and Rhodes 1992; Van Warden 1992; Molin and Masella, 2016). This approach plays an influential role in policy-making as it describes how the relationships between policy-makers (often in more than one level or type of the government) and certain groups (interest groups or non-governmental organisations) can influence and implement policy across various fields (Garnett and Lynch, 2012; Cairney and McGarvey, 2013). Key criticisms on these two literatures focus on the underestimation of the role of the local and national levels of government in steering change in policy.

Reflecting on this criticism of network-related governance, it is important to understand the interactions between the national and local government so to explore how the ‘local level’ engages in the broader national strategies (Lemprière, 2017). However, the role of the local level is also important in this research, which aims to explore the core factors describing the success of English and Scottish LAs in the use of waste-fed AD plants. The literature on urban climate governance highlights the importance and actions of local governments in cross-cutting issues, such as climate change and sustainability (Bulkeley and Betsill, 2013; Heijden, 2019). It also illustrates how the relationships between the central and local government shape the municipal capacity to influence climate governance (Bulkeley and Kern, 2006; Bai, 2007; Holgate, 2007; Romero Lankao, 2007; Schreurs, 2008; Corfee-Morlot et al., 2009; Eckersley, 2017; Eckersley, 2018). Although, the literature on urban climate governance mostly focuses on the formal competences or the degree of autonomy that local authorities can have from a legal perspective, it has not analysed in depth the power dynamics and interconnectedness of actors, influencing the processes of decision-making (Bulkeley 2010, Shey and Belis, 2013; Eckersley, 2018).

1.7 Research Questions and Thesis Structure

In the UK the deployment of AD has been affected by multiple levels of environmental governance; European, national, and local, especially during the last decade. Policymaking at the devolved level can also be a contributing factor to different deployment rates of AD across England, Scotland, Wales, and Northern Ireland, but it has not been researched. The research aims to understand deeply how governance has influenced the deployment of waste-fed AD as a case of sustainability transition in the UK. The national level of government is investigated, with a focus on comparing England to Scotland, as they are the two devolved nations with the majority of waste-fed AD plants in the UK. These two nations also have differences in waste management, AD deployment and energy production, which are worth investigating further in this research. Along with the devolved level, the exploration of the local level will provide evidence from the research focusing on the interface between AD plants and the food waste collections of local communities. The research addresses the following question and sub-questions.

To what extent and why is the deployment of waste-fed AD in England different from Scotland?

A. What is the role of the UK environmental governance on the deployment of waste-fed AD?

B. What is the impact of the devolved and local levels of governance on waste-fed AD in the UK?

C. What are the core factors explaining the success of English and Scottish Local Authorities (LAs) in the use of AD plants for food waste management and renewable energy production?

This thesis addresses these research questions by exploring in depth the governance aspects which influence the adoption and development of waste-fed AD on the ground. This first chapter has introduced key concepts and different perspectives towards low-carbon transitions, while highlighting their weaknesses to explore the governance of sustainable development. It also introduces waste-fed AD as a case of sustainability transition in the UK. The following four chapters (2-5) provide the theoretical foundations to develop a better understanding of the role of governance in supporting the uptake of an environmental technology. Chapters 6 and 7 contain the empirical part of the PhD research. Chapter 2 discusses the literature on sustainability transitions to highlight the question of governance, which is an issue rarely explored in sustainability transitions. Chapter 3 describes the methods used to undertake comparative research with the selection of cases to investigate the interface between waste-fed AD plants and local communities in England and

Scotland. Chapter 4 presents the AD policy landscape by focusing on the different policy streams, key actors, and levels of government, influencing the uptake of AD in the UK. Chapter 5 presents the analytical framework, which draws from the four academic literatures: multi-level governance, network governance, policy networks approach and urban climate governance. Chapter 6 presents the findings of the empirical stage of the research, while exploring the evaluative power of the factors, introduced by the analytical framework in chapter 5. Chapter 7 provides a comparative analysis of the findings, while providing the answers to the research questions and highlighting areas of future research. Finally, chapter 8 is the conclusions chapter of the thesis, which presents the key findings of the study and provides the answers to the research questions.

Chapter 2 Sustainability transitions and the question of governance

2.1 Objectives and Structure of the Chapter

This chapter reviews the literature on sustainability transitions and explores the question of governance. Sustainable development requires social, technological, and institutional transitions. Governance plays an important and challenging role in the achievement of sustainable development, and this has also been acknowledged in the sustainability transitions literature (Loorbach et al., 2017; Frantzeskaki et al., 2012; Loorbach, 2007). In section 2.2 I introduce the concepts of sustainability and sustainable development and present how governance mechanisms and strategies are essential for the three pillars of sustainable development. In section 2.3 I explore the role of governance in the transitions towards sustainability. In sub-section 2.3.1 I present the two key approaches of understanding governance in sustainability transitions, which are related with the scope of this research and are the following: socio-technical and socio-institutional (Loorbach et al., 2017; Patterson et al.2017). These approaches conceptualise transitions in the same way but explore transition governance in different ways. These differences in exploring governance are highlighted in the socio-technical frameworks of the MLP (Geels, 2002), TIS (Markard, 2020; Markard, et al., 2016; Bergek et al., 2008), and the socio-institutional framework of TM (Frantzeskaki et al., 2012; Kemp et al., 2007; Loorbach, 2010; 2007). However, governance mechanisms, dynamics, actors and levels influencing AD deployment in the UK cannot be explored in-depth by these three important frameworks of the transitions literature.

Based on the critical reviews of the literatures, the role of governance is recognised as important, but its exploration remains overlooked (Patterson et al., 2017). Governance recognises the blurred boundaries among the different actors of the state, market, and society (Ehnert et al., 2018; Kooiman, 2003; Stoker, 1998; Rhodes, 1996), while focusing on the creation of the conditions for ordered rule and collective action. Nonetheless, sustainability requires consideration of governance and the literature on sustainability transitions does not explore in depth central-local government relations, which are critical to this research. Although, they recognise the role of policy as an important factor of sustainability transitions, the role of local government in transition governance is undervalued. Consequently, they overlook the role of interactions, competition, and coordination of actors from the society, market, and different levels of government. For this reason, in section 2.4 I present how the literature on sustainability transitions can engage better with governance concerns by taking into consideration seven factors identified in the literatures on urban climate governance, multi-level governance, network governance and policy networks approach. Section 2.4 provides the foundations of the analytical framework, which is illustrated in chapter 5, and section 2.5 summarises the key points of this chapter.

2.2 Sustainable development: its achievement depends on governance

Sustainability is a concept which welcomes a holistic and interdisciplinary approach to secure the existence of humanity in the future. It is closely related to the concept of sustainable development, which is a process of achieving sustainability, through three key dimensions of human activities: economic, social, and ecological (Figure 2.1; Theis and Tomkin, 2015; Brundtland Commission, 1987). Sustainable development is an evolving and continuous process which requires transitions to happen. It is supposed to be an open-ended goal of global efforts in the different sectors of our society. However, embedding sustainable development in our daily life is one of the current challenges of our times. In many societies which strive for sustainable development, wider transitions are essential (Loorbach, 2007) in culture, beliefs, governance, and technology (Kemp et al., 2007). Rapid technological progress can work in favour of sustainable development, while achieving environmental protection, economic prosperity, healthy well-being of population along with social and cultural progress, only if effective governance mechanisms are in place. The latter is a prerequisite for setting the scene for effective stakeholder coordination in all the above-mentioned sectors.

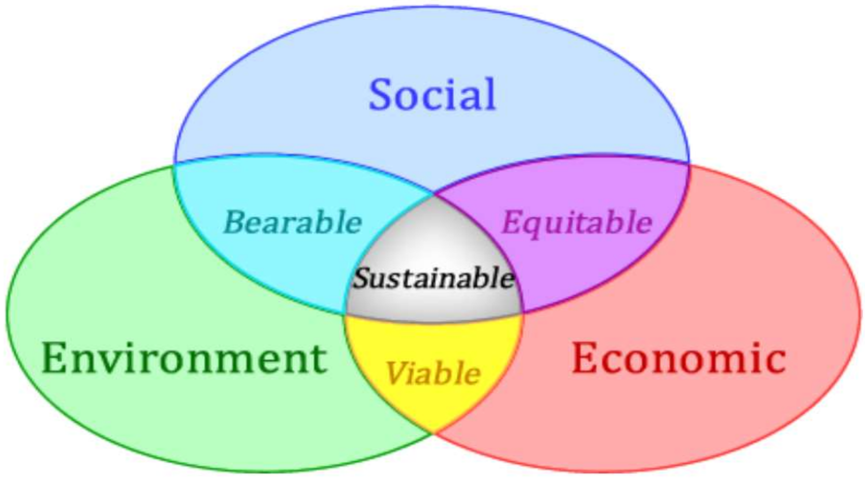

Figure 2.1 Overlapping themes of sustainable development (Source: Theis and Tomkin, 2015)

The relationship between sustainable development and governance has evolved through time. Sustainable development has become a central concern for policy makers and closely related with the growing evidence and concerns of the harmful effects of human activities on our planet. It originated from the environmental movement of the 1960s to 1980s, which raised concerns over the impacts of pollution, resource depletion, population growth and industrialisation on nature (Robinson, 2004). By the mid-1980s, the issue of sustainable development became an important global topic and led to the establishment of the United Nations (UN) World Commission on Environment and Development (WCED), which is also known as Brundtland Commission (Nochta, 2018). The commission, led by former Norwegian Prime Minister Gro Harlem Brundtland, published a report titled 'Our Common Future' in 1987 (Brundtland Commission, 1987). The report linked sustainable development with societal development, economic prosperity, environmental protection, and social cohesion (Frantzeskaki et al., 2012). It also recognised economic growth as both a cause and a potential solution for environmental degradation (Robinson, 2004).

Overall, the report of the Brundtland Commission was the starting point for a continuous and inclusive dialogue on sustainable development among scientists, researchers, and policymakers. The Brundtland Commission made the first systematic attempt to define sustainable development in its report 'Our Common Future' (Brundtland Commission, 1987, p.41) as

> '… development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.

This report also underlined the importance of equity and responsibility, which is both intergenerational (between the current and future generations) and intragenerational (between developed and developing countries) (Frantzeskaki et al. 2012; Holden et al., 2014; Nochta, 2018). However, this simple definition of sustainable development was criticised for being deceptive as it hides complexities and contradictions (Redclift, 2005). Specifically, the terms 'needs' and 'development' are vaguely defined, and many different interpretations have been given for both (Redclift, 2005; Loorbach, 2007). Nonetheless, this definition works as a key point of reference for many governments around the world in their effort to achieve sustainable development.

Sustainable development becomes complex and challenging, when a country tries to embed it in its governance strategies (Loorbach, 2007). The achievement of sustainable development by national governments demands a constant exchange between interests and visions of different actors, involved in various processes. Consequently, each change in these processes brings new complexities to society and governance needs to respond to these changes continuously and effectively. The challenge is to integrate effectively into their national policies the notion of sustainable development as it was introduced by the Brundtland Report (Frantzeskaki et al. 2012). Loorbach (2007, p.24) underlines the importance of governance in the achievement of sustainable development, which needs

> ‘a continuous governance process that enables representation of various perspectives, values and interests and creates space for experimentation, innovation and learning’.

Different countries have adopted different governance mechanisms and strategies (such as their own sustainability councils and indicators) to address the challenges of sustainable development (Loorbach, 2007). Sustainable development is presented as the intersection of economic, social, and environmental pillars (Figure 2.1; Loorbach, 2007; Theis and Tomkin, 2015). The existence of the three pillars eased the way of adopting the UN Millennium Development Goals along with their specified targets. The pillars, goals and targets of the sustainable development aimed for a huge multi-level improvement of the whole planet.

Sustainable Development is characterised by four basic principles: intergenerational nature, importance of scale, integration, and plurality of interests (Frantzeskaki et al., 2012). They indicate how the governance needs to respond to embed sustainable development in our daily lives. The first principle defines sustainable development as a process with a long-term duration, which inevitably involves more than one generation and is mindful of the next generations. The intergenerational nature of sustainable development was also reflected in the report ‘Our Common Future’. The second characteristic recognises the importance of scale, because sustainable development occurs at different levels and involves multi-level processes (Loorbach, 2007; Frantzeskaki et al., 2012). However, the activity of local or regional levels may or not necessarily contribute to national or global sustainability as there are a plethora of other factors which can enable or disable this dynamic bottom-up influence on sustainable development. The third characteristic refers to its integrative nature since different sectors, such as environmental, economic, and social have to be considered in sustainability (Frantzeskaki et al., 2012). Last, the involvement of different sectors leads to the existence and participation of multiple actors with different interests, which need to be considered in decision-making processes, addressing sustainable development at all levels (Loorbach, 2007;

Frantzeskaki et al., 2012). The interactions and cooperation of actors are vital aspects for the achievement of sustainable development and need to be analysed in depth, along with the governance which eventually influences these interactions.

To sum up, sustainable development is a 'complex, multi-level, multi-actor, and long-term process' (Meadowcroft, 1997; Loorbach, 2007; Frantzeskaki et al., 2012). This is a continuous and open-ended process, with an open agenda for action which co-evolves through time (Kemp et al., 2007) and is redefined by every generation (Meadowcroft, 1997). It also leads to sustainability, which is a multidimensional and intergenerational phenomenon, subject to ongoing discussions and debates (Markard et al., 2012; Loorbach, 2007). However, sustainability is not pre-defined (Loorbach, 2007). Both sustainability and sustainable development have become vague terms because different institutions use these terms in various ways. Exploring the governance mechanisms and strategies tied to the pillars of sustainable development holds greater significance than offering diverse definitions of sustainability and sustainable development.

2.3 Transitions towards sustainability: the role of governance

Transitions research emphasises the necessity of tackling major sustainability challenges with the aim of informing 'governance and policy for sustainability transitions' (Loorbach et al., 2017, p.601). It approaches sustainable development as an open-ended, long-term, and complex process of changes, rather than a definitive and stable process (Kemp et al., 2007). Transitions research conceptualises transitions as a model of changes and equilibrium phases, which has its origins from innovation studies, evolutionary biology (Rotmans et al., 2001; Geels, 2002) and complex system approaches (Fischer and Newig, 2016). The main assumption is that societal systems go through periods of radical change, which are followed by long periods of relative stabilisation (Rotmans et al., 2001; Frantzeskaki et al., 2012). However, one of the factors contributing to this change is governance. Transitions research approaches governance as a collaborative process where systemic solutions, disruptive innovations, and reflexive institutions are shaped through experimentation and learning (Loorbach et al., 2017). This section provides an introduction to the transitions literature, while exploring key aspects of the socio-technical and socio-institutional approaches towards governance in the sustainability transitions literature. Nonetheless, governance arrangements and relationships between different government levels are not explored in this literature.

One key aspect of sustainability transitions is that governance often plays an important role (Smith et al., 2005; Markard et al. 2012). Sustainability transitions may accelerate differently in various policy contexts. Sustainability is a long-term goal, which sets the direction and purpose of the transition, and requires decisive actions from a range of state and non-state stakeholders. In a purposeful transition, political actors along with institutions and regulations can play a key role (Markard et al. 2012). Governance has the power to influence the uptake of a certain technology or the wider use of an innovation, however a question which is not explored in depth is how governance shapes sustainability transitions. Loorbach et al. (2017, p.612) refer to transition governance as a 'multi-actor process in which systemic solutions, disruptive innovations, and (reflexive) institutions are formed by experimenting and learning'. However, there are different viewpoints on the role of actors in transition governance as there may be a high-level and multi-actor or a single-actor approach who leads the Transitions Management (TM) within a multi-actor setting (Van Raak, 2016). In this governance approach, 'a sustainable process and a sustainable outcome of the governance' are both equally essential for pursuing sustainability (Frantzeskaki, et al. 2012, p.34). In other words, there is need for a more open and inclusive mode of governance, which is more flexible than the top-down governance model (Frantzeskaki, et al. 2012).

Although the role of governance is widely recognised, sustainability transitions research is not closely connected to the core principles of sustainability governance (Mourato and Wit, 2022). Recent studies in sustainability transitions refer to the processes of transition governance (Loorbach et al., 2017), however they do not delve into the intricacies of public policy, regulations, decision-making processes, coordination (Mourato and Wit, 2022). Furthermore, these studies lack a comprehensive exploration of the evolution and multi-level dynamics of these aspects. While sustainability transitions research adopts a co-evolutionary perspective to conceptualise transitions (Geels, 2012), it does not specifically refer to Evolutionary Governance Theory (EGT), which is an approach of studying how different aspects of governance are subject to change and influence each other over time (Mourato and Wit, 2022; Van Assche et al. 2014). Specifically, EGT is an emerging field in sustainability governance which provides an evolutionary perspective on the way institutions, markets, and societies evolve (Mourato and Wit, 2022; Van Assche et al. 2014). Although there are few studies on the importance of evolutionary governance for the development of multi-level perspective in transitions (Markantoni, 2016), the sustainability transitions research does not consider these valuable insights for examining consistently the role of governance. Furthermore, Loorbach et al. (2017) recognise that transition governance can develop further the potential of networks which facilitate the ways actors organise themselves to produce solutions to environmental and societal problems, drawing on insights from the literature on meta-governance, network governance and multi-level governance.

Transitions are multi-dimensional and entail different shifts to change the dynamics of system from one state of equilibrium to another. They need time to gradually accelerate and finally achieve equilibrium which is characterised by inertia and stability (Rotmans et al., 2001). Transition involves non-linear and multi-phase processes, which take place at a different speed and level. They may have a range of development paths as they can be bottom-up or randomly emerging successfully or unsuccessfully. Transitions differ in the scale of transformation, the period when they occur and their processes (Rotmans et al., 2001). The process of transition can be conceptualised as an S-shaped curve with four phases, which form a model originating from evolutionary biology and demographic dynamics (see Figure 2.2; Rotmans et al., 2001; Loorbach, 2007). This is the multi-phase concept which describes the four phases of transitions. The first phase is the pre-development, when the experimentation of innovative ideas take place and the change is being initiated (Rotmans et al., 2001). The second phase is the take-off stage when the innovation or shift starts building up and the system begins to change. The third phase is the acceleration or breakthrough phase, when fundamental, structural changes take place along with collective learning, diffusion and embedding processes (Rotmans et al., 2001; Figure 2.2). The last phase is the stabilisation of the system, which reaches a new equilibrium after embracing all these new arrangements.

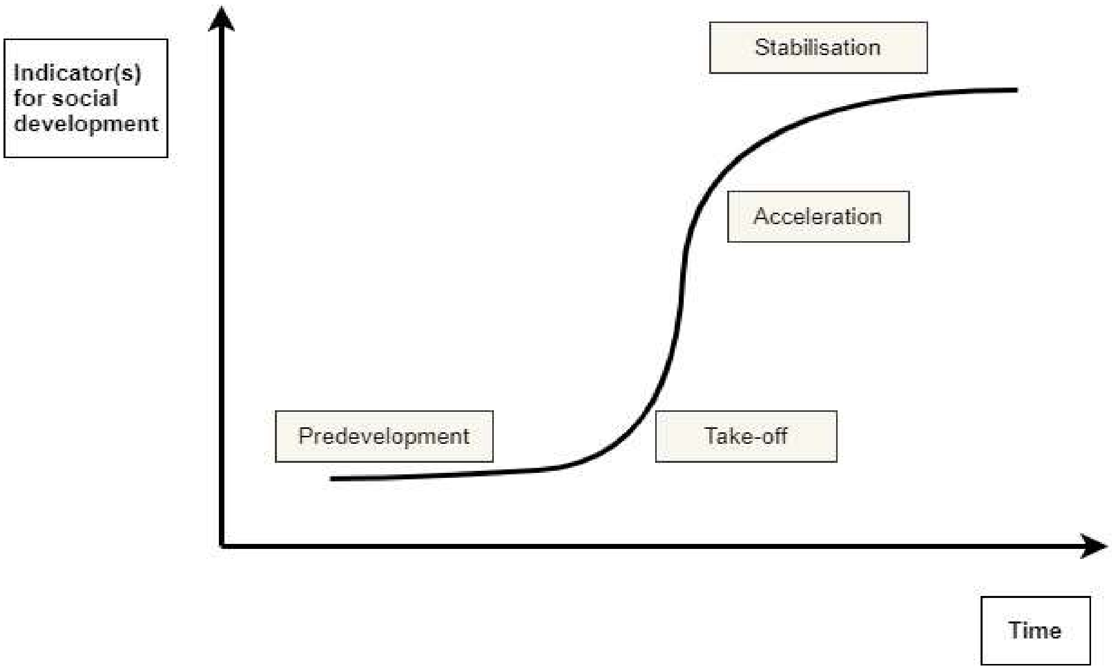

Figure 2.2 Phases of transitions (adapted from Rotmans et al., 2001)

Transitions bring gradual and continuous changes in 'technological, material, organisational, institutional, political, economic, and socio-cultural' dimensions (Markard, 2012, p.956), which shape our society. Agency refers to the role of actors, such as individuals, communities, social movements, or firms who can influence the speed and trajectory of transitions. Geels (2020) recognises that there are different dimensions of agency and transitions, which originate from the differences in ontologies towards social problems. Furthermore, different stakeholders respond differently to transitions – they can be as resistant to transitions as they are proactive in promoting and governing them. In the transitions research, scientists can also play an important role for these changes to happen, so there is a normative, social dimension which needs to be recognised as it brings specific standards, values, or ideals guiding these processes (Scholz, 2017). The direction, scale and speed of transitions can also be influenced by policy, but cannot be completely controlled (Rotmans et al., 2001). In this study, chapters 5 and 6 highlight the significance of coordination as a governance factor. This coordination encompasses cooperation, conflict, and competition among diverse institutions with different goals and interests in the uptake of waste-fed AD, which is the sustainability transition examined in this research.

Transitions research is an evolving, diverse, and expanding field as it started with exploring the nature of technological transitions and has also expanded to contribute to the societal challenge of sustainable development. The strength of the transitions research lies in its ability to accommodate diverse views on the role and approach of research on transitions, while also facilitating debates across disciplines through the common language and concepts of transitions (Loorbach et al., 2017). The literature on technological transitions approaches the shifts of technological regime emerging from niches, through a process of competition, which involves variation and selection (Kemp, 1994; 1998; in Loorbach, 2007). The term 'technological transition' (Kemp, 1994 in Loorbach, 2007) refers to the structural change of a specific technological system. This change results from innovations which emerge in niches and compete with the dominant system dynamics, such as variation and selection (Loorbach, 2007). Technological transitions are technological changes which transform societal functions, such as production, housing, communication and transport, and societal elements, such as regulations, infrastructure, industry, and user practices (Van den Ende and Kemp, 1999 in Geels, 2002). An example is the transition from punched card technology and small office technology to digital computers (Van den Ende and Kemp, 1999 in Geels, 2002). However, governance in transitions literature is approached as a high-level management of transitions because it focuses on actors and dynamics and their influence on collective agency to shape a regime change (Loorbach et al. 2017; Van Raak, 2016).

The field of sustainability transitions emerged within transitions research and has rapidly developed over the past twenty years. This field has become a unique research area and focuses on the nonlinear dynamics of societal change with the aim of addressing major societal challenges, related to sustainable development (Loorbach et al., 2017). It has introduced a range of novel concepts and tools that bolster interdisciplinary research and are beneficial to innovation practices and policy-making. The insights gained from sustainability transitions have significantly influenced policy-making and societal understanding of complex, enduring issues. There is a clear link between innovations and sustainability as this field aims to understand how environmental innovations accelerate and how they can change existing systems (Geels, 2011; Frantzeskaki et al., 2012). Transition concepts are also used to assess innovation policies and facilitate transformative networks and experiments (Loorbach et al., 2017). Sustainability transitions are defined as enduring, multi-faceted and radical changes towards more sustainable patterns of production and consumption, which are adopted through innovative and environmentally friendly technological developments (Markard et al., 2012). The pathway to sustainability also faces challenges, such as strong path dependencies and lock-ins (Unruh, 2000; 2002; Markard, 2012; Nochta, 2018), which may influence the transition process.

Sustainability transitions possess three key characteristics which make them unique (Geels, 2011), however these unique traits are not employed in evaluating the effectiveness of such transitions. Firstly, they have the specific goal of sustainability (Smith et al., 2005), which is a ‘collective good’ (Geels, 2011). However, state, and non-state actors (such as enterprises, industries, policymakers, politicians, users, civil society, engineers, and researchers) have different incentives, interests, and behaviours towards these transitions. Secondly, sustainable products and services may often have a lower and more expensive performance compared to other widely used technologies (Geels, 2011). Thirdly, sustainability transitions are mainly observed in the sectors of transport, energy provision, agri-food production, and consumption (Geels, 2011; Markard et al., 2012; Bilali, 2019). In these sectors, major corporations have significant influence, but they would rarely lead a sustainability transition, which can jeopardise their economic interests. However, given their substantial power, resources, and assets, they can easily influence and support the breakthrough of environmental innovations (Geels, 2011). Further, the reaction and response of the market are not further investigated when new innovations and sustainable modes of production appear. Overall, sustainability transitions will need changes in policies, which include politics and power struggles, because existing interests may try to reverse these changes (Geels, 2011). For this reason, coordination, relations between national and local governments and the role of market need to be further explored in the governance of sustainability transitions, along with learning, experimentation, and policy.

The question of large-scale societal changes in sustainability is approached in various ways: 'technological, institutional, social, ecological, economic, or cultural' (Loorbach et al., 2017, p.609). These different approaches of understanding sustainability transitions led to the development of the socio-technical, socio-institutional, and socio-ecological perspectives on sustainability transitions (Loorbach et al., 2017; Patterson et al. 2017;). The variety of viewpoints for understanding and exploring transitions is surpassed by an even broader range of strategies for their governance (Loorbach et al., 2017; Patterson et al., 2017). These perspectives share similarities in conceptualising these transitions as multi-level, multi-actor, non-linear processes in which experimentation and learning play a key role (Loorbach et al., 2017; Patterson et al., 2017). Because they originate from different disciplines, so they use different methods to explore the transition governance in sustainability. The socio-technical approach provides an evaluative stance with the use of frameworks (MLP and TIS), in which the role of technology is significant along with the influence on the agency to direct these transitions towards sustainability. The socio-institutional approach adopts a more reflexive stance to transition governance as it also recognises the influence of technology, but it values more the role of agency, institutions, structures, learning, practices, and discourses. The socio-ecological approach emphasises the role of the agency and adaptive governance in the complex, human-ecosystem interactions, and their impact on the ecosystem resilience (Loorbach et al., 2017; Osterblom et al., 2010). It is only referred here along with the other frameworks to illustrate the breadth of tools and approaches of governance in the sustainability transitions, but it is not further explored as this research does not explore any human-ecosystem impacts of waste-fed AD.

2.3.1 Socio-technical and socio-institutional approaches in sustainability transitions

The purpose of this research is to explore and evaluate the impact of environmental governance on the uptake of waste-fed AD. Therefore, it focuses on the evaluative approach to governance in sustainability transitions. Evaluation is used in the transitions research to explore the influence of factors on a specific phenomenon or problem and provide insights on how intentional actions interact with the societal systems in transitions. Both MLP and TIS provide a socio-technical approach to evaluate governance (Loorbach et al., 2017). TM provides a socio-institutional framework which has a set of tools and strategies to provide an experimental exploration of transition governance, including transition arenas, transition scenarios, transition experiments and transition monitoring (Loorbach et al., 2017). Although these approaches recognise the crucial role of governance, this is an area which is arguably underdeveloped, especially considering its importance in understanding and analysing sustainability transitions (Patterson et al., 2017). The question of governance needs to be positioned at the core of research on sustainability transitions (Loorbach et al., 2017; Patterson et al., 2017; Smith and Stirling, 2010; Smith et al., 2005).

In the socio-technical approach, human activities are interpreted as socio-technical systems, composed of both social and technological elements (Geels, 2004; 2010; Loorbach et al., 2017) which co-exist, interact, co-evolve and influence changes to society and technology (Kemp, 2010). Examples of socio-technical systems are evident in different sectors, such as energy and water supply, transportation (Loorbach et al., 2017). These systems consist of stakeholder networks (such as groups of individuals, households, enterprises, organisations), institutions (policies, regulations, standards, technical and social norms), artefacts (resources and material elements) and knowledge (Geels, 2004; Markard et al. 2012). While technological transitions focus primarily on technology-driven changes, socio-technical transitions consider the broader context of social, economic, and institutional factors which shape how technology is adopted and integrated into society (Geels, 2004; Geels and Schot, 2010; Kemp, 1994; Markard, 2012). Because of socio-technical transitions, societal sectors (such as production, housing, employment, planning, and policymaking) are radically influenced (Markard, 2012).

There are two major analytical frameworks, which have a socio-technical approach, and these are the following: the MLP and the TIS framework (Loorbach et al., 2017). The MLP is a descriptive, middle-range framework[1], which is used for analysing overall dynamic patterns in socio-technical transitions to sustainability (Geels, 2011). Although, the MLP does not address the question of governance directly, it recognises policy, market, user preferences, knowledge, industry, science, and culture as factors contributing to sustainability transitions. The MLP analyses the emergence of environmental innovations as system innovations and explains how

[1] The MLP was introduced by Geels (2002; 2004) and it is built on previous research focusing on technological systems, conducted by Kemp (1994), Rip and Kemp (1998) and Rotmans et al. (2001). Furthermore, the concepts of the multilevel model originate from evolutionary economics, innovation and technology studies and neo-institutional theory (Geels 2002; 2004; 2005a,b; 2006; 2011).

these can replace or change the existing socio-technical system towards sustainability (Geels, 2011; Nochta, 2018; Figure 2.3). The MLP is used in studies of historical, present, and future transitions to sustainability, which explain the development of environmental innovations influencing the regime (Geels, 2011). Another socio-technical framework, which is also used for the evaluation of governance in sustainability transitions, is TIS (Loorbach et al., 2017). TIS focuses on innovation policy and approaches innovation as a system in which technologies coevolve with an emerging market, user preferences and governance (Jørgensen, 2012; Bergek et al., 2008; Hekkert et al., 2007). These mechanisms are often referred to as the '*motors*' of innovation (Suurs, 2009), and they are factors influencing the degree to which a novel technology can expand and conquer an established market (Loorbach et al., 2017). TIS is applied in novel technologies, which are associated with industries of clean-tech sectors (Bergek et al., 2015), such as wind, biofuels, and photovoltaic energies (e.g. Bergek et al., 2008c; Bergek and Jacobsson, 2003; Jacobsson and Bergek, 2004; Negro et al., 2007; Negro and Hekkert, 2009).

In socio-technical systems, the establishment of a new equilibrium leads to a stable and established pathway of development, which is the 'regime' (Loorbach, 2007). The 'socio-technical regime' refers to

> 'the dominant culture, structure and practice embodied by physical and immaterial infrastructures (for example roads, power grids, but also routines, actor-networks, power relationships, regulations)' (Loorbach, 2007, p.20).

The socio-technical regime influences the processes of decision-making and behaviour of stakeholders. In the MLP, the regime is of primary importance because it is the 'meso' level influenced by the developments at the 'micro' level (niches) and 'macro' level (landscape) (Geels, 2002; 2004; 2010; 2011; Smith et al., 2010; Figure 2.3). It is dynamically stable because it evolves incrementally and resists to innovative shifts, which intend to restructure the established socio-technical system

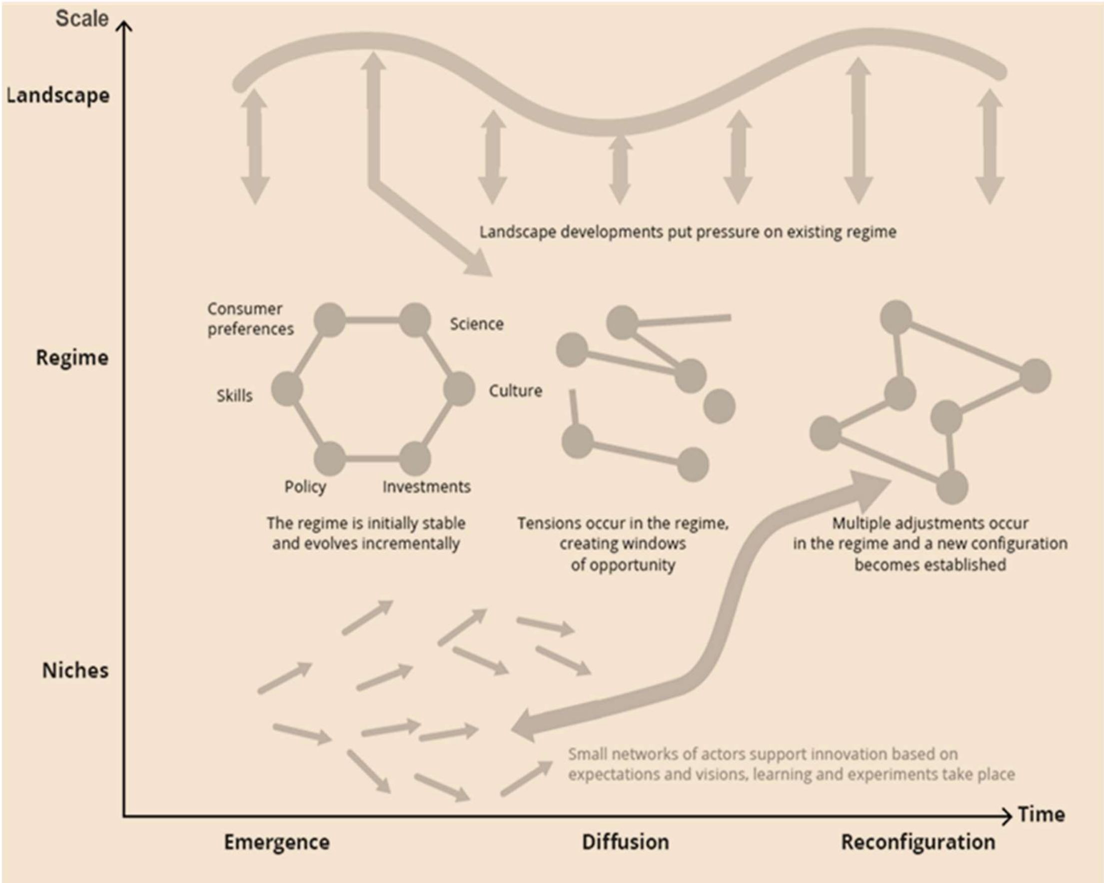

Figure 2.3 The multi-level perspective (niches -regime -landscape) *(based on Geels, 2006)*

(Loorbach, 2007; Geels, 2011). Each level has its own, unique arrangement of elements (Geels, 2011). Niches serve as protected spaces, which allow actors (such as entrepreneurs, start-ups, and spinoffs) to create novel technologies and radical innovations, which can be driven by either market forces or government initiatives. The landscape includes technological advancements, demographical trends, political ideologies, social values, macro-economic developments (Geels, 2002; 2004; 2011) and even exogenous shocks, such as oil shocks or a pandemic. However, the specific level at which the governance structures are situated, and their exact content remain unclear. Furthermore, the reason local policy is often associated with the regime while national policy is considered part of the landscape is not clearly defined (Bilali, 2019). In the MLP framework, transition is the result of interactions and processes across these three levels (Geels, 2010; Kern, 2012). The innovations build their pathways towards the regime and may diverge from existing regimes, while transformations at the landscape create pressures on the regime. Pressures may lead to tensions and eventually to destabilisation of the regime, which creates windows of opportunity for innovations to change or replace the existing regime and lead to 'regime shifts' (Nochta, 2018). Nonetheless, successful niche development requires communication of expectations, the creation of large-scale social networks, and learning processes across multiple dimensions (Schot and Geels, 2008; Geels, 2011).

Although the MLP recognises the role of governance in the existence and participation of many different stakeholders, who tend to stabilise, change, or replace the existing socio-technical regime, its role is not explored in depth. Actors interact with others and socio-technical systems, while being embedded and influenced by regulatory structures, institutions, culture, and social networks (Geels, 2020; Geels and Schot, 2007). The specific characteristics of the governance situation influence the processes of an environmental innovation (Smith et al., 2005), but the MLP does not demonstrate how interactions take place and influence both the existing governance mechanisms and the progress of sustainability transitions (Smith and Stirling, 2010). The formulation and implementation of public policy requires multiple state and non-state actors from different sectors, levels, and sub-regimes to participate in socio-technical transitions towards sustainability. There is need to explore cooperation across a range of different stakeholders and levels of government, while defining their specific responsibilities and influence on the success of a sustainability transition. In this socio-technical approach, it is essential to explore the role of the 'context', where regime shifts take place, by unpacking three key factors: governance, economic and geographical. Geels (2011; 2020) acknowledges that the MLP has under-developed topics and can benefit from addressing criticisms. Some scholars, including Markard et al. (2016) and Geels (2014a), have begun exploring these issues within the MLP framework. Geels (2014a) specifically investigates politics and power within the context of the UK electricity system, emphasising the importance of exploring the destabilisation and decline of existing regimes for future research.

TIS is a socio-technical framework used to evaluate governance in sustainability transitions. It is a widely used approach to analyse the development and diffusion of new technologies which can contribute to sustainability transitions and create new industries (Bergek et al., 2008; Hekkert and Negro, 2009; Markard et al., 2016; Markard, 2020). It provides an understanding of innovation as a systemic process in which technologies coevolve with an emerging market structure, a governance structure and user preferences (Loorbach et al., 2017). TIS framework is used to evaluate the performance of specific technological innovation systems with the aims of identifying obstacles or problems into policy interventions and strategies and addressing them by making national policy recommendations (Hekkert et al., 2007; Bergek et al., 2008; Suurs, 2009; Alkemade et al., 2011; Loorbach et al., 2017; Markard, 2020). TIS contributed to the adoption of concepts, such as systemic instruments and policy mixes (Alkemade et al., 2011; Jacobsson and Karltorp, 2013; Smits et al., 2010; Weber and Rohracher, 2012; Wieczorek and Hekkert, 2012).

TIS framework conceptualises the transition process as a build up process of different technological innovation systems (Hekkert et al., 2007; Alkemade et al. 2011). It aims to comprehend the mechanisms which facilitate technological advancements, without necessarily considering the regime context of existing systems as is the case in MLP. A TIS consists of a network of actors, institutions, and artifacts which interact to create, produce, and use a specific technology (Markard, 2020). There is a plethora of actors who are involved in a TIS and these are the following: technology manufacturers, suppliers, retailers, academics, government and non-governmental organisations and private sector (Markard, 2020). Institutions comprise of formal and informal structures. Examples of formal structures are regulations, technology standards or public policies and examples of informal structures are collective expectations, cognitive frames, user practices, social norms, or culture. Networks have an influential role as they bring together different types of organisations and actors for knowledge exchange, formal alliances, and advocacy coalitions (Markard, 2020).

Market formation, learning and knowledge, entrepreneurial experimentation are key performance indicators of a TIS which aims to provide policy recommendations to overcome any failures and obstacles. The other performance indicators are: guidance of the search, legitimation, resource mobilisation and development of positive externalities (Markard, 2020, Bergek et al., 2008; Hekkert and Negro (2009; Hekkert et al., 2007; Jacobsson and Bergek, 2011; Johnson, 2001). Hekkert and Negro (2009) applied the TIS framework to analyse the use of biofuels in the Netherlands, identified key system failures hindering biofuel development (such as lack of coordination, uncertainty, and institutional inertia), and offered policy suggestions to address these issues. Akin to the MLP, the TIS framework recognises the importance of policy as a key factor for the uptake of innovations, which lead to regime shifts (Loorbach et al., 2017; Alkemede et al., 2011). The evaluative approach of TIS framework aims to inform policy processes by providing a broader transition perspective. It focuses on incumbent and competing policies in various domains and raises critical questions about the focus of innovation, such as why policies often lack attention to upscaling or institutionalisation. This type of evaluative approaches also creates the space for more experimental governance processes (Loorbach et al., 2017). However, a criticism of the TIS framework is that it focuses on policy development and strategy at the national level of government, without considering the interrelations between the national and local levels of government.

The socio-institutional approach[2] takes a normative and reflexive stance towards governance in sustainability transitions, compared to the more analytical and descriptive frameworks of the socio-technical approach (such as MLP and TIS). In this approach, the role of technology is important for understanding transitions, but the

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[2] The socio-institutional approach is a term rooted in social sciences, including economics, political science, sociology, governance studies, and geography and is applied to complex societal systems, which face environmental challenges (Loorbach et al., 2017).

focus is on how power, interests, structures, behaviours, institutions, and regulations lead to the creation of path dependencies, and how these are influenced by social innovations (Loorbach et al., 2017; Van Raak, 2016). Social learning, culture and daily practices are also recognised as influential factors on the dynamics of transitions (Loorbach et al., 2017; Van Raak, 2016; Beers et al, 2010). The socio-institutional approach critically explores the role of power, politics, agency and institutional dynamics, and their influence on inertia and lock-in in the different stages of transitions (Fuenfschilling and Truffer, 2014; Hoffman, 2013, Meadowcroft 2009; 1997; Voß, et al., 2009). There are studies, which adopt this approach, perceive systemic changes as political or socio-political (Loorbach et al., 2017), such as the democratic tensions in the management of transitions (Jhagroe and Loorbach, 2015) and the role of local and community - based energy initiatives management (Arentsen and Bellekom, 2014). The socio-institutional perspective is applied to societal systems in environmental related sectors, such as mobility, waste management, and energy (Loorbach et al., 2017; Arentsen and Bellekom, 2014; Kern and Howlett, 2009), but it is also adopted in non-environmental sectors, including health care (Van Raak, 2016), education, finance, and democracy (Loorbach et al., 2017; Jhagroe and Loorbach, 2015). Moreover, most studies which adopt this approach focus on specific geographical locations, such as the Netherlands, Belgium, or central Europe (Loorbach, 2010; Loorbach et al., 2017). A key prescriptive framework which adopts a socio-institutional approach to governance is the TM.

TM provides an experimental exploration of transition governance, while focusing on system innovation and socio-technical coevolution (Jhagroe and Loorbach, 2015; Voß et al. 2009; Kern and Howlett, 2009). It addresses transitions as multi-level and multi-phase changes in social systems (Loorbach, 2010). TM is also characterised as an innovative governance model which aims to address the policy challenges of regime transformations (Loorbach and Rotmans, 2010; Loorbach, 2007; Kemp et al. 2007) and influence specific dynamics in transitions (Loorbach et al., 2017). TM framework describes three levels of influence on social systems: a strategic level of beliefs, ideas and opinions expressed by people, a tactical level of rules, infrastructure and regulations expressed by representatives of key organisations and an operational level of practices, innovations, and activities, led by entrepreneurs or small businesses (Loorbach, 2007). TM aims to support the creation of informal networks, coordinate innovative policies, and protect niche alternatives, which may lead eventually to regime changes (Smith et al. 2005; Loorbach, 2010). It brings processes of co-evolution, transition experiments, learning, reflexivity and adaptation into a multi-phase and multi-level form of governance.

As a governance model, TM provides a set of transition-based governance instruments, such as transition areas, transition scenarios, transition experiments and transition monitoring (Loorbach et al., 2017). TM has been applied to various case studies of managing sustainability transitions and started gaining prominence because of its scientific basis and practical advancement in the governance of sustainability transitions (Loorbach et al., 2017). Examples of the TM application on how individuals and transitions areas managed the direction of transitions exist in the sectors of urban water management (de Haan et al., 2015; Bos et al., 2012) and waste management (Parto et al. 2007). TM framework addresses the different sectors as complex, adaptive social systems (Nill and Kemp, 2009; Voß et al., 2009; Markard et al., 2012). Conceptually, TM combines governance with technological transitions and complex systems theory (Markard et al., 2012).

In the TM framework, regime transformations come internally within the societal system because pioneering individuals form networks which drive and promote changes through environmental innovations in their daily lives (Loorbach, 2007). However, there are two key elements of this framework, which attract criticism and require further development. Firstly, the importance of politics, power and actor competition is devalued in the interactions and cooperation of actors in the transition arenas (Nochta, 2018). This may underplay the effects of politics and power on transitions as there are different processes of collaboration in transition arenas, where conflict and competition among different stakeholders of different levels may be unavoidable (Kuzemko, 2013). Secondly, the empirical research of TM mainly explores transitions at the national level of government, which is taken to be the main scale of governance essential for transitions to happen (Bridge et al., 2013; Markard et al., 2012; Truffer et al., 2015; Truffer and Coenen, 2012; Nochta, 2018). Despite the reference to steering in governance processes, the importance of other levels of governance, such as the regional and local level, is not equally recognised for regime changes. There is a need to develop an understanding of the local conditions which are essential for a successful transition management (Heiskanen et al., 2009; Kuzemko, 2013; Nagorny-Koring and Nochta, 2018 in Nochta, 2018).

2.4 Exploring environmental governance

The role of governance is recognised in the sustainability transitions literature, but this literature is not closely related with the environmental governance or governance of sustainable development (Mourato and Wit, 2022; Loorbach et al., 2017). In sustainability transitions, governance processes take place in a fluid and adaptive way and aim to support and lead the transformations of the regime, while involving networks of multiple agents (as seen in the MLP, TIS and TM). Environmental governance is the way environmental issues are managed by various actors and institutions, with the goal of sustainability. It involves resolving conflicts over resources, coordinating stakeholders, and adapting to changing circumstances. However, there is no single or universally accepted definition of environmental governance. So, in this section I explore how environmental governance is defined in the literatures on multi-level governance, urban climate governance, network governance and policy networks approach. The purpose for this exploration is to identify the key factors and dynamics of the national and local level which shape the linkages between sustainability and governance. This section presents how these governance literatures can enhance further the literature on sustainability transitions by considering the following seven factors: coordination, learning and knowledge, autonomy, local experimentation, internal capacity, market, and urban/rural typology. Specifically, these factors are used in chapters 6 and 7 to explain the differences in the governance of waste-fed AD which lead to the different deployment rates in England and Scotland.

Environmental decision-making involves trade-offs and tensions at different scales across space or time and vertically or horizontally (Kurian and Ardakanian, 2015; Howarth and Monasterolo, 2016; Cairns et al, 2017). Environmental governance refers to institutions, policies, regulations, incentives, and organisations, which form a diverse set of stakeholders, processes of coordination to resolve conflicts and address problems at the different levels of decision-making. Policies influencing resource allocation need to consider the interconnectedness of risks and challenges, while recognising competition of resource use, opportunities, synergies, and common goals (Kurian and Ardakanian, 2015; Howarth and Monasterolo, 2016; Cairns et al, 2017). Policymakers are in cooperation with state, private and voluntary organisations to increase the capacity and impact of their decisions and acts (Eckersley, 2018), but conflicts and competition may not be always avoided between different sectors. Consequently, this may influence the power relationships between different actors and their potential to develop policies (Peters and Pierre 2001 in Eckersley, 2018). Decisions on environmental issues are not only taken based on scientific evidence, but they also express political significance, take into consideration the wider policy context and geographical aspects, while having an impact on environment, economy, and society.

Environmental governance is a multi-level process that reflects the multi-level nature of environmental issues. Multi-level governance recognises two types of environmental governance: type I, which is based on vertical and hierarchical structures, and type II, which is based on flexible and horizontal arrangements (Hooghe and Marks, 2003; Bache and Flinders, 2004). Paavola (2016; 2008) refers to multi-level environmental governance which examines the interactions and coordination of actors and institutions working together to address environmental issues. The key characteristic of this literature is that these actors and institutions belong at different spatial scales, from the local to the global as environmental problems can expand at various geographical scales.

Coordination is an important element of governance in a multi-level context. Multi-level governance considers how different levels of authority and actors can perform governance functions more efficiently and effectively, while using governance functions of implementation, monitoring, and enforcement. In the multi-level governance system, the market significantly influences decision-making and policy-making processes by interacting with government organisations at various levels, contributing to the complexity of relations, and affecting regulatory outcomes. An example is the role of carbon markets in a multi-level system of environmental governance (Paavola, 2016). This literature also analyses the economic and institutional drivers of multi-level environmental governance systems, such as collective action economies of scope, institutional constraints, and path dependency (Paavola, 2008). The literature on multi-level governance also recognises geography as important because it helps to set the spatial context and identify the territorial levels of decision-making and how these levels interact with each other (Görg and Rauschmayer, 2009). The delineation of authority and power between the capital and subordinate local entities is evident in the literature on multi-level governance, given that decision-making is centralised in large cities and capitals. Nevertheless, acknowledging a role for LAs in the coordination and decision-making with the entities of the other levels of government underscores their inherent capacity within this multi-level governance system.

Networks are recognised as part of the agency in the frameworks of sustainability transitions literature, such as the TIS and TM. However, the role of networks of actors and institutions and its influence on environmental policymaking are explored in depth by two inter-related literatures: network governance and policy networks approach.

> 'Network is viewed as a mechanism of coordination, or what has often been referred to as network governance' (Provan and Kenis, 2008, p.232).

Network governance is the process of steering networks followed by public authorities in accordance with specific rules and procedures, which aim to produce and deliver public services (Molin and Masella, 2016; Sørensen and Torfing, 2009). Policy network approach focuses on the interaction of state and non-state actors to define public policies (Borzel 1998; Klijn and Koppenjan 1995; Marsh and Rhodes 1992; Van Warden 1992; Molin and Masella, 2016). Network governance is a mode of governance adopted in different sectors, but it also works as a response to problems characterised by environmental uncertainty and complexity (Wang and Ran, 2023; Jones et al. 1997). A key advantage of network governance is that it relies on informal social systems, rather than hierarchical, formal, or contractual arrangements, to facilitate learning and cooperation among autonomous actors who have the same goals (Jones et al. 1997). Consequently, transaction costs are reduced, and market activities are benefited (Jones et al. 1997). Coordination is a process which facilitates the allocation of resources and the control of joint actions across a network of organisations. Due to this network coordination, learning and knowledge sharing is enhanced, capacity to address complex problems and competitiveness for better services are both increased (Provan and Kenis, 2008). In the network governance literature, the role of market pertains to collaboration and coordination, whereas in the multi-level governance literature, market addresses the dispersion of authority across various levels, sectors, and states. Both network governance and policy networks approaches highlight the importance of network relationships in policy-making, but also face criticism for devaluing the role of state in driving policy change.

Local government is highlighted in the literature on urban climate governance, which emphasises the role and actions of LAs in addressing climate change and sustainability (Bulkeley and Betsill, 2013; Heijden, 2019). In this literature, the role of cities and the influence of their networks play a dominant role in taking initiatives against climate change (Nguyen, et al., 2020). Market is recognised as an influential actor in climate mitigation and adaptation initiatives; however, its effectiveness depends on their design, inclusivity, and dynamics. In these initiatives, institutions, governmental and non-governmental organisations, civil society actors, businesses, community groups, and citizens also take an active role in networks. Coordination is an important factor in urban climate governance, which seeks to foster collaborative, participatory, and informed decision-making processes to enable transformative actions and co-benefits for urban development (Nguyen, et al., 2020; Romero-Lankao et al., 2018). Consequently, learning plays a central role as it influences how actors search, review, conceive of and adopt new forms and processes of interaction, decision-making and policy to govern urban climate change in innovative ways (Wolfram et al., 2019). Furthermore, in the literature on urban climate governance, internal capacity, autonomy, and experimentation of LAs are crucial factors for effective urban climate governance and sustainable transformation. The literature on urban climate governance uses geography to frame the spatial extent or scale over power can be exercised (Bulkeley, 2012). Furthermore, the urban and rural typology of LAs is a key characteristic, which influences their authority and resources to make decisions.

LAs proactively experiment with innovative approaches to address climate challenges. Specifically, these experiments can create new 'political spaces' and involve technical interventions in infrastructure networks (Bulkeley and Castán Broto, 2013). LAs also enhance their internal capacity for transformative climate governance through co-ownership of long-term strategies, financing mechanisms, and space for experimentation (Hölscher, 2020). However, there are also a few cities who exhibit strong autonomy in urban climate governance. For example, London's city authorities demonstrate autonomy, stakeholder participation, and local leadership in low-carbon mobility (Drummond, 2021). Some pioneer cities have adopted a wide array of governance alternatives, which are ambitious and often opportunistic, to fulfil the objectives of their ambitious strategies. While this approach enables the cities to secure immediate initial outcomes, this disjointed mix of traditional and alternative governance tools seems to impede their progress towards their goals (Heijden, 2021). However, the literature on urban climate governance does not explore the power and interdependence of actors in decision-making (Bulkeley 2010, Shey and Belis, 2013; Eckersley, 2018).

The literature on network governance, policy networks approach, multi-level governance and urban climate governance is explored to identify key factors which can influence the arrangements and effectiveness of environmental governance. Coordination, learning and knowledge, autonomy, local experimentation, internal capacity, market, and urban/rural typology are seven factors, which are highlighted as significant in these four distinct literatures of governance. The significance of market, networks, learning, experimentation and geography is also identified in the sustainability transitions literature, however their influence on governance structures and effectiveness of these transitions is not explored in depth. Furthermore, the literature on sustainability transitions does not evaluate how both national and local governments engage together, nor their impact on the success of such transitions.

2.5 Conclusions

This research addresses waste-fed AD as a case of sustainability transition in the UK, while exploring the role and effectiveness of governance in this transition. This chapter has stressed the importance of governance in the pathway towards sustainability and identified the socio-technical and socio-institutional approaches towards governance in the sustainability transitions literature. Specifically, the role of governance is examined in the socio-technical frameworks of MLP and TIS and the socio-institutional framework of TM. Policy is essential for a sustainability transition to take place as changes in the policy context will cause further changes to initiate or accelerate a sustainability transition.

Although transition researchers position the role of governance high in their agendas, their approach focuses on steering, mobilising, and empowering innovations, which can initiate sustainability transitions. Furthermore, the role of the national level of government is dominant in the socio-technical and socio-institutional approaches towards governance, without considering the influence of the LAs and the central-local government relations in sustainability transitions. Recent studies of sustainability transitions overlook the influence of multi-level dynamics of policies, regulations, decision-making processes, and coordination on the progress of these transitions. Nonetheless, the strength of the transition research is its openness to conceptual tools, theories and methods from other disciplines and domains (Loorbach et al. 2017). There is much to learn from theories in political sciences (Markard et al., 2012). For this reason, the research uses the literature on multi-level governance, network governance, policy networks and urban climate governance to explore and evaluate further the role of governance in the uptake of waste-fed AD in England and Scotland. The exploration of these governance literatures led to the identification of seven factors, which can enrich further the governance approaches of sustainability literature. Coordination, learning and knowledge, internal capacity, autonomy, local experimentation, market, and urban/rural typology are the factors which constitute the analytical framework in chapter 5. These seven factors create a rich analytical framework of governance effectiveness in sustainability transitions. This analytical framework also assists in formulating the questions for the semi-structured interviews and guiding the case selection strategy as presented in chapter 3.

Chapter 3 Methodology

3.1 Objectives and Structure of the Chapter

The chapter describes the interpretive approach to research, along with the mixed methods used to address the research questions. The research examines how waste-fed AD is governed in the UK as an example of an environmental technology with cross-sectorial impacts at the national, devolved, and local level. The research aims to assess to what extent and why the deployment of waste-fed AD is different in England from Scotland. In this research, the literature on multi-level governance along with the literature on network governance, the policy networks approach and urban climate governance lead to a set of explanatory factors, which help us understand how waste-fed AD deployment has evolved. A set of governance, economic, and geographical factors and criteria constructs the analytical framework, which guides the choice of the research methods in this chapter. The challenge, however, lies on how various stakeholders of the public, private and non-governmental sector interact and influence the uptake of waste-fed AD in this multi-layered and complex setting of governance. This research aims to apply mixed methods to enrich knowledge in this topic under investigation.

This chapter provides the rationale for the choice of research methods and offers details on the different methodological steps of the research. Section 3.2 describes how the research adopts an interpretive approach to answer the research questions while using mixed methods, including both quantitative and qualitative approaches. Section 3.3 presents the use of documentary analysis, while explaining how the documents were selected and analysed. Section 3.4 explores how the key actors of waste-fed AD deployment were identified and invited to participate in the research. Section 3.5 illustrates how the analytical framework was used and developed through the distinct stages of the empirical work. Section 3.6 refers to the case selection processes, which include the definition of a case (3.6.1), the construction of a dataset (3.6.2) and the adoption of an adaptive case selection strategy (3.6.3). In sub-section 3.6.3, there is a detailed description on how the English and Scottish

LAs were selected for comparison purposes and why the initial selection approach had to be redesigned. Comparison focuses on the uptake of waste-fed AD plants on the ground by selecting LAs which use or used waste-fed AD plants or preferred In-Vessel Composting (IVC) as a way of waste disposal and treatment, while adopting specific selection criteria. Section 3.7 shows why and how the semi-structured interviews were conducted. This section also explains the coding and analysis approach adopted. Section 3.8 refers to the ethical considerations of the research. The last section (3.9) concludes by summarising the stages of methodological design and explaining how this addresses any limitations to achieve rigour and generalisability.

3.2 Research design: an interpretive approach

Epistemologically, I adopt an interpretive approach, which assumes our knowledge of the world consists of multiple realities as there is no one 'truth' of the reasons why things happen the way they do. In other words, there are different meanings and perspectives people use to make sense of the world around us and these are taken into consideration. This interpretive standpoint allows me to identify the similarities and differences in waste-fed AD uptake of England and Scotland, while also exploring the underlying reasons. I am also considering the quantified outcomes of different LAs to construct a representative sample in the research. Moreover, I am trying to interpret the outcomes and explore the role of governance in them, while re-interpreting the perspectives of various stakeholders in England and Scotland. So, I use theory to understand the governance of waste-fed AD in the UK. This theory results from the sum of different theoretical understandings of the socio-technical transitions AD brings in England and Scotland.

From an interpretive standpoint, the research design is driven by the need to employ methods which are the most 'fit for purpose', divided into three main stages (Table 3.1). The key question aims to answer a 'Why' question and is divided into three sub-questions to be explored in-depth (Table 3.1). This thesis has a strong comparative element, which is reflected in the research design. Despite the focus on England and

Scotland, it aims to offer explanations that transcend the specificities of geography and time. Table 3.1 illustrates the multi-method design of the research, linking the methods with the research sub-questions and participants, along with the identified methodological challenges. The research combines both quantitative and qualitative research methods to answer the research questions and to analyse findings. In this research, analysis of policy documents and interviewing are the main qualitative methods and descriptive statistics is the quantitative method, used in the case selection process for the comparative design. Combining methods is a useful strategy to overcome limitations and enhance strengths of particular methods (Stern et al., 2012). The data findings from one method can enhance or even confirm findings from the other and this methodological triangulation can enrich the analysis. The combination of methods also has the potential to identify relationships built on synergies and trade-offs among demand and supply of resources, strategies of public agencies and behaviour of resource users and environmental outcomes (Kurian et al., 2016).

The decision on the use of qualitative or quantitative methods to answer the research question stems from an ontological and epistemological standpoint towards the perception and knowledge of the world around us and how we conduct research. However, a dichotomy between qualitative and quantitative is an oversimplification of assumptions and choices researchers make on their work (Alexander et al., 2016). Positivists are characterised by scientific rationalism as they have an objective ontological sense towards the 'reality' and are keen to measure the world 'out there' with the use of quantitative methods. Qualitative methods are more suitable for researchers who have a relativist ontological outlook, where there is not only one crystalised and complete reality as there is also value in understanding the interactions between the different perceptions of the world. Qualitative methods are traditionally used by interpretivists who 'seek explanation and understanding by using stories' (Alexander et al., 2016, p.130). Interpretivism deals with wholes and investigates cases holistically. It also enables the researcher to be open to a full range of views, while achieving richness in detail and meaning (Greenwood, 2023). For example, in this research, the interpretive approach taken by the researcher provides a detailed focus on analysing stakeholders' understandings of different policies, strategies, and incentives that influence the uptake of waste-fed AD. The value of qualitative methods is highlighted by critical realists, who investigate the causal interrelationships between mechanisms, contexts, and outcomes (Smith and Elger, 2012; Pawson and Tiley, 1997). Critical realism has influenced the development of policy evaluation studies, however in this research the focus is not on the evaluation of policy programmes.

The significance of qualitative research is found in its capacity to delve into participants' perceptions and experiences, as well as the dynamics of institutions, processes, and relationships (Edwards and Holland, 2013). Overall, interviews were particularly useful to assess and compare governance effectiveness in the deployment of waste-fed AD, and the researcher was receptive to stakeholders' feedback, both positive and negative, on governance and policy. Understanding the reasons behind their perspectives is equally important (Greenwood, 2023). This use of an interpretive approach in interviews is a key difference from critical realists, who interview stakeholders as the experts of the topic and lead the discussion based on their theory (Smith and Elger, 2012; Pawson and Tiley, 1997).

There are elements of the social world which require a more interpretive approach and others which need a positivist stance for quantification. The adoption of mixed methods is an effort to recognise and bring together the best aspects of both approaches to provide 'a richer and stronger array of evidence', which cannot be achieved using different methodological tools (Yin, 2009, p.63). To be exact, bridging the two approaches is not done in a balanced way as the qualitative element of the research is clearly more dominant, however it is done in a way to address the nature and needs of the research. Furthermore, mixed methods can be used to illustrate findings in detail and address more complicated research questions with the most applicable techniques (Yin, 2009; Bryman, 2006). So, it was decided early on to adopt

Table 3.1 Research questions and design: an interpretive approach

Key Research Question: To what extent and why is the deployment of waste-fed AD in England different from Scotland?

Research sub-questions	Methods	Explanatory factors	Research participants	Challenges
A. What is the role of the UK environmental governance on the deployment of waste-fed AD?	Qualitative: Documentary analysis, semi-structured interviews.	Coordination, learning & knowledge, market, proximity to a facility, urban and rural typology.	Key actors of the UK and Scottish Government, non-governmental and industry organisations, AD market.	Selection & recruitment of the interviewees, structure of topic guide.
B. What is the impact of the devolved and local levels of governance on waste-fed AD in the UK?		Coordination, learning & knowledge, autonomy, local experimentation, internal capacity, market, proximity to a facility, urban and rural typology.	Key actors of devolved, regional, and local government influencing AD deployment: waste and AD companies, non-governmental organisations.	
C. What are the core factors explaining the success of English and Scottish LAs in the use of AD plants for food waste management and renewable energy production?	Documentary analysis. Case selection strategy: definition of case and population, creation of a dataset, descriptive statistics. Semi-structured interviews.	Coordination, learning & knowledge, autonomy, local experimentation, internal capacity. proximity to a facility, urban and rural typology.	Waste officers of LAs, waste management companies, AD plant operators & investors.	Dataset creation, descriptive statistical analysis, selection criteria and number of cases, (influencing the generalisation of findings). Recruitment of the interviewees, availability of time & resources.

a mixed-methodological approach, due to the complicated nature of the waste-fed AD policy landscape. It was also clear that the creation of an LA dataset and use of descriptive statistics have the potential to increase the rigidity of the approach taken with the last two research questions, which clearly refer to the local level (Table 3.1).

Despite the necessity to employ mixed methods, they also bring two key advantages to the research. First, it allows the researcher to use systematically different methods to obtain or confirm the validity of evidence. This process of triangulation is 'the development of converging lines of inquiry' (Yin, 2009, p. 115) and can verify findings with the use of multiple methods for the examination of a specific fact or phenomenon. Triangulation also allows the researcher to convince the reader that the conclusions are not subjective or unrelated with a specific method. Second, it allows findings to be enriched with the use of alternative data sources. For example, as we will see below, the construction of a dataset and the use of descriptive statistics enabled to select specific LAs as cases. These selected LAs provide an opportunity to interrogate the role of the local level more closely, while uncovering any details or meanings which cannot be captured quantitatively.

There was a reflexive and adaptive approach in the design and empirical stage of research. Reflexivity involves recognising the researcher's role in shaping the meanings attributed to social interactions and acknowledging the potential influence the investigator may have on the research (Bowen, 2009). Reflexivity was a continuous process in which I was engaged to critically examine my own biases, assumptions, and subjectivity throughout the research process (Olmos-Vega et al., 2023). As a reflexive researcher, I continuously made decisions to adapt to data, methodological needs and any unexpected situations (Varpio et al. 2020). Consequently, this meant that I remained open to emergent evidence and explanations, during the fieldwork and analysis stages. This openness enabled the design of the research to develop further as I was progressively exploring the uptake of waste-fed AD technology through the three stages of data collection (Table 3.1). These stages involved conducting an analysis of relevant policy documents, selection of cases and semi-structured interviews with stakeholders. Reflexivity and interpretation were also evident in the crafting of the analytical framework and specifically in the development and refinement of its factors (section 3.5). This reflexive and adaptive approach enabled me to unpack the significance of meanings, which were generated from re-interpretating interviews' and documents' findings, without imposing any initial presumptions on specific perspectives (Hammersley, 2013). The 'end point' of the empirical stage was reached when a comprehensive picture of the waste-fed AD was constructed to sufficiently answer the research questions, while using the analytical framework. In other words, this end point marked the theoretical saturation, when further data collection would provide no new insights or details, instead it would provide a repetition of existing evidence. Reflexivity in the methodological design involves making decisions which are ethical, rigorous, and aligned, while ensuring coherence and enhancing the whole study (Olmos-Vega et al., 2023).

3.3 Documentary Analysis

The analysis of policy and strategy documents was the first qualitative method employed. Documentary analysis involves finding, selecting, appraising and synthesising data contained in documents as it is a systematic process for reviewing and evaluating these documents (Bowen, 2009). It enables researchers to examine and interpret data to uncover meaning, gain understanding, and develop empirical knowledge from both printed and electronic materials (Bowen, 2009). Mixed methods studies sometimes include documentary analysis, which is combined with data from interviews to minimise bias and establish credibility (Bowen, 2009). In this research, the rationale for document analysis lies in its role in methodological and data triangulation, as well as the significant value of policy and strategy documents in informing the research inquiry.

Desk research involved web searches, which used specific keywords related to the use of waste-fed AD in the UK. These searches provided certain documents which were initially noted and skim-read. Time, place, credibility and relevance of the publication or material were key selection criteria of documents for the analysis. After ensuring high relevance to the research, the selected documents were thoroughly examined and interpreted. Rather than employing a systematic coding method, I wrote summaries from each document to highlight its contribution to the research questions. This approach was better suited for mapping key aspects of the collected written material focusing on related regulations, policy initiatives, incentives and waste-fed AD development.

Most documents used in this analysis were publicly available and cover the period from 2005 to 2023. They included information on policies, strategies, regulations, and incentives in the sectors of climate change, energy, and waste, influencing directly and indirectly the AD deployment of the UK. These documents also provided useful insights into the institutional and structural dynamics of the UK policymaking processes and its influence on waste-fed AD. Furthermore, reports which focused on economic and strategy aspects of the AD industry were also included, while few industry documents required payment for access. The review included statistical data, reports, policy briefs, news articles, and research conducted by private or third-sector entities. In addition, certain documents of the LAs (including Waste and Climate Strategies and Sustainability Local Plans, draft proposals, consultation responses, reports, and committee proceedings) were obtained from their websites.

Documentary analysis provided background and context, which set the foundations for the next stages of the empirical work. In this study, all these documents gave a valuable insight into the institutional and structural dynamics inherent in the policy-making process and were used to complement, inform findings from the interviews and quantitative study. Documentary analysis contributed to the identification of key stakeholders who were interviewed in the next stage of the research. It also contributed to the generation of interview questions as the information found in documents can indicate relevant questions to ask to interviewees during the research process (Bowen, 2009). This richness of data enabled to track change in the use and development of a technology, such as AD, over time and verify information from interviews when research participants have forgotten the details of regulations, incentives, technological performance, and dates.

Despite its advantages, documentary analysis has limitations related to the credibility, accuracy, and representativeness of selected documents, which are relevant to this PhD research. All secondary sources used in this study were official documents from the UK Government, Scottish Government, local authorities, and private companies. This diverse selection helped avoid biased representations from specific actors, as it included publications from almost all key organisations involved in waste-fed AD deployment in the UK. However, secondary data inherently poses challenges since it was not directly collected by the researcher (Cowton, 1998; Bowen, 2009). This can affect the validity and reliability of the data. Nevertheless, the relative objectivity of published documents, including statistics and progress reports on waste-fed AD, and their contemporaneity (2000–2022) with the phenomena studied, enhance their reliability and validity (Van Thiel, 2014). Additionally, the accuracy and quality of statistical data in municipal and industry reports, such as food waste tonnages and carbon emissions trends, could not be verified. To mitigate the risk of false information, multiple documents were analysed to seek convergence across different data sources and methods. Interviews with key stakeholders and statistical data were also used to enhance, validate, and triangulate the data from selected documents, as recommended by Bowen (2009) and Olsen (2004). It also was imperative to include the viewpoints of stakeholders, moving beyond the narratives found in official policy documents as this enabled the exploration of motivations, processes of governance and impacts on policy (Greenwood, 2023).

3.4 Identification of key actors

For the qualitative stages of the research, I identified and contacted key stakeholders of waste-fed AD deployment at the national, devolved, and local levels of government. Around one hundred actors were identified during desk research, while using different professional platforms related directly and indirectly to waste-fed AD.

So, initially interviewees were mapped and selected while conducting online research. In addition, a 'snowball' method was used because the initial interviewees recommended others to be interviewed. Snowballing is a useful sampling method when there is no easily accessible data of stakeholders related with a specific phenomenon (Sturgis, 2016). As the AD industry has a certain number of members who all share the same specific interest in the uptake of the technology, snowball sampling proved effective. The waste-fed AD sector is relatively small, and actors know each other and can provide contact details of experts. The selection of AD consultants, policy and industry experts was based on their job role, responsibilities, and expertise in a specific policy area, which is influential to AD deployment.[3] It was deemed essential to assess that the selected research participants were able to reveal useful information, while answering the questions. Research participants were contacted by e-mail, which provided all relevant information on their participation and the purpose of the research.[4]

A key challenge addressed was the selection and recruitment of the right stakeholders in the sector of waste-fed AD, without having any overrepresentation of a specific stakeholder type within the sample of interviewees. In snowballing sampling there is a risk to connect and interview only a specific network of individuals who know each other, and this inevitably creates a source of bias, with the overrepresentation of certain views (Sturgis, 2016). To tackle this risk, I conducted extensive online research of potential interviewees, while identifying their working experience and skills and their relation to waste-fed AD through LinkedIn. Consequently, this combination of sampling methods provided a balanced representation of the different sectors and professions related with waste-fed AD.

[3] A full list of the interviewees is in Appendix I.

[4] The Participant Information sheet and the interview consent form, which were attached to the emails sent to the research participants, are included in Appendix II.

3.5 Crafting the Analytical Framework

The analytical framework plays a crucial role in a mixed-method research design by providing a structured approach to the collection and analysis of qualitative and quantitative data, which is essential for answering the research questions. The analytical framework, developed in Chapter 5, guided the empirical stages of the research as it provided a 'set of analytical principles designed to structure our observation and explanations of the world' (Cairney 2013, p. 5). Specifically, it provided guidance, consistency and interpretation during the different stages of this research. The analytical framework plays a significant role in interpreting findings, identifying emerging themes and patterns and drawing meaningful conclusions. This section presents how the analytical framework was developed through the different stages of this research.

The analytical framework guides the selection of appropriate research methods, tools, and techniques for data collection and analysis. In this study, it was initially developed through a review of relevant academic literature during the preparation for the empirical stage. Before fieldwork, the framework was theory-led, incorporating prevalent themes and factors from the literature on multi-level, network, and urban climate governance. This provided a consistent lens, ensuring coherence and transparency across different research components. For example, the factors of the analytical framework shaped the interview questions,[5] the case study protocol,[6] and the selection criteria of LAs.

The analytical framework informed the coding and analysis of data from documents, interviews and cases. During fieldwork, I engaged in a continuous, reflexive, and cyclical process, using the topic guide during interviews and interpreting findings while referring to the framework to ensure coherence through the study. Initially theory-led, the analytical framework became more data-driven as the first interview findings were analysed thematically. The initial list of themes and factors expanded

[5] The topic guide used at the first and second round of interviews can be found in Appendix III.
[6] The case study protocol, used for this study, can be found in Appendix IV.

significantly despite clearly predefined codes. Through thematic analysis, I reread and reviewed the data to uncover emerging themes and categorise them into groups, while making my own interpretations. The extensive list of themes was gradually refined to seven key factors of governance effectiveness, which served as filters for analysing in-depth information from documentary analysis and integrating it with interview findings. At the end of the thematic analysis, the key factors, derived mainly from literature on governance, also incorporated interpretations, meanings and examples from the interviews and documents. This thematic analysis provided evidence on the factors and success criteria of waste-fed AD deployment at local and regional levels in the UK, focusing on England and Scotland. By adopting a reflexive and interpretive approach to designing the analytical framework, I actively contributed to the construction of themes and recognised the potential influence of my interpretation on this PhD research. Overall, I demonstrated objectivity by fairly representing the research material and sensitivity by responding to even subtle cues in the data selection and analysis from interview transcripts and documents, as recommended by Bowen (2009).

3.6 Case selection

3.6.1 Definition of a case

In this research, comparison also includes the devolved and local level of UK governance as it enables the researcher to explore how policy diversifies at these two levels and which economic, governance, and geographical factors may lead to this differentiation. To address the final research question, it is crucial to examine the 'success criteria' which enhance the efficiency of food waste collections for AD at a local level. Methodologically, this approach enables 'to identify similarities and differences across a range of places and scales' (Hansen and Coenen, 2016, p.105). The definition and use of cases is appropriate for this research, in which context is important and a holistic approach is taken to identify certain attributes or conditions (Ragin, 2014; Kumar, 2011). Furthermore, comparison is also central to any case-based method (Byrne, 2009).

Defining a case carefully is important because this will determine the size and number of cases, which will allow the depth or width of the case-oriented research. Cases are defined as configurations – 'as combinations of characteristics' (Ragin, 1987 in Byrne, 2009, p.102). In qualitative research, comparison involves comparing these sets of characteristics that form the cases (Ragin, 1987 in Byrne, 2009). Having an interpretive stance, the researcher was open in establishing the definition criteria of a case, while collecting any relevant data to construct a dataset of the relevant population of LAs. During these first steps of the case study the researcher also excluded a few cases from the scope of the research, and this also enabled the clear definition of the investigated cases. It is important first to define the cases by focusing on their specific characteristics and on the wider population and then decide which cases should be selected for research and analysis.

In this research, each case represents a Local Authority, which has specific economic, socio-demographic, and geographical characteristics. Each case can be considered as a single entity, which has different individuals (Kumar, 2011). So, each case or LA has their waste managers, AD plant operators, households, and waste management companies. Specifically, the case is an LA, which is defined by the following characteristics:

-unit of analysis: the meso-level. They are UK local councils which use a waste-fed AD plant or IVC facility within close proximity.

-units of observation: interviews with members of local councils, waste management companies and AD plant operators.

-units of variations: environmental policy targets of LAs, types of waste management and disposal of LAs, and socio-demographic features of LAs.

- time: The different sources of data, which were used to construct the dataset for this study, had a final update in May 2019. This means that the dataset encompasses information pertinent to the LAs, with data recorded in 2018.

- space. In brief, each one of my cases (UK LAs which use waste-fed AD or IVC for its waste disposal) has certain spatial characteristics; they are characterised as urban or rural LAs and belong to a national level (England and Scotland).

Furthermore, a case study protocol was created to enable the researcher to frame investigation at the local level (Appendix IV). The case study protocol worked as a guide to complete eight interviews focusing on LAs because it included open-ended questions, which work as 'reminders regarding the information that needs to be collected and why' (Yin, 2009, p.86). It included key questions to be asked of each case and these questions are closely related with the inquiry, the analytical framework and the wider data collection process of the research. Overall, the case study protocol is essential in a multiple-case study because it is an effective way of ensuring 'reliability' and 'consistency' across all cases examined when it comes to data-collection (Yin, 2009).

3.6.2 Construction of a Dataset: Population of English and Scottish LAs with AD plants

This comparison-oriented approach in research brings a considerable amount of information for each case and includes technical, economic, socio-demographic, and geographical variables, which led to the creation of a dataset. There is no existing publicly available dataset that includes evidence and information on how the UK LAs treat and dispose their food waste. For this reason, the dataset was created as a result of merging different available datasets and works as a point of reference for the case selection strategy, which includes English and Scottish LAs with waste-fed AD plants in their territories. This means that the cases (or LAs) of the Northern Ireland and Wales are not included. As stated above, one of the factors that determines whether a case was in or out is the nation of the LA. In total, the dataset has 96 LAs, which comprise the population under investigation.

The dataset incorporates data on 132 waste-fed AD plants, which is originated from the official information portal curated by the National Non-Food Crops Centre

(NNFCC Ltd).[7] This specific version of NNFCC data contains information on the waste-fed AD plants, which use mainly municipal solid and food waste for their operation, built in the UK during 2000-2018 as the first waste-fed AD plant was completed and started operating in 2000. In addition, the NNFCC Ltd dataset was also used for the selection of waste-fed AD plants because it provides important information of the AD plants, such as the name of AD plant and developer, postcodes, year of completion, type of feedstock and capacity of AD plants (in KWe). The postcodes were used to identify the LAs that have at least one waste-fed AD plant.[8] There are LAs with more than one waste-fed AD plant situated in its territory. For example, in North Yorkshire there were seven waste-fed AD plants recorded in 2019. The name of the LAs also led to the classification of an LA as a county council, London borough, metropolitan district, non-metropolitan district, and unitary authority. The type of feedstock, capacity of AD plants (in KWe) and year of completion are valuable variables in the dataset constructed as they illustrate the status of waste-fed AD deployment in Scotland and England. The completion year is a useful point of reference as it signposts how AD deployment has been influenced after the adoption of certain policy initiatives. The following set of variables have been provided by the NNFCC dataset in 2019: a. type of LA; b. number of waste-fed AD plants (in 2019); c. tonnes of total feedstock (kt) used by waste-fed AD plants of LAs; d. total energy capacity (kW) produced by waste-fed AD plants of LAs; e. completion year of waste-fed AD plants; and f. feedstock (type). In the dataset, certain aspects of the LAs were considered as important descriptive characteristics for them, such as the type of feedstock used by the AD plants located in their territories.

Furthermore, this dataset was enriched with extra variables, which reflect the wider socio-demographic and environmental conditions of the local level influencing AD

[7] The data illustrates an interactive map of the UK and can also be downloaded from here: http://www.biogas-info.co.uk/resources/biogas-map/attachment/ad-portal-map_site-list_external_may-_2019.

[8] The local councils were identified by inserting the postcodes of AD plants in the following website: https://www.gov.uk/find-local-council.

deployment. It also includes data originating from other resources, the UK Office for National Statistics (ONS), SEPA, the Scottish Government and DEFRA. The dataset also includes the following variables: a. estimated population (mid-2019); b. Gross Disposable Household Income (GDHI) per head of population at current basic prices - GBP (2019); and c. Household waste generated (tonnes) in 2019. For the first two variables, data originates from the UK ONS. Specifically, GDHI is a useful concept to measure the 'material welfare of households' as it refers to their disposable income, which is the total amount of money individuals have left for spending or saving after paying all direct and indirect taxes and receiving any direct benefits (ONS, 2019).[9] Household waste generated (tonnes) in 2019 is another useful indicator as it enables to see how much of this type of waste is generated in England and Scotland and its data originates from two sources:[10] DEFRA for English LAs[11] and SEPA for Scottish LAs.[12]

This dataset provides a large population of English and Scottish LAs with at least one waste-fed AD plant in their territories as it contains data from multiple, online sources of evidence. It has a specific and clear focus on food waste AD plants at the local level. I also tried to include some environmental variables, which are related to the environmental performance of LAs and to the definition of success. The following variables have also been considered: a. rates of food waste recycling; b. waste led to landfill (tonnes); c. amount of food waste ending to landfill; d. household waste recycled & composted; and e. residual household waste per head. However, there is no sufficient data of food waste collections at LA level and the rest of the waste-

[9] The following ONS website was used for Gross disposable household income (GDHI): https://www.ons.gov.uk/economy/regionalaccounts/grossdisposablehouseholdincome/bulletins/regionalgrossdisposablehouseholdincomegdhi/1997to2019

[10] It is worth mentioning that Defra uses the financial year of 2018-19 for the time reference, whereas the Scottish Government and SEPA refer to the calendar year of 2019.

[11] The following dataset was used from Defra: https://www.gov.uk/government/statistical-data-sets/env18-local-authority-collected-waste-annual-results-tables.

[12] SEPA has the following website, with all the relevant data and information: https://www.sepa.org.uk/environment/waste/waste-data/waste-data-reporting/household-waste-data/.

related variables could not be included in the dataset as there are important differences in the calculations and metrics used between the Scottish Government and DEFRA. This is the main reason why the dataset includes only one waste-related variable. Moreover, there are factors which can determine the environmental footprint of the AD plant, such as the amount of produced digestate, methane emissions of AD plants and the distance of food waste to reach the AD plant ('waste miles'), but this data was not available.

As already mentioned above, the constructed dataset includes the collection of all available data related to waste-fed AD and LAs in England and Scotland. [13] The dataset contains 96 LAs and the following nine variables: a. type of LA; b. number of waste-fed AD plants (in 2019); c. tonnes of total feedstock (kt) used by waste-fed AD plants of LAs; d. total energy capacity (kW) produced by waste-fed AD plants of LAs; e. completion year of waste-fed AD plants; f. feedstock (type); g. estimated population (mid-2019); h. Gross Disposable Household Income (GDHI) per head of population at current basic prices - GBP (2019); and i. Household waste generated (tonnes) in 2019 (Appendix V). This data was obtained from the NNFCC (2019), the ONS (2019), SEPA (2019), DEFRA (2019) and GOV.UK. However, there are some weaknesses that need to be highlighted as they also influenced the case selection strategy, presented below. These were also considered by the researcher after the completion of the first ten interviews of the empirical stage. Firstly, the dataset includes LAs with waste-fed AD plants in their territory, but there is not any information about the origin of the feedstock consumed by them as it may come from food waste collected by more than one LA to ensure feedstock supply to the AD plant. In other words, the waste-fed AD plants of the dataset may also process food waste from other neighbouring LAs, however there is no specific information on the origin of this feedstock. Secondly, household waste generated (tonnes) is a useful indicator, but it only reflects a partial amount of waste generated by the LA as

[13] The constructed dataset of English and Scottish LAs with waste-fed ADs can be found in Appendix V.

it does not include the waste generated by business and industry. Reflecting on these two factors, I meticulously assessed the utilisation of the constructed dataset in the case selection strategy.

3.6.3 Adaptive case selection strategy

The research aims to enrich existing evidence on the core factors explaining the success, by focusing on the performance of English and Scottish LAs that use waste-fed AD plants. For this reason, the dataset of English and Scottish LAs has been constructed, but only few cases were selected and further explored. Selecting the cases is a multi-stage process, which requires a grouping of cases and selection of variables. In this research, the case selection strategy was adaptive and inclusive to data coming from the initial interviews. The researcher's reflection on this emerging data and the challenges in the recruitment of interviewees from the first set of selected LAs led to the adoption of a different sampling method and a different set of selected cases. As described below, initially the case selection strategy was influenced by the approach of Most Similar Cases for a Different Outcome (MSDO), however the adaptive and reflexive approach of the researcher led finally to a purposive sampling method and the finalised set of selected cases (LAs). Overall, these processes included different ways of excluding first some cases, based on the adoption of certain criteria and parameters, related with the scope of research. The exploration of six cases is sufficient to provide information about the core factors that determine the success of English and Scottish LAs in the use of waste-fed AD plants. This sub-section describes how the two different set of cases were selected and the reasoning behind any changes.

The comparative method employs the same principles as the statistical method, but it is tailored for situations of complex phenomena with a limited number of cases but numerous variables (Lijphart, 1971 in Della Porta 2008, p. 201). However, the quality of control of the relationship between variables is lower, compared to the use of pure quantitative comparison methods (Della Porta, 2008). One effective way to ensure generalisability in comparative research is to adopt and implement a rigorous case selection strategy, which provides a type of 'control' on the relationships between variables, during the case selection process. There are two main approaches that can provide this control on the relationships between variables and the aspect of generalisability in the findings: Most Similar Cases for a Different Outcome (MSDO) and Most Different Cases for a Similar Outcome (MDSO). Both approaches are used for comparative research and emphasise the importance of cases, which are the observations (De Meur and Gottcheiner, 2009). MDSO and MSDO go beyond experimentation with several variables and a large set of observations. They both approach observations in detail and holistically and 'each case as a separate and unique whole' (De Meur and Gottcheiner, 2009, p.208). MDSO and MSDO use sets of cases chosen for the purposes of conducting comparison efficiently and navigating the analysis (De Meur and Gottcheiner, 2009). Nonetheless, this is not the actual analysis; it is its starting point for identifying similarities and differences among cases.

A most similar comparative case study (or MSDO as defined above) was adopted, as the population of cases under investigation differ on the outcomes.[14] In this research, the selection of cases is a researcher-driven process, based both on the theoretical foundations of the research and the knowledge available and collected for each case of the population. The comparison aims to identify the different outcomes that are interpreted as different levels of success in the adoption and use of waste-fed AD plants at the local level. Success is strongly related with outcomes, which are measured with the use of indicators (Heijden, 2019). However, there is little evidence on the key indicators of success, the ways of communication and financing options of partnership between the AD industry and LAs in the UK (Frith and Gilbert, 2011). One key factor that can influence (to a certain extent) the success of the LAs in the use of waste-fed AD is the successful operation of the AD plant itself. Although successful operation of a waste-fed AD plant does not necessarily mean that its use

[14] Further information on the use of most similar comparative case study (or MSDO) in this research is presented in Appendix VI.

by LAs is successful, an LA can facilitate the successful operation of a waste-fed AD plant[15] (Bourdin and Nadou, 2020) and use it for its own benefit. The operation of waste-fed AD plants is the starting point for defining and explaining the success of LAs in their use as it defines the selection criteria for the cases examined in-depth.

A 'most similar comparative case study' (MSDO) compares the more and less successful LAs with waste-fed AD plants. The more successful LAs have the AD plants with the highest food waste consumption, while less successful LAs fall below the average. Focusing only on successful LAs limits the investigation to common factors among them, so comparing 'strong' and 'weak' performers avoids selection bias and strengthens conclusions. Descriptive statistics (mean, minimum, maximum, median, and standard deviation) helped to identify and group LAs based on their performance (Table 3.2). The MSDO approach emphasises similarity and uses prior knowledge of important causal variables for case selection, ensuring a variance in outcomes of independent variables and similarity in dependent variables (Lemprière, 2016).

Table 3.2 Mean, Median and Standard Deviation of the variables

		Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	**Estimated Population mid-2019**	**Household waste generated (tonnes) in 2019**	**Gross Disposable Household Income (GDHI) per head of population at current basic prices - GBP (2019)**
N	Valid	96	96	90	91
	Missing	0	0	6	5
Mean		62647	206474	82061	20887
Median		50000	142241	55213	20473
Std. Deviation		49857	165687	66859	3575
Minimum		10	26720	13710	14908
Maximum		300000	1141816	412130	33251

[15] The successful operation of the waste-fed AD plant is determined by its size, profitability, its capacity in kWe and the tonnes of total feedstock it uses as input for its operation.

In the dataset constructed, South Ayrshire was chosen as an exemplar case because its waste-fed AD plants consumed the largest quantity of total feedstock during 2019. Five additional LAs were selected using the most similar comparative case study (See Appendix VI for the initial list of selected LAs). After the initial interview with the waste manager of South Ayrshire, the recruitment of the other interviewees from the rest of LAs was impossible as there was no willingness or availability of any potential interviewees to take part in the research. In terms of time, a month was spent by the researcher to try to recruit any interviewees from these LAs, however this was not possible due to these unexpected difficulties to complete the data collection as designed in the Appendix VI. George and Bennett (2005) highlighted a similar type of difficulty in the design of a 'most similar comparative case study', which is the degree of knowledge in the particularities of the cases and context at the beginning of the project. Initially the aim was to have the MSDO design, which is a sufficiently rigorous research design to provide reliable and generalisable (to some extent) findings to a broader population of cases. However, it was not possible to continue with this and this needed to change. For the exploration of the local level, a change in the sampling process needed to happen within the time and resource constraints (time and funding) of a PhD programme, while considering the impacts of the sampling approach on the generalisability of the research findings.

Consequently, the case selection strategy had to change and adapt to these constraints. However, in both cases of selection strategy, the same number of LAs were selected as cases for the cross-comparison between English and Scottish LAs. The previously adopted MSDO approach provided an extensive knowledge of the created dataset and led to the selection of six LAs, including the exemplar case of South Ayrshire Council.[16] To address the challenges of the previous sampling approach, a purposeful sampling was adopted. Purposeful sampling is a non-probability sampling technique which focuses on the units or cases that are

[16] The list of English and Scottish LAs, selected in the most similar comparative case study, is presented in Appendix VI.

investigated and selected by the researcher to meet the purpose of the research (Douglas, 2022; Palinkas et al., 2015). Overall, there are fifteen strategies of purposeful sampling categorised based on their emphasis on similarity, variation, and nonspecific emphasis (Palinkas et al., 2015).

Taking into consideration the specific constraints and challenges in the research participant recruitment, purposeful sampling was the best choice because it is a convenient type of sampling, while providing expert insights from heterogenous cases. In parallel, as the information was emerging from the first ten to fifteen interviews of the empirical stage, two factors that were not included in the construction of the dataset and the first case selection were deemed essential to be factored in the second round of case selection. While having a reflexive and interpretive approach on the analysis of these interview findings, these factors seemed to be influential on the management and disposal of food waste and use of waste-fed AD by LAs. These are the following two factors: classification of an LA as urban or rural and the inclusion of LAs who use IVC for the food waste disposal as there is a competition between AD and IVC for the disposal of food waste (Table 3.3). Furthermore, it was essential to collect information from participants who were easily accessible to the researcher, and these were the cases of Bracknell Forest Council and Northumberland County Council. Both were cases identified after contacting LARAC and ADBA and provided interviews with experts who are individuals with a high level of knowledge about the use of AD. Similarly, East Lothian Council and Renfrewshire Council are two Scottish LAs that were identified during interviews with waste managers and AD plant operators (Table 3.3). They are also heterogenous as they use the two different and competitive ways of food waste disposal: IVC and AD. East Riding of Yorkshire Council has been already included in the constructed dataset and was included in this set of selected cases because it is an interesting and heterogenous case. It has used IVC for more than ten years now, despite the operation of a waste-fed AD plant in its territory, so it was useful to include it after initial communication with its waste team.

Table 3.3 List of 6 Local Councils selected in both England and Scotland					
	Name	Urban/ rural[17]	Type of LA	Use of AD or IVC	Estimated Population mid-2019
SC	South Ayrshire Council	Rural	Council Area	AD	112,610
SC	Renfrewshire Council	Urban	Council Area	IVC	179,100
SC	East Lothian Council	Urban	Council Area	AD	107,090
EN	Bracknell Forest Council	Urban	Unitary Authority	AD	122,500
EN	East Riding of Yorkshire Council	Rural	Unitary Authority	IVC	341,200
EN	Northumberland County Council	Rural	Unitary Authority	AD	322,400

Purposive sampling is a useful approach of identifying information-rich cases or making the most out of limited resources, as was the case with the empirical stage of this research (Palinkas et al., 2015). In other words, it met the needs of the researcher to complete data collection effectively. Nonetheless, there are also advantages and disadvantages of purposeful sampling that need to be recognised as improper design in case studies, which does not recognise any risks, can limit the ability to apply findings beyond the specific cases examined. Firstly, the sample shown in Table 3.3 provides a more realistic representation of the food waste management of LAs in Scotland and England. The population remains an important filter to classify cases, but their classification as a rural or urban LA is a factor also considered in the sample. Moreover, the urban and rural typology is a geographical factor of the analytical framework. Secondly, purposeful sampling enables the

[17] For English LAs, the following rural/ urban local authority classification is used: https://www.ons.gov.uk/methodology/geography/geographicalproducts/ruralurbanclassifications/2001ruralurbanclassification/ruralurbanlocalauthoritylaclassificationengland. For Scottish LAs, the following classification is used: https://www.gov.scot/publications/scottish-government-urban-rural-classification-2020/documents/.

researcher to make logical, analytical, and theoretical generalisations from the sample examined in Table 3.3. Thirdly, it builds well on the previous stages of this study: the construction of the dataset, descriptive statistics and MSDO design also reflect the increasing knowledge of the researcher on the possible variation of cases under examination. A key drawback of purposeful sampling is the risk of research bias which can influence the generalisability of findings (Palinkas et al., 2015). However, the sampling and resampling of cases led to the minimisation of the risks of bias as it added further criteria in this selection process. Compared to MSDO, with the choice of purposeful sampling, the researcher loses the control of choosing cases based on their similarities of the dependent variables and the opportunity of investigating any interrelationships between the variables chosen in the first set of selected cases by MSDO. To avoid a selection of case, whose unique dynamics may not be applicable elsewhere, the following sampling criteria were key for selecting cases and securing the generalisability of the findings: estimated population, use of AD or IVC, urban or rural LAs (Table 3.3).

3.7 Semi-structured interviewing and coding

Interviewing is an important tool of qualitative data collection in the fields of policymaking, evaluation practice and research as it enables the researcher to explore stakeholder discourses on policies and their impacts, which cannot be properly quantified. Stakeholders' views reflect their specific background, knowledge and experiences and need to be interviewed, because they are either involved with or affected by the development of waste-fed AD and have insights or even disagreements which are not captured in publicly available policy or strategy documents. In semi-structured interviews, the researcher asks specific questions in the same way each time but has the freedom to 'alter their sequence and probe for more information' and adapt the question to 'the level of comprehension and articulacy' of the interviewee (Fielding and Thomas, 2016, p.282). For this purpose, semi-structured interviews were used during the scoping and empirical stage of the research.

Having a reflexive approach led to the adoption of orienting concepts, which guided the scoping stage of the research and were sufficiently adaptable to the evolving nature of the PhD research. These orienting concepts were derived from the theoretical work conducted in the early stages of the thesis, supplemented by insights from the documentary review and a continuous reflection and interpretation of the researcher throughout the empirical stage. These orienting concepts are also illustrated in the topic guide, which was used in semi-structured interviews, as it set certain key points and guidelines to be followed during the discussion between the interviewer and interviewee (Fielding and Thomas, 2016).

The scoping stage involved an initial consultation with a small number of key policy and industry experts of AD and included semi-structured interviews, which took place from January to March 2018. The aim of these interviews was to provide a broad overview of the context and policy processes, influencing the deployment of AD in the UK. Conducting scoping interviews offered two key benefits to this research. First, the scoping interviews helped me to test and refine my interview questions and research design, while making any necessary adjustments. Specifically, they enabled me to ensure the clarity and effectiveness of my questions in eliciting the desired information as they provided feedback from my interactions with research participants. Second, the scoping interviews provided an opportunity for me to practice and become more comfortable with the interview process, which had the potential to enhance the quality of the data collected (Van Teijlingen and Hundley, 2001). Prior to the scoping interviews, the topic guide was constructed and included open-ended questions and key points to be discussed with all interviewees,[18] with minor variations to reflect different job roles, expertise, or time constraints. Ten scoping interviews were conducted with policy experts, civil servants, and industry representatives, specialising on the different sectors of the AD, such as DEFRA, BEIS, Ofgem, FSA, EA and the ADBA.[19] Half of these interviews

[18] The topic guide used at the scoping stage is provided in Appendix III.
[19] A list of the scoping interviews is provided in Appendix I.

were conducted face-to-face, while the other half took place online. All of them lasted approximately one hour. The completion of these interviews led to the mapping of further stakeholders, experts, policy, and strategy documents and contributed further to the understanding of the wider policy landscape, which influences the uptake of waste-fed AD.

A second round of qualitative data collection was comprised of semi-structured interviews from key stakeholders involved in waste-fed AD. In total, twenty semi-structured interviews were conducted with AD experts and consultants who work in the private, public and third sector.[20] Prior to this round of interviews, a revised topic guide was created to outline the main discussion points and to explore the factors and criteria of the analytical framework,[21] which is presented in Chapter 5. These key discussion points were transformed to open-ended questions, which were addressed to the interviewees, with minor adjustments to fit with their expertise and role, so they could have sufficient knowledge and experience to answer certain questions.

These interviews revealed stakeholders' perceptions of the governance, economic and geographic factors, along with other criteria influencing policy decisions. This also enabled the researcher to explore the extent to which various stakeholders believe specific policy choices favoured the development of waste-fed AD and whether stakeholders perceived actual or potential unintended consequences to have occurred. Interviews were conducted until a saturation point was reached, where an extra interview had nothing to add or contribute to the research. This round of semi-structured interviews also informed the construction of the dataset, selection of cases and LA representatives for the last round of interviews. For example, interviewees were asked to suggest a local authority, which can be characterised as an 'exemplar' in the use of waste-fed AD for the purposes of renewable energy production and waste management. Following the first ten

[20] A full list of the interviews is in Appendix I.

[21] The topic guide used at the second round of interviews can be found in Appendix III.

interviews, the case selection was reconsidered and redesigned due to the reflexive and interpretive approach adopted.

The interpretive stance of the researcher led to the adoption of a coding strategy that was theoretically informed, but not completely tied down to pre-existing theory in a way that may exclude important factors not previously considered. Coding data is an important stage for organising data into categories or instances of occurrence as it enables comparisons to be made between different groups of cases (Seal, 2016). Both interview and documentary data were catalogued, organised, and analysed using NVivo. Specifically, interviews from the scoping and empirical stage of research were transcribed, coded, and analysed in NVivo.

Coding of the data was made with the use of codes that were closely related with the factors and criteria of the analytical framework (as already discussed in section 3.5). Although these codes originate from four different academic literatures, they were set adaptively to prevent any over-reliance on deductive reasoning. Furthermore, the researcher was open to any themes dominating during the coding stage and they were also considered at the analysis stage. Data was coded to allow space for a narrative to be constructed for the role of national, devolved, and local levels of government in the deployment of an environmental technology, whose uptake brings a socio-technical transition towards sustainable development. This was essential to form the basis for the comparative analysis undertaken in Chapter 7. Overall, the coding and analysis of findings emerging at different stages of the research provided data that helped the researcher become familiar with the AD policy landscape in the UK and its uptake at the local level. This data benefited the research design, which was adaptive, and led to the update of the research design and sampling methods.

3.8 Ethical considerations

All respondents received the Participant Information sheet and Interview Consent form, attached in Appendix II. Consent was sought to record the interviews, and interviewees were informed that their participation in the research was entirely voluntary, and that they were able to withdraw their consent at any time before, during or after the interview. Most of the interviews were conducted online (through MS Teams, Skype, or Google Meet), but there were only five scoping interviews that took place face-to-face.

In many cases there was the possibility for follow up discussions or emails in the weeks or months following the interview. This two-way dialogue was often useful for the research to clarify any certain aspects of AD technology and industry and to develop new ideas and thoughts, while getting any updates on the latest developments in the sector. Moreover, the researcher got engaged in several discussions with industry and government practitioners at various specialist conferences and seminars on AD, organised by the relevant trade unions, such as ADBA, WBA and REA. At the beginning of each interview, interviewees were informed that any contributions would, where possible, be anonymised. They were also informed that data would be handled in conformity with both the University of Westminster's Code of Practice for Research, the Data Protection Act (2018) and the General Data Protection Regulation (GDPR). Following the guidelines of the UK Research Councils, interviews were transcribed and will be stored digitally for future reference and validation for the next five years. In addition, the ethical guidelines of the University of Westminster were followed from the beginning to completion of this research project. It is also worth noting that the data collection strategy was approved by the University's ethical review committee in January 2022.

3.9 Conclusions

This chapter has described how this comparative research was designed with the use of mixed methods to answer the research questions. The researcher is open, reflexive and attentive to detail and adopts an interpretive stance, which is reflected in the design, methods, data collection, coding, and analysis of the research. Consequently, this research was inherently open, explorative, and adaptive during the scoping and empirical stages. Data collection was divided into three key stages, which are closely interrelated with each other and the purpose of the research. The analytical framework guided the decision-making on the adoption of the 'best fit tools' to develop a mixed-methodological design and collect both qualitative and quantitative data. The first stage explored the influence of the environmental governance on AD development and the key actors of AD in the UK. The second stage explored the impacts of the devolved governance on waste-fed AD deployment, while focusing on England and Scotland. Documentary analysis and semi-structured interviews are two qualitative methods that were used during the first two stages of the research. The last stage focused on the comparison between Scottish and English LAs and used mixed methods, which include the construction of a dataset, descriptive statistics, and semi-structured interviews with waste managers of LAs.

Overall, I had a reflexive and adaptive approach to the research design, and any iterations aimed to achieve rigour and generalisability of the findings. Hence, the construction of a dataset with all LAs with waste-fed AD plants, the inclusion of descriptive statistics and an adaptive case selection strategy, respectively. From the beginning of the research, the data and findings from early stages informed the design of the subsequent stages. For example, the review of policy documents informed the selection of interviewees at the scoping stage and empirical stage. Furthermore, the emerging findings of the semi-structured interviews informed the case selection strategy, which was most-similar case selection and then changed to a purposeful sampling. The adoption of a purposeful sampling approach enabled to recruit experts, willing to participate from heterogeneous LAs which use IVC or AD. The study of six cases provides sufficient information about the core factors describing success of these LAs and can provide some form of generalisation to the population of LAs in the context of their contributions to the development of waste-fed AD. It also provides enriched data diversity and 'more width than breadth' in the research findings, as they are presented in chapters 4 and 6.

Every methodological approach has its own limitations, which need to be recognised. Overall, the methodological design was mainly researcher-led and justified, while the interviews were mainly interviewee-led. The risk of researcher bias was acknowledged and how this would influence empirical diversity, but the decision-making behind each methodological step is explicitly described in this chapter as there were also actions to address these limitations and risks. Time and resource restrictions and challenges to complete data collection were also considered throughout the research. It is likely that there would be certain conditions which influence the extent of theoretical generalisations. The implications of these conditions on the generalisability of the findings are discussed in Chapter 8.

Chapter 4 AD policy landscape in England and Scotland

4.1 Objectives and Structure of the Chapter

This chapter presents the deployment of waste-fed AD in the UK and an analysis of policy and regulatory conditions of the UK, which can influence its uptake. Chapter 2 presented an overview of the literature on sustainability transitions, including the key theoretical frameworks, the Multi-Level Perspective (MLP), the Technological Innovation Systems (TIS) and Transition Management (TM). However, this literature tends to overlook the issue of how cross-sectorial coordination among stakeholders can impact the deployment of environmental technologies, like AD. So, the research aims to address these gaps by exploring how AD is governed in the UK as an example of sustainability transition. This chapter has a purpose to explain the governance aspects of AD by presenting the key actors, levels of government and the different policy narratives, streams and instruments, influencing the AD deployment in the UK. AD has the potential to contribute to circular economy and the fight against climate change. The benefits of AD technology are closely related with the sustainable development goals as it provides opportunities for soil conservation, sustainable agriculture, waste recycling and renewable energy production (Duruiheoma, 2015), which can be promoted and utilised with mechanisms of governance in place. It is important to explore these mechanisms, which influenced the AD deployment in the UK so far, while recognising the power and impacts of key actors with various jurisdictions at different levels of government.

The UK is a unitary state, which has strong elements of multi-level governance, due to its devolution. The devolved administrations of the UK represent the national level of the devolved nations; Wales, Scotland and Northern Ireland and the local authorities represent the sub-national level of government. Local government is a devolved policy matter, so each devolved nation is responsible for the specificities of its LAs, but there are some commonalities. Policymaking at the devolved level can also be a contributing factor to different deployment rates of AD across the four devolved nations, however it has not been researched. This is the gap of knowledge that this research aims to fill in, while focusing only on England and Scotland. These two nations have concentrated most waste-fed AD plants in the UK, however there are important differences between these two devolved nations, which are worth exploring as factors influencing the deployment of waste-fed AD.

All these elements of (national, regional, local) governance can influence the implementation of policies on climate change, renewable energy, waste and environment in the UK and these policy streams can have an impact on the rollout of an environmental technology, such as waste-fed AD. The chapter illustrates how the deployment of waste-fed AD is influenced by different policies and levels of governance in the UK. It is rather a multi-level influence on AD, and this highlights the need for a multi-dimensional theoretical approach, which is essential for an in-depth exploration of factors, leading to local and national differences and success in the use of waste-fed AD.

4.2 Governance of AD in the UK

This section aims to explore how the existing governance of waste-fed AD in the UK makes the most out of its benefits and deals effectively with its challenges. Firstly, the section presents the plethora of state and non-state actors and their role in the development of waste-fed AD in the UK, along with the role of devolved administrations and LAs and its influence on the uptake of waste-fed AD. Secondly, the influential role of national government is examined by presenting the main policy narratives and streams affecting AD; environment, climate change, renewable energy and waste, while the role of devolved administration is highlighted in the devolved policy streams.

In the UK devolution, Northern Ireland, Scotland, and Wales have significant autonomy to shape and adopt their own policy and regulation in the sector of environment, including food waste, which is a key feedstock for waste-fed AD. This autonomy leads to policy divergence in the sectors of environment, climate, and waste (Velenturf et al. 2018), but within the framework, which was already set by the EU (Cowell et al. 2020). This was the status quo before Brexit when the UK was following the EU environmental governance. After Brexit, the role and influence of the EU policy is a key difference between England and Scotland, as the latter aims to maintain a close relationship with EU. European policy and incentives appear as a significant driving factor of governance in Scotland. In Scottish policy development, there is clear a reference to the EU legislation and regulations and their influence of the environmental policy agenda. For example, the EU Principle of Subsidiarity (as it is defined in Article 5(30) of the Treaty on EU[22]) still frames the processes of decision-making in Scotland. Decisions are aimed to be taken at the lowest level, which is the closest possible to the citizen, despite the dependence of LAs on Scottish Government and the UK Government (COSLA, 2014).

Overall AD can also contribute to the UK's energy, waste, and climate change targets (Röder, 2016), however the question I aim to address here is how the existing environmental governance of the UK influences the deployment of waste-fed AD through the different actors, levels of government, policy narratives, streams and incentives. Moreover, I also explore the policies and regulations adopted by Scottish Government in the different sectors which influence waste-fed AD deployment, while comparing them to the policy and regulatory framework in England, adopted by the UK Government.

4.2.1 State and non-state actors in AD

This sub-section presents the variety of state and non-state actors and their role in the development of AD in the UK. In the wider context of bioenergy, including AD, stakeholders are defined as those actors who are influenced by or can influence a decision (Röder, 2016). This broad definition includes a few different individuals, agribusinesses, farming communities, energy generators/providers, policy makers, regulators, local authorities and their residents, scientific researchers, and

[22] For more information on the Principle of subsidiarity, please check the following link: https://eur-lex.europa.eu/EN/legal-content/glossary/principle-of-subsidiarity.html

environmental activists (Röder, 2016). In the United Kingdom there is a variety of actors, which influence the governance and deployment of AD directly and indirectly at an international, national, regional, and local level.

Environmental governance is guided by emerging environmental issues and the agendas of various stakeholders. Each stakeholder has different jurisdictions and power, along with a particular policy interest and focus on different aspects of waste-fed AD deployment. The EU has set waste policy parameters across all Member States in a hierarchical arrangement, which was designed to provide consistency at a national level and this hierarchical approach worked in the environmental governance of the UK as the environment is a devolved policy issue (Cowell et al. 2020). Furthermore, the EU recognised the benefits of the integration of food waste management and AD process as a sustainable plan of biogas production from waste (Acharya and Cave, 2021). Since Brexit, Scotland and Wales seem keener to keep closer ties with the EU than the Westminster Government. Environment is a devolved policy issue, and the Scottish Government is keen to continue being in alignment with the EU environmental policy developments, whereas the UK Government is independently reassessing whether to retain or redesign environmental laws, which originated from the EU legislation.

The UK Parliament and Government Departments form the ministerial, high-level of governance, where the policy is conceptualised, formed, and driven. Department for Energy Security & Net Zero (previously called BEIS[23]) works on energy, electricity, renewables, and climate change, but has a clear focus on energy policy. DEFRA works on environment, waste, air quality, land use, agriculture, and pollution prevention. So, the division of jurisdictions and interests between these two departments is clear. However, environmental policy issues are complex and may need actions taken

[23] BEIS existed until March 2023, when it was split into three Departments: the Department for Business and Trade (DBT), the Department for Energy Security and Net Zero (DESNZ) and the Department for Science, Innovation and Technology (DSIT). Responsibility for national security and investment policy has gone to the Cabinet Office.

by more than one Department. Department for Transport is also important for the deployment of AD, because production of biomethane from AD plants can also be used in the transport sector. Biomethane can be used as a fuel of heavy trucks and consequently can contribute to the decarbonisation of heavy truck vehicles, the reduction of GHG emissions and noise, and improvement of air quality (EBA, 2023). There is also the Ministry of Housing, Communities and Local Government (MHCLG) whose work focuses on aspects of local government and local communities, which can benefit from the use of AD technology. The ministerial departments also have their own Arm's Length Bodies (ALBs), which are also government public bodies working closely with the Departments. For example, DEFRA works in close partnership with its ALBs, including the Environment Agency and Natural England, and MHCLG works closely with the Planning Inspectorate which is its executive agency.

Despite the fact, that policy is mainly adopted and shaped by the central government in Westminster, the UK has four devolved nations, which adopted their own environmental policy after the devolution. The role of the devolved governments and its influence on the deployment of AD are further explored here as the devolved governments have adopted policies related with the development of AD, while being in coordination with the centre and the EU. In the policy areas of environment, climate change, renewable energy and waste, decision-making expanded from the centre to the peripheries to include multiple levels and actors, but this also has various impacts at the different levels of the government. One of these impacts can be the different rates of the uptake of certain environmental technologies, such as AD, in the devolved regions of the UK. The UK Government has transferred decision-making authority and legislative powers to devolved tiers of government. The devolved administrations in Scotland, Wales and Northern Ireland have legislative authority, which covers a wide and increasing range of policy areas. The UK Government remains sovereign but adopts a position of non-intervention in these devolved policy matters.

Consequently, Scotland, Wales, and Northern Ireland enjoy different degrees of autonomy, and have set their own responsibilities and targets for the environment, energy, waste, agriculture, and fisheries. In the policy area of food waste, the devolved parliaments of Scotland, Wales and Northern Ireland have all mandated requirements for food waste collections by LAs. However, there is no mandate for separate food waste collections in England. The Scottish Parliament and Scottish Government set the legislative requirements for food waste management and treatment in alignment with the wider environmental targets. The Scottish Government has used its devolved powers to pursue long-term and ambitious goals for 'zero waste' (Cowell et al., 2020) and act on food waste reduction, prevention, and management. Furthermore, Scottish Government has developed a national strategy to support the integration of food waste to AD plants, while involving key actors who are presented in the following paragraphs. In renewable energy, Scotland has executive powers for the development of technology and full powers for planning approval, whereas Wales now has the authority to approve planning for energy projects risen to 350MW (Strachan et al. 2015). Overall Scotland has more devolved powers and more autonomy compared to Wales in law, order, and the judiciary (Haf et al., 2018). Although Northern Ireland has the most legislative powers in energy policy amongst the devolved administrations, but the least number of community-led energy initiatives (Strachan et al. 2015; Haf et al., 2018). In addition to the overall UK renewable energy targets, the devolved administrations set their own targets, which give a certain direction to their policies, as presented in sub-section 4.2.3.

Regulators work along with the Ministerial Departments for the coordination of policy implementation, which influences AD deployment in the UK. Environment is a devolved policy issue, so there is a different environmental regulator for each of the four devolved administrations. In England, Environment Agency (EA) is responsible for environmental regulations, waste licensing, planning permissions and environmental permits of waste-fed AD plants (EA, 2022; House of Commons, 2006).

It also sends inspectors to AD plants to check how these facilities are run to report and prevent any violation of permitting and environmental regulation, as in the past there were incidents of illegal digestate disposal (EA, 2022). DEFRA works closely with the EA to explore the impacts of permit requirements on AD deployment and enforcement mechanisms, with the aim of enhancing policy learning and further policy development, based on this cooperation (House of Commons, 2006). The EA deals with the operational side of AD plants, such as ammonia emissions from AD plants. There is also Natural Resources Wales (NRW), which is the Welsh regulator of the marine, forest, and waste industry. Scottish Environment Protection Agency (SEPA) is the Scottish regulator whose role is to protect and enhance the environment and human health, while ensuring that the existing regulatory framework supports sustainable economic growth. SEPA is in cooperation with Scottish Government, Zero Waste Scotland and other UK Government organisations and agencies, which work on the deployment and operation of waste-fed AD plants. The Northern Ireland Environment Agency (NIEA) is a regulatory body within the Department of Agriculture, Environment and Rural Affairs and aims to protect the natural and built environment, while supporting economic growth.[24]

There are also other government organisations and agencies who work on various aspects of natural and built environment and their work influences different aspects of the AD development and operation. The following organisations have jurisdictions and authority in all or different devolved administrations. The Office of Gas and Electricity Markets (Ofgem) is the the UK independent National Regulatory Authority, which aims to protect the interests of electricity and gas consumers and be responsible for the operation of renewable energy schemes. These schemes benefited the creation and operation of AD plants. Industry works closely with Ofgem so to maintain compliance to existing regulations (Thomas, 2016). Ofwat is the Water Services Regulation Authority, which regulates the water and wastewater

[24] For further information on the strategic purpose and priorities of NIEA, see: https://www.daera-ni.gov.uk/northern-ireland-environment-agency.

industry in England and Wales.[25] Ofwat also sets the regulatory framework of water and wastewater companies who own and operate AD plants processing sewage sludge. It is a key regulator for water industry as it provides funding to the sector, and this is reviewed every five years. The Animal and Plant Health Agency (APHA) is an executive agency of DEFRA and works on behalf of the Scottish Government and Welsh Government. APHA works on the regulatory framework for the disposal and use of digestate on land (DEFRA, 2014). Health & Safety Executive (HSE) is the regulator of Great Britain for workplace health and safety and controls the risk of major accidents at industrial sites.[26] It is also responsible for the health and safety regulations of the design, building and operation of AD sites, which also have to comply with the 'Animal By Products Regulations' (DEFRA, 2011).

Along with government and regulatory agencies, there are also not-for-profit organisations which work on resource efficiency, circular economy, responsible consumption, and production. For example, Zero Waste Scotland is a not-for-profit environmental organisation, funded by the Scottish Government, and undertakes research and informs policy and regulation development.[27] Zero Waste Scotland works closely with SEPA and APHA on regulations related with the operation of waste-fed AD plants. It also cooperated with the Industrial Biotechnology Innovation Centre, and they created platforms, which aim to bring together biogas producers, technology providers, researchers, policymakers, and investors (Pitcairn et al., 2017). However, the gas production is not regulated as regulations cover only catastrophic failures and digestate leakage from AD plants. Furthermore, most AD operators are not necessarily experienced gas operators and gas production from AD has risks, which need to be mitigated through regulations.

[25] For further information on the role of Ofwat, see: https://www.ofwat.gov.uk/about-us/.

[26] Further information on the role of the HSE can be found here: https://www.hse.gov.uk/aboutus/index.htm.

[27] Further information on Zero Waste Scotland is found here: https://www.zerowastescotland.org.uk/about-us/who-we-are.

In England, a similar role is played by the Waste and Resources Programme (WRAP) which is a climate action non-governmental organisation and provides advice and guidance on resource efficiency, food waste prevention, disposal, and collection. WRAP has played a key role in AD governance in the UK and brought together policymakers, industry, researchers, and the wider community (Edwards et al., 2015). WRAP works with governments, businesses, and communities to deliver practical solutions to improve resource efficiency and waste management in the UK and around the world. The Courtauld Commitment 2030 is a successful example of WRAP's work on these issues as it is a voluntary agreement across the entire UK food chain, which contributes to the reductions of food waste, GHG emissions and water use.[28] In the early days of AD deployment in the UK, WRAP had an active role in establishing the AD industry by providing technical expertise, evidence and data, funding and support with investment and loans and even contributed to capacity building through the creation of certification schemes to support the industry to develop (Edwards et al., 2015; WRAP, 2010). It also worked with LAs to support them with the adoption of food waste collections (Edwards et al., 2015).

LAs are responsible for the collection, disposal, and management of waste and play an important role in climate protection and production of clean energy (Webb et al., 2017; Iacovidou, 2012). In the case of AD, the local level of governance involves both state and non-state actors. LAs are key local actors of the AD infrastructure in the UK. The actions and services of LAs have explicit regulatory and statutory authority. Local government is responsible for the provision of major public services for people and businesses and employs a substantial workforce in specific areas. Examples of these services are social care, education, housing and planning, waste collection and recycling, licensing, business support, registrar services and pest control (LGA, 2020). Many of these services are directly provided by the resources and staff of the councils, while others involve regulating, monitoring, licensing, and certificating the

[28] Further information on the Courtauld Commitment 2030 can be found here: https://wrap.org.uk/taking-action/food-drink/initiatives/courtauld-commitment .

activities of public and private organisations (Game, 2005). Across the UK, around two million people are employed by LAs. Despite the diverse range of activities and services they deliver, they do not have a ‘power of general competence’ (Norton, 2016, p.308). Their role is also constrained within the confines of financial and regulatory powers held and policies pursued by national government (Norton, 2016). Since 2010 the UK has faced austerity, which meant deep and lasting cuts to government budgets, which were dedicated to LAs (Gray and Barford, 2018).

Local government in Wales, Scotland and Northern Ireland comes under the control of the relevant elected assembly and not the central government of Westminster in London (Jones, 2016), however their regulatory authority is dependent on the British Parliament. Local government consists of local councils, which is the most common type of local authority in the UK. There are several types of local government in the UK, but the most common differentiation is between one or two tiers of authorities (Table 4.1). The two - tiered local government – county and district councils- is evident in parts of rural England. Whereas in England, Scotland, and Wales, one tier of local government is evident through the presence of metropolitan and unitary councils. (Game, 2005; Norton, 2016). In England, London, Manchester, and other Combined Authorities are special cases governed by a mayor-led Greater Authority, illustrating more of a regional, than local model of government (Table 4.1).

Through the Local Authority Representative Organisations, LAs can communicate their needs, opportunities and challenges and engage positively with governments on various issues, related to the environment, energy, and waste management. The Convention of Scottish Local Authorities (COSLA) represents the Scottish local government and acts as the employer association on behalf of all 32 Scottish Councils. COSLA is a cross-party organisation which works on the political priorities of the 32 Council Leaders with the aim to secure the resources and powers they need[29], so it works as the mediator between Scottish Government and LAs. Local

[29] Further information on the role of COSLA can be found here: https://www.cosla.gov.uk/about-cosla.

Government Association (LGA) is the English Counterpart of COSLA, but it is bigger in size and deals with the wider issues of environment and climate change from a local

Table 4.1 Types of Local Councils in England	
Two-tier	
County Councils	Responsible for education, social services, transport, strategic planning, fire and public safety, consumer protection, refuse disposal, smallholdings, libraries, waste management and trading standards
District or Borough Councils	Responsible for council tax, local planning, housing, local highways, building regeneration, environmental health, rubbish and recycling collection.
Single tier	
Metropolitan Councils	Cover large areas and exercising all the powers presented above of county and district councils.
Unitary Authorities	Cover smaller areas and exercising all the powers presented above of county and district councils.
Combined Authorities	Cover areas of the joint member councils, while combining resources and powers devolved to them.
In metropolitan areas, some functions, such as fire, police, and public transport, are provided by joint authorities, with representatives drawn from each of the councils in the area concerned.	

Source: Norton (2016), LGA (2019)

perspective. However, LGA's work does not cover waste management and AD deployment in detail, these issues are under the remit of the Local Authority Recycling Advisory Committee (LARAC), which represents the local government recycling officers and has members from England, Scotland, Northern Ireland, and Wales[30]. LARAC represents the views and challenges of LAs in recycling, waste, and resource management, including food waste collections and the use of waste-fed AD plants by LAs. It is a network of waste managers of English LAs and has an Executive Board of 20 members serving LA waste management officers and organises various waste awareness programs and events. Furthermore, there is also an organisation called 'Local Partnerships' which is a key interface between LAs and national government as it aims to help councils and combined authorities in England and

[30] Information on LARAC can be found here: https://larac.org.uk/about-larac.

Wales to address climate change through waste efficiency and renewable energy. It is jointly owned by HMT, Welsh Government and LGA[31].

LAs have the power to make decisions at the local level. As planning authorities, they have a significant influence on the location of AD plants. However, there are also other stakeholders who play a key role in the deployment of AD and are influenced by the decision-making of both national and local level. Non-state actors involved in the AD sector are the following: manufacturing companies, equipment suppliers, AD operators, gas network operators, companies, big and small-scale AD plants, investment groups, consultancies, food processors, farmers using AD plants, households who collect food waste for AD plants, and the local community. There are also people who are willing to invest, run or own an AD plant and promote AD technology, with the aim of giving value to waste. For AD operators, the dialogue between the government and wider operator group is happening via their trade bodies, who represent their interests as it is easier for AD operators to directly contact the trade bodies.

Industry is a key stakeholder. In the UK, industry's interests are mainly represented and promoted by two trade bodies, which are the Anaerobic Digestion and Bioresources Association (ADBA) and the Association for Renewable Energy and Clean Technology (REA). Both REA and ADBA work on the promotion of bioenergy and biogas in the UK. They engage in different ways with the government, regulators, and their members, by organising conferences, working groups, and sending newsletters, providing AD certification schemes, and educational material to their members. Through this stakeholder engagement, they influence government support which enables AD industry to grow and thrive in both nations. ADBA is the trade association for the AD industry, companies and organisations working on novel technologies and processes which complement the AD process and products in the UK[32]. Furthermore, there is also the World Biogas Association (WBA), which has a

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[31] Information on Local Partnerships can be found here: https://localpartnerships.gov.uk/about-us/.
[32] More information on the role of ADBA is found here: https://adbioresources.org/.

close working relationship with ADBA and engages with the biogas industry at an international level[33]. REA is the trade association who undertakes activities of lobbying, networking, information, and communication and Renewable Energy Assurance Limited (REAL Ltd) is its subsidiary, which runs several certifying schemes, which focus on renewable energy, clean tech, organics, and composting[34]. Their members are small and large AD operators, AD developers, AD equipment providers, water companies, farmers, food & drink retailers, and waste companies.

Farmers and regulators can influence the quality of the digestate and biogas production, coming from AD plants. There is a big AD presence on farms and farming enterprises and National Farmers' Union of England and Wales (NFU) represents farmer's interests in the sector of AD. National Farmers' Union Scotland (NFUS) is the sister organisation who promotes the interests of Scottish agriculture to the national level of governance, both Scottish and Westminster governments[35]. End-user and farmer schemes ensured the good quality of digestate, which is safe to use on the farm for crops and animals and reassured farmers' confidence in spreading digestate on the ground. Quality Meat Scotland is an example of end-user as a certifying public organisation, which promotes the Scottish Red Meat sector with the aim to improve its efficiency, profitability, and its contribution to Scotland's economy[36]. It provides quality assurance schemes, which ensure good quality of meat by certifying the quality of land where the animals are fed. Along with Food Standards Scotland, who is the responsible actor for the implementation and monitoring of food and feed regulations in Scotland[37], they have worked together to ensure the impacts of digestate on land are safe for the food chain and guide farmers on how to use it. Zero Waste Scotland conducted risk assessments and field trials for the quality of the digestate and created guidance for farmers on the use of digestate and provided

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33 Information on the mission of World Biogas Association is here: https://www.worldbiogasassociation.org/mission/.
34 Information on the role and activities of REA can be found here: https://www.r-e-a.net/about-us/.
35 National Farmer Union Scotland: https://www.nfus.org.uk/about-nfus.aspx.
36 Quality Meat Scotland: https://www.qmscotland.co.uk/qms.
37 Food Standards Scotland: https://www.foodstandards.gov.scot/.

dedicated training for farmers who had the opportunity to share their experiences (Zero Waste Scotland, 2023). Encouraging farmers to use the digestate, providing them support to use it and then allowing them to talk about their experiences enabled them to build their confidence in using the digestate originating from waste-fed AD (Zero Waste Scotland, 2023). However, it is left to the farmer to decide whether they want to use the digestate effectively, otherwise the inefficient and unsafe use of digestate will have negative knock-on effects. Finally, businesses and households produce million tonnes of food waste annually and have a key role in participating to the food waste collection service and accepting the presence and use of waste-fed AD plants.

4.2.2 Policy narratives in England and Scotland

After identifying state and non-state actors in AD, gaining insight into how and why these actors frame issues is important. This understanding allows us to explore their thought processes, actions, and potential motivations for changing their perspectives and behaviour. Discourse and narrative are key factors to understand strategic positions and actions of policy actors (Fischer 2003; Hajer and Wagenaar 2003; Miedzinski, 2015). Discourse is 'a shared way of apprehending the world' (Dryzek, 2005) and informs policy discussions by examining communicative interactions among political actors translating problems into policy issues (Fischer, 2003; Miedzinski, 2015). Narrative is 'the main unit of analysis used to analyse policy discourses' (Miedzinski, 2015, p.78). Narratives help form policy tools, convince both decision-makers and the public, and influence every step of the policy process, in particular the phase of policy design (Crow and Jones, 2018, Silva et al., 2016; Miedzinski, 2015). In this section, I explore broader policy and political narratives in the UK and Scottish Governments, which shape rationales for divergent policies in the sectors of climate change, renewable energy, and waste. The divergence lies in the contrasting market approaches: a social market in Scotland and a liberalised market in England (Webb and Horst, 2021). Scottish policy divergence has been sustained by contrasting political-economic narratives in successive UK and Scottish

Governments (Webb and Horst, 2021). As a result, the dominant narratives in long term climate, energy and waste commitments shaped differently the deployment of waste-fed AD in England and Scotland.

In England, the UK Government's political narratives focused on 'liberalised markets, prioritising short-term energy supply prices, reducing green levies' on tariffs and ending public funding for energy efficiency' (Webb and Horst, 2021). Specifically, the UK Government has long emphasised the implementation of supply-side energy policies (Webb and Horst, 2021). This emphasis on supply-side energy policies is reflected on the promotion and use of renewable energy incentives. Consequently, long-term climate protection efforts in England have sometimes marginalised demand-side energy efficiency (Webb and Horst, 2021). In the case of bioenergy, there have been two contrasting narratives or visions for the future in the UK policy-making. The dominant vision supports bioenergy expansion within centralised energy systems, while the marginal vision advocates for decentralised biomass use which is managed by local communities, with the aim of recycling and carbon sequestration (Levidow and Papaioannou, 2016). The dominant narrative of the UK Government has been strengthened through stakeholder consultations which favour the industry co-investment and co-decision on policy priorities (Levidow and Papaioannou, 2016). The narrative of bioenergy centralisation, justified by cost-effective greenhouse gas savings, shaped evidence gathering for 'sustainable bioenergy' and influenced beliefs about policy problems and interventions (Levidow and Papaioannou, 2016; Boswell et al. 2011).

Since devolution, the Scottish Government's political narratives focus on a social market, social inclusion, and environmental justice, which have fostered strategic action in public policy (Webb and Horst, 2021; Scandrett, 2007). Consequently, these policy narratives positioned clean energy as a central element of the Scottish economy and contributed to divergence from UK policy in economy, energy, climate, and environment (Webb and Horst, 2021). Despite lacking powers over energy supply, Scottish policy-makers take a comprehensive and planned approach, leveraging specific policy institutions and funding, to influence energy demand and reduce carbon emissions (Webb and Horst, 2021). The alignment of government and industry actors in Scotland has been facilitated by framing renewable energy expansion as central to the nation's economic and environmental future, emphasising green jobs, growth, and international competitive advantage. Over time, party politicisation of renewable energy expansion has been minimal and Scottish Governments worked collaboratively across sectors and parties to influence the UK renewable energy policy (Webb and Horst, 2021; Cowell et al., 2017). The Scottish policy community on energy development contributes to legitimising the Scottish Government's assertive use of devolution powers (Cowell et al., 2017).

The climate and waste policy narratives in England and Scotland differ significantly. While England's approach emphasises economic growth and relies on market-driven solutions, Scotland aims for net-zero emissions by 2045, demonstrating a stronger dedication to climate action and sustainability (Webb and Horst, 2021). Scotland's more ambitious commitment emphasizes planning, sector-specific carbon budgets, social inclusivity, and institutions, such as the Just Transition Commission, for achieving net zero emissions (Webb and Horst, 2021). These policy narratives and instruments reflect Scotland's commitment to a sustainable future and its proactive approach to addressing climate change. These narratives also provide a comprehensive framework for transitioning towards a circular economy and achieving zero waste. In Scotland, zero waste policy is a distinct policy area, which belongs to the larger narrative of circular economy (Figus et al., 2020) and is reinforced with the development of waste regulation. However, in England the support of voluntary initiatives and the absence of waste regulation left circular economy as a marginal vision.

4.2.3 Policy streams of waste-fed AD

AD depends heavily on land, food, water, and energy systems and contributes to the reduction of the GHG emissions and related climate change as well as other environmental impacts on biodiversity, farming, and waste management.

Consequently, the wider environmental governance of the UK influences the deployment of AD. However, the policy aspects of AD deployment have received limited attention in the academic literature. This section aims to present how AD governance in the UK has been influenced by the policy streams of climate change, renewable energy, and waste management. The majority of policies and incentives focus on energy production and waste management; however, they do not regulate the simultaneous interaction of these two aspects of AD. In parallel, key strategies have been adopted by the UK Government and influenced the deployment of the AD sector. Levidow and Papaioannou (2016) refer to the multiple policy visions in which AD is included, because AD is illustrated as a solution to various social and environmental issues, such as decarbonisation, energy security, renewables, and rural development. The adoption of AD Strategy was the first step to set the vision for the AD and identified the barriers to its deployment in the UK, whereas the Action Plan set out the actions in detail (DEFRA, 2011). Although the AD strategy was an important first step and gave a boost to the AD industry, it was not the only factor which favoured a significant growth of AD plants since 2010.

Climate policy

Climate policy sets the foundations for a framework to address the problems of global warming and excessive amount of GHG emissions. Setting emission reduction targets has been a top priority of climate and energy policy agendas at international, European, and national levels. These targets are expressed as CO_2 eq and based on the contribution of the GHGs to global warming. In the global fight against climate change, the UK plays a distinctive role, because it adopted an ambitious national action plan, which has evolved through time. The use of waste-fed AD can help the UK meet its commitments as it can minimise or restrict the use of fossil fuels, reduce the GHGs emissions coming from landfilling of organic waste and displacement of mineral fertilisers. However, AD plants are responsible for harmful emissions of hydrogen sulfide, ammonia, siloxanes, methane, and carbon-dioxide, which form the GHGs emissions (Edwards et al., 2015; Vasco-Correa et al., 2018). For this reason, there is need for the use of the right technological equipment and adoption of measures for the abatement of ammonia emissions, which is already addressed as a challenge for AD deployment. Overall, climate change policy supports the use of renewable energy production and AD is an example of a low carbon technology, whose promotion and support via policy can lead to new investments and jobs in the AD sector.

At international level, the United Nations Framework Convention on Climate Change (UNFCCC) has played an influential role in the adoption of the European and consequently the UK energy policies (Ekins and Lees, 2008). Under the UNFCCC, the Kyoto Protocol set the target of the GHGs reduction by an average of 5 per cent during 2008-2012, in comparison to 1990 levels, and included individual legally binding emissions for the highly emitting 'developed countries' (United Nations, 1998). After the Kyoto Protocol, a new era of global climate efforts started with the 2015 Paris Agreement, which calls all nations to keep a global temperature rise well below 2 degrees Celsius above pre-industrial levels and their temperature increase, even further to 1.5 degrees Celsius (United Nations, 2015). The response of the EU to global climate efforts was the adoption of key policy documents: plans, roadmaps, and strategies by the European Commission. The initial response of the EU to the Kyoto Protocol's binding commitments was the adoption of the 'Energy Policy for Europe' plan by the Commission of the European Communities (CEC, 2007). The 20-20-20 plan focused on energy saving, emission reduction, the overall Union's energy demand to be addressed by renewable sources by 2020 (CEC, 2007). The Energy Roadmap 2050 (European Commission, 2012) and the Roadmap for moving to a competitive low carbon economy by 2050 (European Commission, 2011) set a series of guidelines to assist the EU Member States in developing their national legislation to promote further the reduction of GHG emissions.

In line with the EU targets, the UK has adopted Acts and taken policy initiatives to deal with climate change and energy transition. Because of the adoption of these policies in early 2000s, the UK is characterised as a global leader in addressing the challenge of climate change (Schaffrin et al., 2014; Lorenzoni and Benson, 2014). Previous policies, including the Energy and Climate Change Act 2006, paved the way to the adoption of the Climate Change Act 2008, which requires the reduction of its GHG emissions by 80 per cent on 1990 levels by 2050. The UK Climate Change Act is an example of best practice to combating climate change, supporting low-carbon transition to sustainability, and promoting changes to the energy system, which are reflected in subsequent energy policies. It also marked the energy transition narrative and its development in the UK (Aze et al., 2016). AD is included in this narrative of energy transition in the UK. Subsequent policies supported the energy reform further and addressed the reduction of GHG emissions. Examples of these policies are the Low Carbon Transition Plan 2009, the Energy Act 2010, the Energy Efficiency Strategy 2012, the Community Energy Strategy 2012, and the Energy Act 2013 (Aze et al., 2016).

In 2019 the UK became the first economy to adopt net zero emissions law by 2050. This amended the 2050 GHGs emissions reduction target in the Climate Change Act from at least 80 per cent to at least 100 per cent. Overall, the UK has installed five carbon budgets to control the achievement of its legislated target of 80 per cent GHG emission reduction by 2050 as they restrict the amount of GHGs, which can be legally emitted in a five-year period. The fifth carbon budget requires the power sector to be largely decarbonised by 2030 and emissions to be reduced to 57 per cent by 2030 on 1990 levels (Committee on Climate Change, 2016). In 2021 the UK Government adopted the climate change policy document, which is the Net Zero Strategy (Build Back Greener). The Net Zero Strategy sets out policies and proposals for decarbonising all sectors of the UK economy to meet the ‘net zero’ target by 2050. It also builds further on the Government’s Ten-point plan for a green industrial revolution (HM Government, 2020), which sets the plan for the creation of a green economy. The UK is also in the midst of a technological and societal change and its low carbon transition needs to reflect its wider societal transformation (CBI, 2017). The deployment of waste-fed AD has the potential to contribute to this transformation in the UK. However, this energy transformation is still dependent on nuclear energy, renewable energy, and offshore natural gas production, with the aim of decarbonising the energy sector (Edwards et al., 2015).

In addition to the GHGs emissions reduction target, the UK has also ambitious, legally binding targets, which are the 'National Emissions Ceilings' for five of the most damaging air pollutants, namely fine particulate matter, ammonia, nitrogen oxides, sulphur dioxide, and non-methane volatile organic compounds (DEFRA, 2022). These targets are set by the National Emission Ceiling Regulations (2018), which creates the legal duty to set out measures to meet the 2020 and 2030 emission reduction targets for these five pollutants. Despite these tough limits for ammonia emissions, which were based on a baseline of 2005, the UK missed reaching those limits and ammonia emissions exceeded the legally binding ceilings in 2020. However, in 2005 there was minimum AD development. The reason is that these ceilings were based on a baseline of 2005 when there was no significant development of AD and they need an adjustment so that they can exclude ammonia emissions, which come from AD of non-manure feedstocks (DEFRA, 2023). The revised Convention on Long Range Transboundary Air Pollution (CLRTAP) and National Emissions Ceiling Regulations (NECR) require the reduction of ammonia emissions by 8 per cent, compared to emissions in 2005 by 2020 (and by 16 per cent compared to emissions in 2005 by 2030) (DEFRA, 2023). Overall, the UK aims to reduce ammonia emissions, particularly from agricultural sources via the spreading of manures, slurries, and fertilisers (DEFRA, 2023). AD is also related with ammonia emissions originating from agricultural practices, such as the use and spread of digestate by farmers.

Scottish Government's ambitious climate change legislation sets a target date for net zero emissions of all greenhouse gases by 2045. The Climate Change (Scotland) Act 2009 motivated LAs to carry out their functions and provide their services in the most sustainable way that supports delivery of climate change targets. Furthermore, the Climate Change (Scotland) Act 2009 was amended by the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019, which sets the ambition of 'net-zero emissions target' to be reached by 2045 (Scottish Government, 2023). This is set five years earlier than the achievement of UK's net zero target, which is set for 2050. In May 2018, the Climate Change Bill included technical amendments the Climate Change (Scotland) Act 2009 and raised the ambition of the 2030 and 2040 targets to 70 per cent and 90 per cent emissions reductions respectively (Scottish Parliament, 2019). The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 also amended the Climate Change Plans to meet this target and included new measures, such as creation of a Citizens Assembly and a Scottish Nitrogen Balance Sheet. There is also the Just Transition Commission, which advises Scottish Ministers on how to build a fairer and greener Scotland, while maximising the social and economic opportunities of meeting our climate change targets and managing any risks and challenges (Scottish Government, 2021). Scottish Government has adopted a Climate Change strategic plan which highlights the importance of citizens' participation and emphasises the importance of achieving a 'just' socio-technical transition to achieve the Net Zero target by 2045. Consequently, all LAs need to reach this target, however the provision of commingled waste collection services, which lead to In-Vessel Composting (IVC) facilities, make this target harder to reach as IVC does not capture methane emissions as it is the case of AD technology. In the future, all Scottish LAs will need to adopt segregated food waste collections, which lead to AD plants.

Renewable Energy Policy

Energy policy is not devolved, so Scotland cannot control the subsidy system of the energy tariffs, which had a massive influence on AD deployment in the UK. Furthermore, Scottish Government has always been in favor of renewable energy and AD was perceived as a source of renewable energy and fertilisers, which can be produced and used in Scottish agriculture, while reducing the reliance on buying artificial fertilisers. The UK policy set foundations for the deployment of renewable energy technologies and adopted key strategies which led to a gradual increase in the use of renewables during the last twenty years. In addition, the gradual increase of renewables is strongly related with the policymaking in the renewable energy sector and the EU played a catalyst role. During the last two decades, a significant number of market-driven policy programmes and incentives were introduced to encourage and guarantee payments for the renewable energy deployment in the UK, including the operation of AD plants. It is important to clarify that the promotion of AD has not strictly been the main responsibility of the UK renewable energy policy (Duruiheoma, 2015).

At the beginning, AD deployment in the UK was strongly related with renewable energy policy as it was mainly seen as a form of bioenergy generation (Edwards et al, 2015). There are two strands of renewable energy policy in the UK; firstly, policies and strategies designed to address a range of other environmental problems, inspired by the EU Directives and secondly, a range of renewable energy incentives. Key strategies for the renewable energy and bioenergy were adopted for the promotion of these types of technology in the UK. Further different support mechanisms were adopted to incentivise the uptake of renewable energy technologies, including AD. The UK legislated the six incentive schemes to subsidise favourably all forms of renewable energy, including bioenergy from AD, which have been particularly influential for the farm-fed AD (Edwards et al, 2015; Duruiheoma, 2015; Redman, 2010).

The EU played a key role in the development of renewable energy policy in Europe. The EC Renewable Electricity Directive (2001/77/EC) set the first framework within which AD is a technology of renewable energy in the internal energy market (Lukehurst and Bywater, 2015). The EU Renewable Energy Directive (2009/28/EC) committed the UK to meeting the target of at least 15 per cent of renewables in the total energy consumption by 2020 and reaching the three sub-targets; 30 per cent in electricity, 12 per cent in heat and 10 per cent in transport. It also promoted bioenergy generation from organic waste, because of its significant environmental advantages, such as the GHG savings potential (Edwards et al., 2015; Vasco-Correa et al., 2018). In accordance with the EU 2030 Energy Strategy, the UK set the goal of

40 per cent reduction emission compared to 1990, which equals to a reduction of the GHG emissions of 1990 by about 465mt CO_2 eq in 2030 (Horschig et al., 2016).

In the UK the 2009 Renewable Energy Strategy and the 2011 Renewable Energy Roadmap were introduced to ensure that the right regulatory and financial framework was in place to enable the market to respond to the targets and sub targets of the renewable energy. The 2011 Renewable Energy Roadmap stated the actions to be undertaken for the deployment of AD and the support for better utilisation of biogas and biomethane produced (DECC, 2011). The 2009 Renewable Energy Strategy was an integral part of the UK Low Carbon Transition Plan to secure energy supply, tackle climate change and reduce GHG emissions. The use of more sustainable bioenergy and biogas is also underlined in the Strategy (HM Government, 2009) because of the wide range of sources and uses.

For the development of bioenergy, the adoption of the 2007 Bioenergy Strategy played a key role and recognised the role of AD in the waste management (DEFRA, 2007). It highlighted the role of AD for bridging renewable energy deployment with waste management (Zglobisz et al., 2010). Furthermore, the 2012 Bioenergy Strategy underlined the potential for energy recovery from waste and the optimum use of biomass as ways to maximise carbon and cost effectiveness (DECC, 2012). In 2023, the Bioenergy Strategy was adopted to highlight the opportunities for the use of sustainable biomass across multiple sectors of the economy to support the UK to reach its Net Zero target (DESNZ, 2023). Furthermore, it is the first Biomass Strategy which highlights the role of AD industry in the use and integration of biomass into energy systems. The Biomass Strategy 2023 sets this big overarching policy intentions of the sustainable use of biomass, production of fuel, electricity, gas or biomethane and their contributions to the decarbonisation of certain economic sectors. Nonetheless, reference to biomass sustainability criteria has been made clearer during the development of some key policy incentives, which influenced the deployment of AD in the UK and are presented below.

Policies and strategies tend to utilise incentives as a means of motivating farmers and investors to engage in renewable energy technologies, such as AD (POST, 2011). The incentives are introduced because there is a need for the renewables to get a competitive price, compared to the prices of fossil fuels, such as coal. So, they are introduced to promote the production and use of renewable energy and offer a specific price to attract enough potential producers of renewable energy to invest in this form of technology and meet a specified target. The actual price, which is awarded at the end, depends on several factors, such as the size and type of installation (Letcher, 2016). There have been five main financial support schemes in the UK, which have influenced AD deployment and are the following: the Feed in Tariffs (FiTs), Renewable Obligation Certificates (ROCs), Climate Change Levy, Renewable Heat Incentive (RHI), Renewable Transport Fuel Obligation (RTFO) and Green Gas Support Scheme (GGSS). These incentives aim to cover costs, generate revenue, and make AD technology more competitive against more established technologies of energy generation (Edwards et al., 2015; Vasco-Correa, et al., 2018).

The Renewables Obligation (RO) was one of the first and main financial policy mechanisms for large-scale renewable electricity generation projects (> 5 MWe) during 2002 – 2017. The RO imposed an obligation on licensed energy suppliers to source a specified and annually increasing proportion of their electricity sales from renewable sources, or otherwise had to pay a penalty. Electricity generators received the Renewable Obligation Certificates (ROCs) for the 'green electricity', produced from renewable sources and ROCs gave them a price for the produced electricity, which was above the wholesale market price (Skeldon et al., 2018). Energy generators who were unable to meet their target could buy the ROCs, via auction, from the suppliers who exceeded the levels of their obligation (Zglobisz et al., 2010). ROCs received for specific types of renewable energy technologies changed over time because they were reviewed, while taking into consideration their technological and economic development, every four years (Skeldon et al., 2018). The RO influenced the profitability of waste-to-energy technologies and the energy policy promoting the use of ROCs is related with the waste policy of promoting the use of AD plants (Zglobisz et al., 2010; Skeldon et al., 2018). ROCs provided a source of income to AD plants, decomposing biodegradable waste to produce methane, which was then sold as a renewable fuel or burned on-site to generate electricity (Skeldon et al., 2018).

Overall, the RO provided different levels of support to eligible renewable energy sources in the UK, including solar energy, onshore and offshore wind energy, biomass energy and marine energy. For example, AD was qualified for two ROCs per MWh, which doubled revenues, compared to the rest of renewable energy sources generating the same amount of electricity (Edwards et al., 2015; Zglobisz et al., 2010). However, Zglobisz et al. (2010) argue that the RO failed to encourage the deployment of emerging technologies due to lack of certainty on the future support. Further Horschig et al. (2016) present that the RO had a restricted impact on the production of bioenergy from AD, because it was not accessible to smaller-scale and community-owned projects. The RO was closed to new applicants in March 2017 and is replaced by Contracts for Difference (CfDs), but facilities built under the scheme before that date are still eligible for Renewable Obligation Certificates (ROCs) until the scheme closes in 2037. Along with RO, the Climate Change Levy supported the generation of renewable electricity in the UK. Under certain preconditions, AD facilities were eligible for a Climate Change Levy tax exemption, which had been given to non-domestic users of energy, such as businesses and the public sector (Vasco- Correa et al., 2018; Redman, 2010). The Electricity Market Reform (EMR) is now the main policy programme to promote investments in the low carbon electricity generation, while securing energy supply and improving affordability for energy consumers. EMR is the UK Government's policy response to the energy trilemma and was legislated via the Energy Act 2013.

Smaller-scale renewable sources and AD installations are mainly supported by the FiTs (Horschig et al., 2016; Voulvoulis, 2015) and the RHI, which provide a subsidy on a per kW basis of renewable power generated. The incentives have been an influential factor in the uptake of AD; however, it is not the only policy factor which supported the deployment of AD as this section aims to illustrate. The FiTs were introduced in 2010 to encourage the electricity generation from small-scale renewable sources and supported AD installations of up to 5MWe of electricity production from biogas (Horschig et al., 2016; Voulvoulis, 2015). The FiTs provided support to the AD plants in England, Scotland, and Wales, but it did not cover Northern Ireland (ISABEL Consortium, 2016). According to De Clerq et al. (2017), FiTs is the main UK policy mechanism for driving AD development as it has provided a predictable level of return for renewable energy installations. The RHI was introduced in November 2011 and its aim is to bridge the gap between renewable heat installations and mainstream heat sources (De Clerq. et al., 2017). It has compensated financially property owners who installed renewable energy sources to provide heat rather than the use of fossil fuels or the grid (Vasco-Correa et al., 2018). RHI supported biogas combustion in combined heat and power (CHP) and this aspect provided security for investment in AD plants.

These two renewable energy schemes supported the development of AD plants, however crop-fed processes were supported, without focusing on the use of waste. In their early days, both FiTs and RHI incentivised mainly the use of crops, without adopting a circular economy approach which would holistically consider the use of land, waste, and energy. However, the development of renewable energy schemes has been influenced by a series of accurate decisions. These decisions, which have progressively evolved over time, reflect the lessons learnt and are grounded in evidence (Adams et al., 2015). An example is the inclusion of biomass sustainability criteria after the review phase of the RHI in 2015 (DECC, 2015; Adams et al., 2015). The introduction of sustainability criteria ensures that the UK Government only supports financially the production of sustainable outputs and fuels, which are beneficial for the environment as they set a requirement to meet both a GHG savings threshold and land use criteria (Adams et al., 2015).

There is also the Renewable Energy Guarantees of Origin (REGO) scheme which certifies the eligible renewable output per megawatt hour to eligible generators. Prior to August 2015, the generation of renewable electricity could qualify for Levy Exemption Certificates (LECs), in case all eligible fuel suppliers of 450,000L demonstrated that the generated electricity was sourced from renewable energy (Voulvoulis, 2015). Since 2008 UK fuel suppliers are obligated to provide evidence that a specified percentage of the total supply of road transport fuel originates from renewable sources, under the Renewable Transport Fuel Obligations (RTFO). The RTFO is a subsidy related to the transportation of renewable fuels and requires suppliers to publicly report on the carbon savings and sustainable production of biofuels supplied. However, it is often related with fixed costs, which make the RTFO unsuitable for small-scale renewable energy generation through AD plants (Duruiheoma, 2015).

The Green Gass Support Scheme (GGSS) is the successor of the RHI and opened in 2021 for applications. Specifically, it provides tariff support for AD plants which produce biomethane, injected to the gas grid (DESNZ and BEIS, 2022). Tariffs are provided via GGSS with the condition that 50 per cent of input needs of the AD plant are covered from waste. This shows that policy learning from the sustainability criteria of RHI has been considered and reflected in the design and delivery of GGSS. Furthermore, under the GGSS, participants of the scheme have to cover digestate, which must be spread with the use of low emission spreading techniques to reduce ammonia emissions (DESNZ, 2023). GGSS tariffs are also calculated to provide funding to AD plants for the building of new infrastructure and operational costs. Consequently, GGSS enabled the supply of food waste to AD plants.

FiTs and RHI proved to be beneficial in increasing industry's confidence in investing in the sector of waste-fed AD during the last ten years. Sustainability criteria of RHI are also included to its successor scheme, GGSS, to ensure that 50 per cent of the AD plants' feedstock is residual waste (Ofgem, 2022). Overall, the renewable energy incentives have been valuable for the deployment of AD in the UK, but they had implications on its evolution and performance against social and environmental objectives.

Waste policy

Waste is another devolved matter, and each nation has its own waste strategy. Wales and Scotland have long-term goals in waste policy and have incorporated waste management strategy in the wider context of resource management and sustainable development, however this is not the case for England and Northern Ireland (Fletcher and Dunk, 2018). The four nations have adopted different strategies to manage waste and resources within their own boundaries, while taking into consideration the UK objectives. The devolved administrations published important waste management strategies: Waste Management Plan for England, Scotland's Zero Waste Plan, Towards Zero Waste – One Wales: One Planet and Delivering Resource Efficiency - Northern Ireland (Fletcher and Dunk, 2018). In Scotland and Northern Ireland, certain businesses are required to have separate food waste collections. In Wales, 99 per cent of households are provided with separate food waste collections (House of Commons, 2016). As a result, it has the lowest levels of household food waste going to landfill (WRAP, 2017).

The UK Government currently supports voluntary initiatives, rather than a regulatory approach, to achieve food waste reductions in England (House of Commons, 2016). The UK set the target of achieving a 65 per cent recycling rate by 2030 with the significant reduction of exported waste and residual waste ending in landfills (Zglobisz et al., 2010). The Landfill Allowance Trading Scheme aimed to benefit LAs which reduce the disposal of biodegradable municipal waste (Edwards et al, 2015; Zglobisz et al., 2010). This scheme allowed LAs which did not divert municipal solid waste from landfill efficiently to purchase surplus allowances from LAs which installed diversion efficiencies (Edwards et al, 2015). However, Zglobisz et al. (2010) criticised the fact that the investments on AD as a means of biodegradable waste treatment were limited. In addition to the scheme, a landfill levy was introduced and gradually became the main driver of diverting biowaste and industrial organics

(Edwards et al., 2015). Edwards et al. (2015) argue that as the landfill levy increased in the UK, there was an increase in the number of AD plants commissioned, however more research is needed to identify the real impact of the landfill levy on the growth of AD.

The Waste Strategy for England 2007 set policy priorities for waste management and the EU Waste Framework Directive 2008/98/ EC (WFD) influenced the legislation of the UK on waste management and the adoption of recycling targets by the UK Government and Devolved Administrations. Its aim was to turn EU member states into societies which prevent and recycle waste. In 2008, England had high ambitions for the waste sector and adopted a Zero Waste Places (DEFRA, 2008) initiative to launch a sustainable waste management, which was mentioned in the Waste Strategy for England (DEFRA, 2007). However, this initiative was withdrawn in 2010 due to the financial austerity (Cole et al., 2014). Then DEFRA adopted guidance on applying a waste hierarchy, which states the conditions when biowaste is not economically viable or feasible to be reduced or recycled, then it can be incinerated or end up in landfills (Edwards et al, 2015; DEFRA, 2011). The first three options of waste management are the following: prevention, preparing for re-use and recycling. According to the Waste Hierarchy (DEFRA, 2011), AD belongs at the fourth waste management option as another way of waste recovery, with the following options: incineration with energy recovery, gasification and pyrolysis which produce energy (fuels, heat, and power) and materials from waste. In addition, the PAS 110:2010, which are standards produced by the British Standards Institutions, define when biowaste-fed AD digestate is not waste, but is safe for land use (Edwards et al., 2015). So, the UK has developed capacity for biowaste treatment in the AD sector and the economic and technical arguments presented in the WFD seem quite broad, because they lack the specified conditions when prioritising incineration or landfilling over AD is acceptable.

In 2010, the UK Government made a commitment to work towards a ‘zero waste’ economy by introducing measures to increase energy from waste through AD

(DEFRA, 2011). In 2011 England adopted a Waste Review, which was criticised as lacking ambition and a missed opportunity to emulate the Zero Waste implementation by the Scottish Government (Cole et al., 2014; Hassall, 2013). In addition, the UK Government adopted the Waste Management Plan for England in 2013 to fulfil the mandatory requirements of the Waste Framework Directive (2008/98/EC) (DEFRA, 2013). This plan has clear reference to the AD Strategy and Action Plan of the UK Government and the connection of the waste targets and the potential of AD to achieve these targets.

Recently, AD and its outputs have been highlighted in a few strategies of the UK Government. In October 2017, the Clean Growth Strategy underlined the importance of best practices in AD and the reduction of methane emissions (HM Government, 2017b). The 25-Year Environment Plan outlines the Government's goals, including the 20 per cent reduction of per capita UK food waste by 2025 and the achievement of zero food waste entering landfills by 2030 (HM Government, 2018). AD can contribute to the achievement of this target, however it is not mentioned as a waste-energy recovery method. Furthermore, it recognises that many LAs have adopted separate food waste collections and the need to support the rest to adopt them, but it does not provide further clarity on how the LAs will be supported and whether they will be mandated to collect food waste separately from households. In the Resources and Waste Strategy, AD is showcased as 'the best environmental outcome for food waste, which cannot be prevented or redistributed' (HM Government, 2018a). However, it does not force English LAs to adopt AD as the best environmental way to dispose food waste. Better reference to AD is made in the Waste Management Plan for England 2021 (DEFRA, 2021), however it is illustrated as an alternative to composting for the disposal and treatment of separate bio-waste collections. The Waste Management Plan for England 2021 states the Government's commitment to increase the energy from waste produced through AD, but without any reference to specific targets (DEFRA, 2021).

Moreover, the Environment Act 2021 refers to separate collections of household waste from non-domestic premises. It gives an indication that separate food waste collections will be mandated in the future, but clarity, guidance and funding are needed for the adoption of these collections by LAs. Nonetheless the Environment Act 2021 recognises the need to enable LAs to deliver weekly separate food waste collections to prevent food waste going to landfill or being incinerated. It also recognises the additional financial pressures LAs will need to face to ensure that costs arising from new duties and additional equipment are met (DEFRA, 2022a). So, LAs need 'sufficient time to adapt to their new duties and to communicate changes with householders' (DEFRA, 2022a). The Environment Act is a key document as it sheds light on the practical issues of food waste collections by LAs. However, it recognises only the need for time for this transition to happen in LAs and it does not provide further clarity on issues of funding and guidance, which are needed by LAs.

A key difference between England and Scotland is the waste legislation. England aims to make it a requirement for LAs and businesses to segregate their food waste in 2023, while the Waste (Scotland) Regulations 2012 have been in force since 1st January 2014 (Zero Waste Scotland, 2023b). Since 2010, the Scottish Government has embarked on a more ambitious sustainability programme for waste and resource management, than the UK Government (Cole et al., 2014). In 2010, Scottish Government adopted the Zero Waste Plan, which was supported with the provision of £154 million during the period 2008 – 2011 at both local and national levels (Cole et al., 2014; Scottish Government, 2010). In the Zero Waste Plan, there is a clear recognition of the role of AD to process food waste originating from mandatory separate material collections (Scottish Government, 2010).

In Scotland, the introduction of waste regulations initiated the adoption of strategies which expanded from waste treatment or disposal to resource management (Cole et al., 2014). The introduction of the Waste (Scotland) Regulations 2012 brought a favourable change towards food waste recycling and treatment, which would not have been otherwise possible, as they mandated separate food waste collections with rural exemptions. The rural exemptions were stated as;

> 'An authority need not arrange for a receptacle to be provided under subsection (2) if-
>
> (a) the property is in a rural area, and the authority considers that the separate collection of dry recyclable waste from the property would not be environmentally or economically practicable; or
>
> (b) the authority considers that dry recyclable waste if not presented in a receptacle will be deposited at a bring site' (The Waste Scotland Regulations 2012).

In 2014 both LAs and businesses of non-rural areas began mandatory food waste collection and recycling, marking a positive step toward the supply of AD plants. Specifically, all food businesses generating more than 50 kilograms in non-rural areas to recycle their food waste. In 2016 the requirements were extended to include these businesses, which generate more than 5 kilograms of food waste (Zero Waste Scotland, 2023b).

Consequently, Scotland has adopted the mandatory food waste collections, which secured feedstock supply and increased the tonnages of waste-fed AD facilities. This also enabled AD plants to become more profitable and sustainable as they do not rely only on LAs, but also on businesses to provide them with food waste (Zero Waste Scotland, 2023b). The separate collections of food waste were very influential in the reduction of the food waste going to landfills and worked as an implementation mechanism of the 'waste hierarchy' (Scottish Government, 2017). Furthermore, they have been effective in the collection of commercial food waste as the businesses became aware of their obligations and needs of waste segregation. Since 2021, landfill operators of Scotland are prohibited from accepting biodegradable municipal waste. This ban on biodegradable municipal waste aims to decrease landfill use and greenhouse gas emissions, while maximising resource value from residual waste. It also encourages LAs and businesses to enhance food waste management strategies, with support and guidance from organisations, such as Zero Waste Scotland and SEPA (Scottish Government, 2019).

Scottish Government has adopted the Food Waste Reduction Roadmap and the Target Measure Act Programme, which aim to help Scotland's food and drink industry reduce food waste and tackle climate change (Zero Waste Scotland, 2023). This programme was developed by the Institute of Grocery Distribution (IGD) and WRAP as part of a route map to food waste reduction. By 2025, businesses registered to this programme will help achieve Scotland's ambitious target to reduce food waste by one-third (Zero Waste Scotland, 2023a). While this is the target set by Scottish Government, the participating businesses set their own individual targets of food waste reduction to register, report and track their own food waste (Zero Waste Scotland, 2023a). However, there is also a need to support LAs to revise their own food waste management strategies, because around two thirds of food waste come mainly from households (Materials Recovery, 2022). Scotland aims to reduce food waste by 33 per cent by 2025 and by 50 per cent by 2030 in food production and supply chains (Scottish Government, 2019). In the 2019 Food Waste Reduction Action Plan (FWRAP), essential actions to prevent food waste are set to prevent food waste in Scotland. In the Consultation paper for the route map to 2025, six key priorities are set to enable the Scottish Government to reach its overall waste and recycling targets by 2025 (Scottish Government, 2022).

Resource and waste management is closely related with circular economy as Scotland aims to become a circular economy where products and materials keep their value for the longest possible duration. Circular economy is also defined as part of the solution to the global climate emergency (Zero Waste Scotland, 2023c). In 2016, Scotland adopted a circular economy strategy to launch actions which aim to reduce the amount of produced waste and ensure that most of valuable materials are recovered after their usage. Making things last – a circular economy strategy for Scotland (Scottish Government, 2016) is a key document, which sets long-term targets for recycling and composting 70 per cent of all Scottish waste by 2025 and sending no more than 5 per cent of waste to landfill. This governmental effort of Scotland to adopt a circular economy model is also supported by the adoption of the Circular Economy Bill to make progress towards the 2025 targets (Scottish Government, 2022). Furthermore, Scottish Government adopted PAS 100 composting process or PAS 110 Anaerobic Digestion process, which define high quality recycling and process of food waste. They aim to turn collected food waste into a high value resource, while following the principles of circular economy.

England can follow the example of Scotland as there is need to divert the food waste from landfill to reduce the GHG emission generation. If England adopts the waste regulations, which mandate food waste collections, then AD investors and operators will be enabled to get feedstock for their AD plants and to plan their investments more sustainably. Overall, policy and regulatory frameworks of Scottish Government on food waste management, treatment, disposal, and reduction have been supportive for the deployment of waste-fed AD. Although in the UK most policies and initiatives focus on the efficiency of energy production and waste management, they do not regulate the simultaneous interactions of these two aspects of AD. Unfortunately, little attention has been paid to the maximisation of the benefits from these interactions (Voulvoulis, 2015). There is a need to promote efficient forms of energy from waste and reduce amount of residual waste going to landfills and AD is an environmental way to treat food waste, which cannot be prevented or recycled further.

4.3 Conclusions

This chapter presents the key stakeholders, the policy narratives and streams which influence the development of waste-fed AD technology. AD is an environmental technology which uses organic waste to produce bioenergy and biofertilisers. During the last decade, the introduction of financial incentives started increasing the number of AD plants and the amount of bioenergy they produce. Although most AD plants are in England, Scotland has achieved a higher rate of waste-fed AD deployment per capita than Scotland. However, AD has not yet reached its full potential of operation in the UK, despite the prospects in both the waste and energy sectors. The governance of AD can play this role of strengthening the positive aspects of AD technology, while limiting its negative impacts on the society, economy, and environment.

This chapter also maps state and non-state actors, policy streams and levels of government, influencing AD development in the UK. The devolved administrations of Scotland, Wales, and Northern Ireland have their own legislation and policy strategies in environment, climate change, renewable energy, and waste, enriching the policy context already set by the UK Government. The devolved nations have their own structure of local government; England has a two-tier local government (with county and district councils), whereas the rest of the nations have a single tier local government, named as local councils. At the national level of government, the focus is on the three main policy streams of climate change, renewable energy, and waste, because they represent the sectors, most closely related to the technology of waste-fed AD in the UK. Along with the renewable energy schemes, the UK addresses challenges in waste management, the green circular economy, and transition to net zero. There are also important benefits of waste-fed AD, such as the methane mitigation from (agricultural) waste, carbon sequestration and nutrient recycling in soil. These need to be recognised and rewarded holistically in the policies influencing AD deployment. Furthermore, all these need to be reflected in the adoption of an updated AD strategy, which needs to set a new vision for the role of the AD in the future, to address the economic, environmental and climate challenges ahead.

No single policy and level of governance influence the deployment of AD in the UK. Waste-fed AD deployment is a cross-sectorial policy issue, which is influenced by EU, the UK Government, devolved administrations and LAs. Across the devolved nations of the UK, there are differences in climate, energy, and waste policies, which can lead to lack of coherence in objectives and implementation across the devolved nations in environmental, energy and waste policy (Fletcher and Dunk, 2018). These differences between England and Scotland are explored in Chapter 7. While comparing Scotland to England, the policy context, which is shaped mainly by the national level of government, is proved to be an influential political factor for the uptake of a certain environmental technology, such as AD. Scotland has adopted a more ambitious and supportive policy and regulatory framework which provided a stronger support to the deployment of waste-fed AD than England. Apart from policy, governance, economic and geographical factors have also influenced AD deployment in the UK and are further explored in Chapters 5 and 6. Specifically, Chapter 5 illustrates a theoretical approach on governance effectiveness, which is used to explain national and local differences in the waste-fed AD deployment in England and Scotland in the following chapters. Furthermore, the role and initiatives of local government is also examined in Chapter 6, which shows how LAs influence policy implementation on the Scottish and English ground and the uptake of waste-fed AD in the UK.

Chapter 5 Analytical Framework

5.1 Objectives and Structure of the Chapter

The chapter introduces the factors which need to be considered when assessing the effectiveness of waste-fed AD governance. The research recognises the importance of the regional and local levels, along with the national level of governance as contributing factors to different deployment rates of waste-fed AD between England and Scotland. As already presented in Chapter 2, the sustainability transitions literature recognises the importance of governance in the transitions towards sustainable development, however the analytical and evaluative tools and methods of exploring transition governance have been under-developed (Patterson et al., 2017). An exploration of the national and local level is essential to investigate the different factors of policy delivery and success criteria, which influence the deployment of waste-fed AD. The analytical framework is 'outcome-orientated' because it is designed with a focus on the results or outcomes to serve as the criteria for evaluating governance on waste-fed AD. Specifically, it aims to assess the effectiveness of these outcomes because it will enable to identify the success factors of waste-fed AD deployment, while investigating the processes, characteristics and mechanisms which contribute to this socio-technical transition.

This chapter identifies propositions and factors to understand the differences in environmental governance between two different countries and/ or regions, influencing the uptake of an environmental technology. In section 5.2, the framework of governance effectiveness influencing waste-fed AD deployment is presented. The research uses this framework to identify the differences between England and Scotland, while focusing on specific factors. These differences may stem from the analysis of three main factors, which influence AD governance at a national and regional level: governance (sub-section 5.3.1), economic (sub-section 5.3.2), and geographical factors (sub-section 5.3.3). As presented in chapter 2, these factors and their interrelations are explored through the critical review of the following governance-related literatures: multi-level, network, and urban climate governance. Reflecting on these factors, some of them can explain the differences in the use of environmental technology at the national or devolved level, whereas other factors can evaluate its successful use at the local level. In section 5.3 I summarise the key points of this chapter. In the following chapter, I present how these factors and propositions are reflected on the key findings of the research.

5.2 The framework of governance effectiveness influencing the uptake of waste-fed AD

The analytical framework is built on a blend of these four governance-related literatures. The differences between England and Scotland in the deployment of waste-fed AD are explored through the lenses of three key factors: governance, economic and geographical. The following graph (Figure 5.1) shows the central role of governance mechanisms and how they are influenced and interrelated with economic and geographical factors. It presents an analytical framework which can be used in the comparison of two nations, with the focus on the uptake of environmental technology. This research focuses on the governance effectiveness in the sector of waste-fed AD in the UK. Table 5.1 presents the grouping of factors, along with their identity and origins from the academic literatures. Governance factors are coordination, learning and knowledge, autonomy, local experimentation, and internal capacity. There is one economic factor which is the market and one geographical factor, the urban and rural typology (Table 5.1). There are interrelationships between these factors, which are explicitly presented in Chapters 6 and 7.

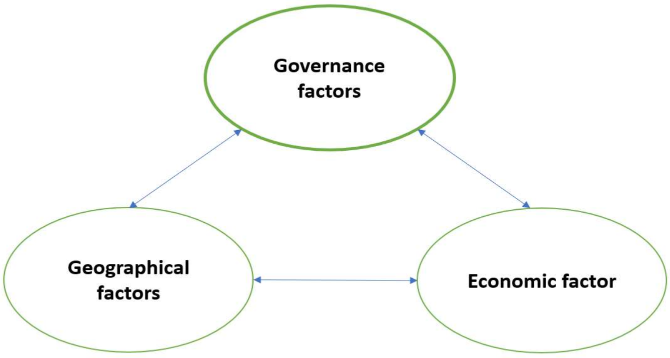

Figure 5.1 Analytical Framework of governance effectiveness in waste-fed AD

Table 5.1 Factors of the analytical framework		
Elements of Analytical Framework	**Identity**	**Academic Literatures**
Coordination	Governance	Urban climate governance, multi-level governance, network governance & policy networks approach
Learning and knowledge	Governance	Urban sustainability transitions, Urban climate governance, multi-level governance, network governance & policy networks approach
Internal Capacity	Governance	Urban climate governance, multi-level governance
Autonomy	Governance	Urban climate governance
Local experimentation	Governance	Urban climate governance
Market	Economic	Urban climate governance, multi-level governance, network governance & policy networks approach
Urban & rural typology	Geographical	Urban sustainability transitions, urban climate governance, multi-level governance

5.2.1 Governance factors

It is important to unpack the governance factors, while assessing how England and Scotland perform with reference to waste-fed AD deployment. The following are elements which are identified in the literature on multi-level, network and urban climate governance and this section presents how each governance factor is approached by each literature and how they are interrelated. Governance factors, which may influence the uptake of waste-fed AD in both England and Scotland, are shaped by the existence of different government levels, networks, and the role of LAs in these two devolved nations. Coordination, learning and knowledge, autonomy, local experimentation, and internal capacity are key governance factors which are influential for the uptake of waste-fed AD.

Coordination

As already presented in Chapter 2, the literature on sustainability transitions overlooks the dynamics, processes, and mechanisms of coordination among cross-sectorial stakeholders with different authorities and interests. In environmental governance, coordination plays a key role as it involves the collaboration, communication, engagement, and networks of all the different actors involved in the decision-making processes. The sub-section examines the factor of coordination while summarising key insights from the four governance-related literatures. Coordination is essential for effective governance and involves interactions between national and local levels of government, influencing their interrelationships.

In multi-level governance, there are two main types of coordination -vertical and horizontal- which reflect the interactions among different jurisdictions and power dynamics. The increased interdependence of different levels is recognised in the literature on multi-level governance, which explores the vertical (type I) and horizontal (type II) dimensions of governance (Hooghe and Marks, 2003). These two dimensions of coordination are also reflected in the multi-level environmental governance (Paavola, 2016), which emerged from European policy studies (Marks, 1992), the proliferation of the EU environmental directives (Jordan, 1999) and multilateral environmental agreements (Mitchell, 2003). Gary Marks (1992) was the first to investigate the coordination of different scales and levels of government in the networked and multi-level nature of European policymaking.

In type I of multi-level governance, the delegation of governmental functions and dispersion of authority to sub-state units involves a limited number of levels, and coordination takes place among sub-national levels, which have autonomy, responsibility, and accountability of their own policies. In this type of vertical multi-level governance, coordination is based on a more traditional assumption of hierarchical policy-making (Peters, 2006). The power dynamics and informal structures are mostly recognised in the jurisdictions of the horizontal (Type II) multi-level governance, which is characterised as fluid, complex, less hierarchical, and open to the participation of interest groups and networks. Referring to the two types of coordination, England is much more akin to the horizontal or Type II of environmental governance (Miller et al. 2000), whereas Scotland is more akin to the vertical or Type I as it has different links with the European and local levels (Eckersley, 2018). Corfee-Morlot et al. (2011) illustrate multi-level governance while using the following three layers of policymaking starting from the core, the inner periphery, and the civil periphery. The core is the centre of decision-making, the inner periphery is composed of non-departmental public bodies and government agencies and the civil periphery includes communities, households, and individuals (Markantoni, 2016; Corfee-Morlot et al. 2011). This illustration has been used for the model of governance in Scotland (Markantoni, 2016; Corfee-Morlot et al. 2011)

Although Hooghe and Marks (2003) provided this useful typology to describe the multi-level interdependence of actors, an in-depth investigation on coordination is essential for this thesis because coordination has the potential to steer the direction of sustainability transitions. Hooghe and Marks (2003) do not address the question on how these two types can influence policymaking and the ways they evolve and change in the future (Eckersley, 2018). As Muinzer and Ellis (2017) argue that the question ‘which is the most important scale or level of governance for sustainability-related actions?' is restrictive and neglects the four governance-related literatures, introduced above. So, a more inclusive question, addressing the 'resolution of environmental problems or conflicts' in the literature on environmental governance, can be the following: 'On what terms and within what parameters should different jurisdictions interact?' (Muinzer and Ellis, 2017 in Cowell et al., 2017, p.1146). Of course, these jurisdictions and power dynamics have different interactions which influence the processes of governance in different environmental issues. Consequently, these two types of coordination cannot explain which actors with different jurisdictions can influence the policymaking processes at the local level (Eckersley, 2018). This weakness may disable the in-depth development of multi-level governance as a robust theory; however, it can work as a useful analogy (Eckersley, 2018). This analogy, reflecting on the two dimensions of coordination, may provide a more fertile ground for a change in the interrelations between public and private authorities, especially on issues of environment, climate change and sustainability (Eckersley, 2018). It also provides an open perspective to identify overlaps and interdependences in stakeholder participation, communication, and coordination.

The research aims to investigate how LAs cooperate, coordinate, and communicate together for the installation and use of food waste-fed AD plants. So, the typology of different levels of government influencing environmental decision-making, provided by multi-level governance, is not enough to enrich our understanding on how LAs collaborate and with other public or private organisations. The literature on urban climate governance also refers to the vertical and horizontal coordination, while recognising the participation of actors in multi-level governance systems, which are important for climate action (Heijden, 2019). Wolfram et al. (2019) recognise the role of civil society, along with businesses, third sector, public authorities and academia in urban climate governance. A key aspect of urban climate governance is the recognition of coordination of actions taken by cities in the fight against climate change as they are important actors who do not work in isolation (Heijden, 2019).

Cities are members of multi-level networks, where they coordinate with municipalities, regional administrations, national government, and international organisations to ensure effectiveness in climate action (Kern and Mol, 2013; Johnson et al., 2015; Bulkeley and Betsill, 2013; Hughes, 2017; Clarke, 2017; Heijden, 2019). Argyriou et al. (2012) also stress the importance of peer support between LAs, which share together expertise in the field of sustainable energy development. A dedicated national government body or organisation may have the 'role of vertical coordinator' to 'orchestrate' actions and initiatives across actors from different sectors and levels of government (Abbot et al., 2016; Bäckstrand and Jonathan, 2017; Heijden, 2019). Similarly, the horizontal coordination works across different departments, agencies and organisations who engage in climate action. This type of coordination is also observed within a city or local authority as it involves different services, organisations, agencies, and departments (Heijden, 2019) and there is also the case of the 'horizontal coordinator', when a dedicated body or even working group at the local or city level focuses on the creation of synergies for the promotion or investment of an environmental technology which involves socio-technical transitions (Lee, 2016; Heijden, 2019).

Coordination is a common challenge faced by an organisation or a group of organisations in terms of leadership, orchestration, and participation. In a multi-level system of governance, the governing process is divided between distinct levels and involves a constant bargaining over policy development and implementation (Moran, 2011). So, coordination is not only a challenge within the same tier of government, but also among the different tiers and coordination problems are also reflected on policy efficiency. In the case of the UK, there may have been greater potential for conflict between the devolved administrations, but this was exacerbated by the fact that there was no framework for addressing systemically UK-wide questions. Because devolution is asymmetrical, establishing different relationships of each nation with the centre is also challenging, because the devolved administrations have no specific incentive to think UK-wide (Norton, 2016).

Devolution gave them the freedom to differentiate in environmental policy issues and adopt their own environmental regulations. The transition towards sustainable development may work as a good starting point for cross-sectorial stakeholders to come together to work in the interests of the UK, however the incentive to nurture this coordination needs to be explored in the case of waste-fed AD development.

Although the literature on urban climate governance focuses on the local level, the coordination is approached from the 'city' level, which sometimes may restrict the interrelationships among various state and non-state actors, who form networks and coordinate together at a micro and macro level. Networks are forms of organisations which interact, synchronise, and cooperate to provide services, tackle issues, and seize opportunities, disseminate information, foster innovation, and procure necessary resources (Kenis and Provan, 2009). The significance of networks is further emphasised in the field of urban climate governance literature, which recognises networks as key players in combating climate change at local, national, and even global level (Eissa and Khalil, 2022; Heijden, 2021). The literature on multi-level governance does not help us to understand the building of power relations and trust within policy networks, and to identify the most influential actors (Smith, 2003; Zito, 2015; Marquandt, 2017; Eckersley 2017a in Eckersley, 2018). The reason for exploring the literature on network governance and policy networks approach, along with urban climate governance is to identify the networks, related with the governance of AD in England and Scotland, and in particular their content, role, actors, relationships, and outcomes. It is vital to understand networks to explore in-depth policy processes in governance (Parag et al., 2013).

Networks are formed through the interconnections among individuals, organisations, initiatives, and actions. These linkages and collaborations give rise to projects and actions which define the network's role and essence. So, investigating networks within their specific contexts involves analysing the relationships among actors and examining their structure in relation to content and power dynamics (Parag et al., 2013). Lipsky (1971) refers to the role of 'street level bureaucrats' who form networks and influence the formation of public policies, such as teachers, doctors, nurses, social workers, and housing officers. Furthermore, there are usually diverse types of organisations, which are parts of these networks (Nagel et al., 2019). The state is one of the actors with a special role as it is not always a unitary actor in networks. At the local level, the state is represented by the LAs in the waste-fed AD related networks. However, members of a network may have different and conflicting interests and motivations, which should be managed to make the networks work (McGuire and Agranoff, 2011; Molin and Masella, 2016).

Relationships between actors can be formed within a network or between networks or even outside the influence of networks. Trust and mutual dependency are essential for the building of effective relationships within networks. Close interaction and communication among cross-sectorial stakeholders do not necessarily contribute to higher levels of trust. Trust and mutual dependency are also common to the two network literatures (policy networks approach and network governance), however the expected duration of the relationships among the various stakeholders is different in these two literatures (Vangen and Huxham, 2003; Molin and Masella, 2016). The key challenge of trust building is to overcome personal interests and preferences to build long-term and cooperative relations within networks (Molin and Masella, 2016). Vangen and Huxham (2003) assert that trust encompasses expectations, risks, and vulnerability within a cyclical process, enhancing collaboration and cooperation among the involved actors. The two network-related literatures recognise the benefits of trust, which are: the reduction of uncertainties (Klijn et al. 2010), the generation of mutual understandings (Provan and Kenis, 2008), the creation of positive relationships between stakeholders (Keast et al., 2006) and the promotion of resource and information exchanges (Vangen and Huxham, 2003). In networks, trust building is challenging as it requires an investment in time and resources from all participating stakeholders (Keast and Brown, 2006; Molin and Masella, 2016). Mutual dependency is created among stakeholders as they collaborate and accept their incapacity to deal efficiently with complex problems without the help of other collaborators (Sandström and Lars Carlsson, 2008; Ansell and Gash 2008; Molin and Masella, 2016). In this process of close interaction and collaboration, the building of trust brings its benefits (as mentioned above) to enhance and develop the network, its role, and outcomes (Klijn et al. 2010; Provan and Kenis 2008; Vangen and Huxham, 2003; Molin and Masella, 2016). Trust promotes stable and long-term collaboration and mutual dependency among network actors, and this influences the effectiveness of networks (Whelan, 2011).

In the policy networks and network governance literature, the state maintains a leading role because it steers both the decision-making processes and the activities related to network's goals and functioning mechanisms (Park and Rethemeyer 2012; Keast and Brown 2006 in Molin and Masella, 2016). In network governance, the State covers two main roles. At a macro level, it facilitates the definition of a shared vision, defines goals and objectives and it establishes adequate communication and accountability mechanisms (Keast and Brown 2002 in Molin and Masella, 2016). At a micro level, when the state acts within the network through public agencies, it participates as a network member, and negotiates activities with managers and other stakeholders (Keast and Brown 2002 in Molin and Masella, 2016). In this case, the State has a secondary role in managerial activities within networks, and the focus is on the operational activities of responsibility of the public managers involved. Public managers act independently and with the freedom of choosing the managerial strategy that seems most appropriate to achieve the goals of the network.

The role of the state is diminished in the process of policymaking by Rhodes (1997) who argues that autonomous and self-organising networks shape policy. Marsh and Rhodes (1992) focus on the impact of policy networks on the policymaking process in all fields and argue that networks shape the nature of decisions and constrain the power of government. The role of self-governing networks is also examined in the work of Elinor Ostrom on the management of common-pool resources (Stoker, 1998). Self-governing networks may lead to an accountability deficit, where the use of resources needs to be made among the state and other influential actors of the networks (Stoker, 1998). In the case of environmental policy, strong state management of networks is required for LAs to have more inclusive processes of policymaking (Hudson et al., 2007). Kickert et al. (1997) believe that the state directs the role of networks through network activation strategies, otherwise they end up being manipulative. However, criticism on the policy networks approach focuses on the underestimation of the role of the state in steering change in policy. A key criticism of the policy networks approach comes from Davies (2002) who argues that it fails to describe part of the policy reality happening on the ground and the influential role of the state, with reference to the field of urban regeneration. According to Davies (2002), there are certain conditions, such as funding, which are shaped by central government and regulation, influencing, and even framing the role and activities of these networks at the local level. Hudson and Lowe (2004) believe that lack of detailed empirical research on policy networks limits the degree to which Rhodes has tested and developed his approach to policy networks.

Participation in networks varies and may depend on the motivation of each participant. Evidence shows that participation in city networks positively influences urban climate governance at city level (Heidrich et al., 2016 in Heijden, 2019). Heijden (2019) specifically refers to the benefits of capacity-building and learning in networks as a result of active participation. However, some researchers argue that cities joining networks, may take advantage of 'the good name of a large network', but may not necessarily be active members of that network (Jonas et al., 2011 in Heijden, 2019, p.5). Other researchers observed that these networks have easily become networks of 'pioneers for pioneers' (Kern and Bulkeley, 2009) and do not always pursue a desirable climate action agenda (Bansard et al., 2017). There is a risk of such networks becoming an end in themselves rather than being a means to an end-goal (Johnson et al., 2015; Heijden, 2019).

Collaboration and participation of stakeholders is expected to improve the outcomes of urban climate governance (Chu et al., 2016; Kwon et al., 2014; Castan Broto and Bulkeley, 2013; Coaffee and Lee, 2016; Haus and Erling Klausen, 2011; Hes and Bush, 2018 in Heijden, 2019). The level of outcome analysis depends on the context of the network and reflects the level at which this network is formed and implemented. It also refers to the depth or scope at which we examine the effects of a network, and it varies based on the stage of network formation and implementation. For example, the outcomes of a local community network are different from those of a national or international network. The most quoted solution is that suggested by Sørensen and Torfing (2005), who see effectiveness and democracy of the governance process as the best dimensions to evaluate outcomes. Their model, known as 'democratic anchorage', emphasises that effective governance should be both efficient and democratic, while evaluating outcomes. Network outcome can be evaluated at two levels: services level, and decision-making level (Molin and Masella, 2016). In the policy network literature, the efficiency and innovativeness of the decision shape the outcome (Sandstrom and Carlsson, 2008).

In this analytical framework, coordination has been mainly derived from the literature on multi-level governance and urban climate governance. These two literatures illuminate the interdependencies and relationships between national and local levels of government, which significantly impact their collaborative efforts. Specifically, urban climate governance recognises a leading role of cities and LAs in the coordination of actions against climate change, whereas multi-level governance acknowledges the role of local government along with the other levels. Coordination is also illustrated as a challenging factor of governance effectiveness within the same and different tiers of government. Network governance and policy networks approach explore the coordination within networks and recognise the participation of non-state actors along with government organisations in this coordination.

Learning and knowledge

Learning and knowledge are essential for effective governance as they reinforce coordination. Efficient access to information, knowledge and learning is essential for mutual dependency and trust among stakeholders, within and outside networks involved in governance. Learning is also essential for adaptation which is required by urban sustainability transitions (Loorbach et al., 2017; Beers et al. 2010). These are key points of reference for the governance literature as they are reflected in its different literatures: urban climate governance, multi-level governance, network governance and policy networks. Aspects of learning and knowledge also significantly influence both local and national government levels, thereby affecting their ability to coordinate effectively.

The access to knowledge and information is a prerequisite of evidence-based or data-driven decision-making, which is also associated with accountability, transparency, and capacity building of the related decision-making processes (Hughes et al., 2020). It is needed for the processes of monitoring, evaluation and learning at various levels of government (Visseren-Hamakers and Glasbergen, 2007). The existence and use of performance-based indicators enable policy implementation and coordination (Visseren-Hamakers and Glasbergen, 2007), which may also influence the uptake of an environmental technology, such as waste-fed AD. Accountability is the responsibility to publicise these processes of governance, so they can be held to account. However, there are implications for how and by whom, local governments are held accountable (Hughes et al., 2020). Furthermore, learning fosters transparency by improving knowledge sharing and communication among various stakeholders. When people learn about processes, data, and decision-making, they can make informed choices and hold others accountable. Transparency is also enhanced when stakeholders learn how to share information openly and engage in communication with others. Learning is at the core of capacity building as it involves acquiring new skills, knowledge, and competencies to perform tasks effectively and reach certain objectives. By building their capacities, stakeholders can better address challenges, implement projects, and contribute to positive outcomes in areas such as infrastructure development, governance, and social inclusion. Learning and use of knowledge serve as catalysts for promoting accountability, improving transparency, and building the necessary capacity to address complex policy issues which are related with the success of a sustainability transition.

In networks, knowledge and problem-solving capacities are spread across actors who are highly interconnected and have different goals. The literature on policy network and network governance recognises that stakeholders, who participate in networks, are mutually dependent in terms of information, knowledge, learning and resources (Keast et al. 2004; Van Kersbergen and Van Waarden, 2004; Sørensen and Torfing 2009; Molin and Masella, 2016). Sharing knowledge and learning takes place within a multi-level network and can be evaluated to improve strategic interventions of environmental policy as it was the case of the local response to the Green Deal in Oxfordshire (Parag et al., 2013). The relative 'openness' of a network is related with the knowledge sharing and plays a crucial role in its effectiveness. Further, there are some open networks to exploratory learning and knowledge-sharing, which helps other networks or organisations to operate or make decisions (McGuire and Agranoff, 2011). McGuire and Agranoff (2011) highlight the importance of network interconnectedness and its influence on organisational performance.

In the literature on urban climate governance, knowledge and learning focus on the implementation of policies, initiatives and socio-technical changes happening on the ground and the lessons learnt from these. Sharing of knowledge between LAs is an effective way of encouraging stronger local action on climate change and the effectiveness of local initiatives and policies can be assessed and cross-compared with other LAs (Argyriou, et al. 2012). Hughes et al. (2020) recognise that there is a trend towards data-driven decision-making in urban climate governance, which can incentivise cities or LAs to focus on specific metrics and facilitate transitions towards the achievement of climate goals. However, the skills shortage in the energy industry can work as a significant obstacle to shape the energy agenda of the UK, because the lack of knowledge and skills may lead to inefficiency to engage in the formation of the UK energy agenda (Fudge et al., 2016). The investment in knowledge and skills of LAs can contribute to more resilient local economies and sustainable urban energy

(Hawkey et al., 2013). Moreover, entrepreneurship is defined by the skills and experience of people involved, and the economic and structural distribution of resources and the prevalent social, institutional, and cultural conditions (Boasson, 2018). Gordon (2016) argues that both network governance and urban climate governance show how cities make themselves accountable in climate action at both local and global networks.

In the literature on multi-level governance, learning is closely related with policymaking processes, such as policy implementation and evaluation, and is defined by various organisational, policy and social learning definitions and frameworks (Paraskevopoulos and Leonardi 2004; Kerber and Eckardt 2007; Borowski et al. 2008; Benz 2012; Gonzales-Iwanciw et al., 2020). Gerlak and Heikkila (2011) recognise that the most influential aspects on the types of learning and knowledge sharing are the design and structure of institutional arrangements, the dynamics of the social network, the technological and functional domains of collective structures.

Internal capacity

Internal capacity refers to the local level of government, such as city, local authority (LA), and municipality. The level of internal capacity within the municipality is suggested as a crucial factor influencing the nature of local governance arrangements (Pierre 2014 in Eckersley, 2018). In the literature on urban climate governance, internal capacity is defined as the LA's ability to achieve its policy objectives without having to rely on other actors for resources (Holgate 2007, Matthews 2012 in Eckersley, 2018). In this research, internal capacity is related to funding availability, use of infrastructure, and access to financial resources so to enable LAs in the adoption of an innovative, environmental technology. Furthermore, political support, leadership and public acceptability are also characteristics of the internal capacity of a municipality and essential for a transition towards sustainability. LAs have internal capacity as they provide and operate various services for the public and use communication strategies to enhance public's participation and knowledge. The role and capacity of LAs are explored to enhance our understanding on how they got involved in the use and uptake of waste-fed AD in the UK.

In the multi-level governance literature, the concept of internal capacity within LAs is critical. Robert Agranoff's work emphasises a bottom-up perspective, focusing on LAs' operational challenges and their role in managing relations with other stakeholders in the context of complex intergovernmental networks (Caponio, 2019). The capacity of LAs lies on their ability to make joint decisions addressing local governance problems with other levels of government, non-governmental organisations (NGOs) and relevant actors. This decision-making capacity of LAs is related to their ability to achieve policy objectives, encompassing service, evaluative, management and organisational capacities (Eckersley, 2018). Further unpacking this capacity, LAs have the abilities: to efficiently deliver services to its constituents, to assess and evaluate their policies and interventions effectively, while coordinating the complex systems of relations with other state and non-state actors. Multi-level governance arrangements require LAs to work collaboratively and coordinate across institutional resources to access resources and knowledge for the achievement of certain policy objectives.

The literature on urban climate governance analyses the four main roles of LAs in the efforts for climate change mitigation and adaptation (Betsill and Bulkeley 2007; Bulkeley 2013). These four roles of LAs frame their behaviour in terms of responsibilities, jurisdictions, power, and initiatives, while positioning LAs at the centre of urban climate governance. Specifically, local governments can self-govern, ensure provision of infrastructure, enable new forms of governance, and regulate. Firstly, self-governance may take the form of internal emissions monitoring procedures for local administrative buildings or measures designed to reduce those emissions. Secondly, they can also ensure the provision of a low-carbon or resilient infrastructure. Thirdly, they can enable new forms of governance through new forms of partnership between civil society and private actors, which experiment with innovation or start adopting behavioural change outside of a binding regulatory framework. For example, this type of enabling activities can include education campaigns to encourage public-transport use or awareness campaigns to reduce food waste. Fourthly, LAs can adopt regulatory frameworks intended to influence behaviours and outcome, including taxes, subsidies, land zoning, congestion charges and land-use planning (Bulkeley, 2013; Bulkeley and Kern, 2006; Lemprière, 2016).

The local political context is also influenced by the wider regional, national political and legislative context (Heijden, 2019). In the case of climate change, there are cities more likely to engage in climate action in contexts which are clearly more supportive in climate action than those that are not (Boswell and Mason, 2018 in Heijden, 2019). Examples of various regional and local policy initiatives and targets are the following: the Low Emissions Strategy (emissions targets in different categories) in the LAs, the adoption of Low Carbon initiatives, the recycling targets, and the renewable energy targets of the LAs. The collaboration and coordination with other LAs, government and non-governmental organisations is essential for the integration of LAs in the wider climate-friendly policy context. Political parties are key actors in the local issues related with environmental degradation and sustainable development so they can prioritise these issues differently in their political agenda both at a national and local level and even influence the LAs accordingly within a multi-level governance context (Caponio, 2019).

Another issue of political and public attention is the investments in the renewable energy and waste sectors. 'Investments in energy infrastructure are often politicised at a local level' (Li et al, 2016, p. 25). Consequently, this local reaction can affect the acceptability of a technology by the public. In this case, the internal capacity of LAs lies on its ability to consider and address local reactions, while ensuring effective policy implementation and public service delivery. Community attitudes towards different technologies may be heterogeneous and subject to change through time. For example, recent UK research into the public acceptability of different energy technologies has shown support for wind and solar energy in principle, but this has not blocked the expression of significant objections to onshore wind farms to be positioned near local communities (Li et al., 2016; Eltham et al., 2008). Nonetheless, community attitudes to certain energy and waste technologies can be positively influenced by the communications strategies and campaigns of the LAs.

Understanding and enhancing the internal capacity of LAs play a crucial role in navigating the complexities of multi-level governance and ensuring effective policy implementation and service delivery. Despite the recognition of the four key roles of LAs by the literature on urban climate governance, LAs have authority on taking initiatives and actions which influence a sustainability transition, but they are dependent on the multi-tier arrangements of other institutions and entities. Effective internal capacity lies on a convergence of the approaches of multi-level governance and urban climate governance. Effective internal capacity enables LAs to make decisions and take actions, while engaging in collaborative efforts to share knowledge, access funding and coordinate actions with other stakeholders.

Autonomy

In this analytical framework, autonomy refers to the autonomy of LAs. This is also the case in the literature on urban climate governance, autonomy is closely related to the local level of government. It is defined as the autonomy for expressing their needs and making decisions in taking urban climate action and governing local affairs (Johnson, et al., 2015; Hein and Pelliter, 2006; Bulkeley and Betsill, 2013 in Heijden, 2019). According to Eckersley (2018, p.141), ‘we should not confuse capacity with autonomy, which refers to the degree of freedom from central direction’. Lemprière (2016) refers to it as a degree of voluntarism. For example, municipal voluntarism involves voluntary activities and initiatives undertaken at the local level to address climate change, through the participation of municipalities in national and international networks (Lemprière, 2016).

Autonomy of LAs is dependent on a patchwork of duties and entitlements from the national and local level of government. Local autonomy is shaped not only by central-local government relations, but also by the processes of decentralisation and privatisation. Decentralisation refers to the transfer of decision-making power and responsibilities from central government to sub-national entities, such as LAs. When local governments have more authority over decision-making, they can tailor services to local needs and preferences because they gain the flexibility to adapt policies, allocate resources, and respond directly to community demands. Privatisation involves transferring public services or functions to private entities and provides a range of choices available to LAs as they can contract private providers for specific services to gain access to specialised expertise, technology, and innovation. Nonetheless, LAs must carefully weigh the benefits of choice against potential risks, ensuring that privatisation aligns with public interests (Kyriacou and Roca-Sagalés, 2019). According to Heijden (2019), processes of decentralisation and privatisation strengthen the autonomy of LAs to make their own choices across a range of local policy areas, including climate change. However, the autonomy of LAs is reflected in the adoption of their own climate change initiatives, which are tailored to their local needs and problems, but are often in accordance with the national climate regulatory and policy framework in their service provision to the public by giving them more choices (Heijden, 2019). Overall, Heijden's work acknowledges that decentralisation and privatisation can enhance LAs' autonomy and choices, but underscores the need for service quality, accountability, and cost-effectiveness to achieve optimal outcomes for the public benefit.

Autonomy is closely related with internal capacity as they both focus on the local level of government. LAs can take autonomous initiatives to address various problems, but this does not guarantee they have the necessary capacity and resources or regulatory authority to act independently. LAs with substantial autonomy may face limitations due to insufficient resources, an ambiguous constitutional status, or reliance on alternative sources of revenues. Paradoxically, increased freedom from higher levels of or central government could diminish the capacity of a municipality, necessitating greater reliance on external actors to achieve its goals (Eckersley, 2018). Research by Homsy and Warner (2015) suggests that such arrangements may leave subnational governments with fewer resources to formulate effective sustainability policies compared to jurisdictions receiving support from other tiers of government in the United States of America (USA).

Local experimentation

Experimentation is attracting attention in different literatures and is increasingly mentioned in the academic discussions on the governance of climate change (Hildén et al. 2017; Huitema et al., 2018). In the transitions literature, 'experimenting is a way to unpack complexity and to gather evidence on the new relations and new roles that a transition requires' (Loorbach et al., 2017, p.614). For example, TM is an approach, which perceives experiments as the foundations for a societal and technological change (Voß et al. 2009; Huitema et al., 2018). Governance experimentation can influence positively the trajectory of sustainability transitions. In the literature on urban climate governance, experimentation is associated with self-initiative and self-organisation of the local level to innovate, test, pilot with the aim to trigger a wider change. In this research, the focus is on local experimentation, which is the experimentation initiated by the local level of government. Local autonomy is a prerequisite for experimentation.

Cities are seen as 'active sites of experimentation' (Jordan et al., 2018), where a policy programme can be piloted, and an environmental innovation can be tested. Moreover Bulkeley et al. (2016; 2019) adopted the term the 'urban living laboratory', to illustrate how and why these forms of experimentation are adopted and learn about the impacts of these urban interventions. This type of sustainability experimentation attracted attention across Europe as it led to new collaborations among LAs, community organisations and universities for the generation and implementation of local knowledge (Bulkeley et al. 2019). The 'urban living laboratories' have the same following characteristics:

> 'geographical embeddedness, learning, participation and user involvement, novel models of leadership and ownership, and evaluation' (Voytenko et al. 2016 in Bulkeley et al., 2019, p. 12).

Nonetheless, experimentation needs a supportive political and legal context at a local and national level for various niches to exist and start developing at a city level (Nejaime, 2009; Heijden, 2019).

In addition, the influence of experimentation on the encouragement of learning and governance innovation still needs to be proven. It may be useful to experiment with distributed forms of monitoring and evaluation to engage more people and enhance the knowledge process (Jordan et al., 2018). However, experimentation may be selective; focusing only on certain policy areas and methods of evaluation and can be used as an excuse to delay policy action (Jordan et al., 2018). Attention is often caught by short-term results, and it is not focusing on actual, diverse, and long-term results.

In the literature on urban climate governance and urban sustainability transitions, experimentation is seen as a positive factor which supports innovation, learning, knowledge sharing and collaboration among different stakeholders. As a factor of governance effectiveness, local autonomy enables experimentation, because it allows LAs the freedom to explore and assess new approaches. Despite their autonomy, LAs often resort to experimentation, due to limited funding, restricted resource access, and lack of a regulatory framework. So, there is need for research to prove whether and to what extent local experimentation is an influential governance factor in the case of a waste-fed AD deployment in the UK.

5.2.2 Economic factors

Market

By considering the role of markets, governance can help create an environment which aims to balance efficiency, growth, equity, stability, and sustainability. This sub-section explores how market is explored in the sustainability transitions literature and aims to identify additional elements related to the market, while drawing insights from the literature on multi-level governance, network governance, policy networks approach and urban climate governance. In Chapter 2, the role of markets is recognised as a complex topic in the sustainability transitions literature.

In the frameworks of MLP, TIS and TM, the market is a key factor in influencing the progress of sustainability transition. Overall, the function of the market is not static or pre-established in sustainability transitions, but instead relies on the specific context, the involved parties, and the governing systems in place. Market power and sustainability are closely related so to facilitate a sustainability transition, it is essential to reduce market failures (Biely and Passel, 2022). In addition, dominant actors and policies can raise or lower market power and its impacts on sustainability (Biely and Passel, 2022).

In the multi-level governance literature, the role of the market is multi-dimensional and examined in the context of shifting power dynamics and authority across various governance levels, spanning from local to global scales (Caponio, 2019, Bache and Flinders, 2004). The interactions of the market with the different levels of government can shape policy decisions and influence the distribution of resources and opportunities (Bache and Flinders, 2004) for niches and innovations to develop further. The private sector has power and authority across the various levels of government from local to global. Caponio (2019) recognises that neoliberal reforms in public administration have led to privatisation and decentralisation of public services, which were held and managed before by LAs. Consequently, this increased the influence of the private sector in the 'vertical intergovernmental relations and horizontal networks between public institutions and private organisation' (Caponio, 2019, p.372). Nonetheless, the market's role is not always beneficial because market-oriented strategies can result in disparities and marginalisation, especially when market forces operate without any restraint or control from the state.

In the urban climate governance literature, the presence of market is not simply recognised as the private sector, but its role is identified as a driver or a barrier to urban climate action. Market can work as a driver of urban climate action. For example, Heijden (2021) suggests that market forces, such as consumer demand, corporate social responsibility, green innovation, and competitiveness, can motivate cities to adopt and implement ambitious urban climate strategies and policies.

However, cities need autonomy to make relevant decisions and internal capacity to adopt and implement these strategies and policies. Furthermore, Gordon (2018) argues that cities can leverage their economic power and influence market behaviour, with the aim of fostering low-carbon transitions. There are also cases where market can work as a barrier to urban climate action. The reliance on voluntary actions, the lack of accountability and transparency, the uneven distribution of costs and benefits, and the potential trade-offs with social and environmental justice can cause challenges and limitations of market-based approaches to urban climate governance (Barbi and de Macedo, 2019). Furthermore, Hughes and Hoffmann (2020) criticise the marketisation of urban climate governance and call for a more democratic and inclusive approach that addresses the root causes of climate change and its impacts. However, there are cities which use market-based instruments as tools for their actions against climate change, such as carbon pricing, green bonds, public-private partnerships, and social enterprises. The research explores how LAs' decisions can influence the market development of waste-fed AD in England and Scotland.

In the network governance literature, the market plays a significant role because it serves as a mechanism of coordination, which influences the modes of network governance and representation within these networks. The dichotomy between market and hierarchies is a key academic debate in the network governance literature developing from the work of Williamson (1975) 'Markets and Hierarchies' (Provan and Kenis, 2008). This academic debate emerged regarding whether networks are merely an amalgamation of market and hierarchical elements, thus positioning them on a continuum between the two, or if they should be recognised as distinct governance structures (Powell, et al., 1990; Provan and Kenis, 2008). The hierarchical approach argues that the network is a discrete form of governance, characterised by rule-bounded bureaucracy, authority, and administration (Provan and Kenis, 2008). The market approach is characterised by price, self-interest, competition, and formal contracts (Provan and Kenis, 2008). The combination of these two approaches has the potential to make networks more effective than operating only in a market approach or a hierarchical approach.

5.2.3 Geographical factors

This research seeks to explore whether geographical conditions of Scotland have been more favourable for the deployment of waste-fed AD than in England. Geography is a key factor to explain energy, socio-economic and spatial relationships, which are created due to the changes brought by the deployment of waste-fed AD. The value of the geography is recognised only by the literature on multi-level governance and urban climate governance, which refers clearly to the importance of scale, but not from a spatial and place-based dimension. This is the reason why the geographical factors are explored here with key insights drawn from the literature on sustainability transitions. In the sustainability transitions literature, there are three conceptualisations of space, which are drawn from theoretical insights of economic geography: evolutionary, institutional, and social (Hansen and Coenen, 2015; Binz et al. 2020; Losacker et al., 2023)

In the literature on multi-level governance and urban climate governance, geography provides the spatial context to identify the levels of decision-making and the interactions of these levels. In other words, scale of governance works as a point of reference in the literature on multi-level governance and urban climate governance to differentiate the influence of a certain level of government within a specific territory. However, there is a subtle difference between these two literatures. On the one hand, multi-level governance does not signify which level of governance is the most important under which circumstances (Görg and Rauschmayer, 2009). While the literature on multi-level governance suggests physical boundaries and geographic divisions, its most essential characteristic is the connections that bridge these levels (Görg and Rauschmayer, 2009). For example, Newig et al. (2016) explore the implementation of the EU Water Framework Directive across the different governance levels and geographical scales to analyse the links among participation, scale, and decision-making. Newig and Fritsch (2009) refer to the 'spatial scale of governance' when dealing with environmental problems, which appear on various spatial scales without necessarily distinct limits. Furthermore, the scalar dimension refers to a 'unit of analysis', which is useful in the case of comparison to examine the position or location of various units on a scale (Gibson et al., 2000 in Newig et al. 2016). On the other hand, urban climate governance highlights the role of the local level, with a reference to a city or local authority. Specifically, Bulkeley (2012) refers to the 'geography of authority' in the governance of climate change and recognises that

> 'where power is viewed as a held set of capacities, its geography is usually considered to be a straightforward matter of the spatial extent or scale over which it may be exercised' (Bulkeley, 2012, p.2433).

The research aims to explain the differences between England and Scotland in the deployment of waste-fed AD in the UK, so the spatial dimension is a critical factor for differences. However, the review of related-governance literatures can only provide a unit of analysis in terms of the place-based dimension. In these two literatures, this recognition of geography is not enough to provide specific spatial characteristics which can influence the development of waste-fed AD as a niche in sustainability transitions. Examining the effectiveness of governance also requires a thorough understanding of geography, as the specific geographical conditions impact the exercise of governance. Murphy and Smith (2013) observe that in the realm of renewable energy, numerous types of natural resources are found predominantly in outlying areas, where the lack of adequate infrastructure poses a challenge on the development of renewable energy.

During the last years, there was a growing body of studies which recognises the influence of geographical factors on energy systems and their transitions, including regional and local conditions and dynamics and socio-spatial formations (Balta-Ozkan et al., 2015; Bouzarovski et al., 2017; Bridge et al., 2013; Castan Broto and Baker., 2018; Hansen and Coenen, 2015; Solomon and Cavert, 2017; Golubchikov and O'Sullivan, 2020). Binz et al. (2020) emphasise the need of incorporating the geographical concepts of scale, place, and space in the sustainability transitions literature as they play a role in shaping capabilities and capacities, which influence innovation practices. Bridge et al. (2023) and Mourato and Wit (2022) agree with the idea of shifting the focus of the sustainability transitions literature from innovation processes to processes influenced by geographical factors as this shift will enable the field to explore spatial differences in the transitions. Furthermore, this will enable the recognition of multi-scalarity of transitions and lead future research to analyse the interdependencies and collaborations across various levels of governance (Binz et al., 2020). This study considers the elements of space and scale in the transition brought using waste-fed AD and aims to analyse the influence of the different levels of governance on the deployment of waste-fed AD in England and Scotland.

For this reason, the adoption of the economic geography perspective, by the literature on urban sustainability transitions, is helpful for the creation of the analytical framework of this research. The importance of exploring the role of geography further is clearly highlighted in the transitions theory, while focusing on 'how place-specificity matters for transitions' at the local level (Hansen and Coenen, 2015, p.105). In addition, the location and availability of space are both crucial factors to consider for the operation of a waste-fed AD plant, as already presented in Chapter 4. With reference to the economic geography perspective, adopted in urban sustainability transitions, the urban and rural typology of LAs is a specific geographical factor which is relevant to governance effectiveness. The typology of rural and urban LAs also influences the proximity and accessibility of an LA to a waste-fed AD plant.

Urban and rural typology

In the literature on urban climate governance, 'urban' refers to the city, municipality, or local authority, while 'rural' denotes the surrounding peripheral areas. Balta-Ozkan et al. (2015) suggest that geographical approaches need to recognise the differences between urban and rural areas in three aspects: types and levels of energy demands, energy related perceptions and the potential for different types of distributed generation technologies (Balta-Ozkan et al. 2015). These differences between rural and urban LAs reflects differences in energy consumption patterns and needs. For example, urban residents are more likely to cut down on heating and use more public transport than rural counterparts though it is the latter who are more likely to have insulated their homes (Balta-Ozkan et al. 2015). The geographical location of an LA determines its characteristics and needs.

Accessibility and proximity to the waste-fed AD plant is a factor to take into consideration for assessing governance effectiveness because of its influence on the local level. In the sustainability transitions literature, geography is related with the importance of technological and industrial characteristics or specialisation of the places examined (Hansen and Coenen, 2015). The development of niches and innovations are also supported by the creation of agglomeration economies, which function as a pool of skills, expertise, specialised labour force, and local networks of private, public, and academic organisations (Hansen and Coenen, 2015; McCauley and Stephens, 2012). The role of industrial clusters is recognised positively in sustainability transitions because proximity of different industries strengthens inter-organisational relations (including collaboration in innovative projects) as co-location of businesses encourages cooperation in innovative projects (McCauley and Stephens, 2012). For example, in England the objectives and initiatives of different regional renewable energy strategies were largely shaped by, and centered around, already existing technologies which were aligned with the region's industries (Smith, 2007a). Furthermore, being geographically close allows manufacturers and industry to gather input from end-users, so proximity is also a crucial factor for the industry development, especially during the initial phase of market development (Hansen and Coenen, 2015).

5.3 Conclusions

The above analytical framework focuses on the governance effectiveness of an environmental technology, which is developing further and entails a sustainability transition. The analytical framework provides governance, economic, and geographical factors and enriches further the sustainability transitions literature with themes and approaches from four literature streams: multi-level governance, urban climate governance, network governance and policy networks approach.

Governance sits at the centre of this analytical framework, so there are five governance factors: coordination, learning and knowledge, autonomy, local experimentation, and internal capacity. Market is the economic factor and urban – rural typology is the geographical factor. There are also interrelationships and interdependencies among these factors. Specifically, four of these factors also refer to the relations between central and local government. Market, coordination, learning and knowledge refer both to the national and local levels of government. Geography also influences both levels of government, but the urban-rural typology characterises LAs. Moreover, autonomy, local experimentation, and internal capacity are three factors which refer to the local level of government.

This outcome-oriented framework is used to evaluate the effectiveness of waste-fed AD governance based on the outcomes related to these factors. This set of factors and propositions is also reflected on the methodology of this research, as presented in chapter 3. These factors and propositions will explain further the differences in both nations, which contributed to the deployment of waste-fed AD in chapters 6 and 7.

Chapter 6 Governance effectiveness in England and Scotland

6.1 Objectives and Structure of the Chapter

This chapter assesses the effectiveness of governance in the deployment of waste-fed AD in England and Scotland. As already mentioned, Scotland has achieved a higher rate of waste-fed AD deployment, compared to England. As presented in chapter 4, one main reason of this difference is that Scotland has adopted a more ambitious and supportive policy and regulatory framework in the waste sector, compared to England. This statement aligns with the socio-technical approach to sustainability transitions, where policy is presented as a key political factor, primarily associated with the jurisdictions of state and non-state actors at the national level of governance. Chapter 5 presents an analytical framework which further investigates the role and potential of governance in facilitating a successful transition to sustainability. This framework acknowledges the influence of governance, economic, and geographical factors in achieving this successful outcome, with further exploration in the following pages.

Specifically, this chapter utilises this analytical framework to answer the main research question: why the deployment of waste-fed AD is different in Scotland from England. In this chapter, I provide the empirical evidence from the analysis of interviews with experts to explore further the significance and dynamics of the above factors, while investigating their contribution to the development of waste-fed AD in both nations. Furthermore, I explore in depth insights on the local level of government from the following three Scottish LAs: East Lothian Council, South Ayrshire Council, Renfrewshire Council and the three English LAs: East Riding of Yorkshire Council, Northumberland County Council, Bracknell Forest Council.

This chapter is organised as follows. In section 6.2 the role of governance is assessed by the following criteria: coordination, learning and knowledge, internal capacity, autonomy, and local experimentation. Coordination and learning and knowledge are criteria for assessing the effectiveness of both national and local governance, which influenced waste-fed AD deployment in the two nations. Internal capacity, autonomy and local experimentation are evaluative criteria of the local governance in both nations. In sections 6.3 and 6.4 of the chapter, the economic factor (market) and geographical factor (urban and rural typology) are also considered in the analysis of the empirical findings, because they further explain existing differences in governance and waste-fed AD deployment.

6.2 Governance

Most waste-fed AD plants of the UK are in England, which is progressing more slowly with segregated food waste collections compared to Scotland. The adoption of the AD Strategy and Action Plan by DEFRA was an influential first step for the development of waste-fed AD across the UK. However, the needs of existing waste-fed AD plants were not prioritised, instead new AD plants were established to take advantage of renewable energy tariffs and their connectivity to the grid (Interview E1_1). AD technology, in England, has been mainly perceived by key stakeholders as a source of renewable energy and incentivised by the renewable energy subsidies. English LAs were not mandated to provide food waste segregated or commingled collections but were free to decide their operational and collection model. AD is an alternative to IVC, but funding is essential for the adoption of waste-fed AD, because it is a more expensive method of waste disposal, compared to other alternative technologies (Interview E1_28 and Interview E1_26).

As sub-sections 6.2.1 to 6.2.5 illustrate, governance contributed to a more strategic development of waste-fed AD in Scotland, compared to England. In Scotland, the uptake of AD technology was coordinated more effectively among Scottish Government, SEPA, Zero Waste Scotland, LAs, industry and farmers. This coordination happens through various mechanisms and the next sub-section presents how it contributes to a higher rate of AD development in Scotland, compared to England. The strategic approach of the Scottish Government aimed to address the needs of existing AD plants along with the needs of whisky and distillery industry of Scotland, while being in alignment with the high-level environmental, climate and waste strategies and policies. Furthermore, waste-fed AD was considered by industry and LAs as an environmentally beneficial choice of food waste disposal to be used and adopted. Following the adoption of the Waste (Scotland) Regulations 2012, Scottish LAs received funding and guidance to invest in food waste collection services, which provided feedstock for AD plants and facilitated an effective sustainability transition. Consequently, AD technology was considered more holistically as a way of food waste treatment and renewable energy production in Scotland, as presented in the sections below.

6.2.1 Coordination

Coordination refers to the ways of interaction and engagement among stakeholders, who adhere to specific processes to attain their objectives, despite the constant change and uncertainty. Their aim is to steer change towards a defined vision (Greenwood, 2023). Waste-fed AD provides a specific policy context where coordination is examined to explore how different stakeholders from both national and local level of government, regulatory, advisory and trade organisations work together in the issues of food waste management, renewable energy, and AD deployment to coordinate the transition of using waste-fed AD. As mentioned in chapter 5, the research adopts an outcome orientated approach to assess the results of this transition and their effectiveness, while shedding light to the processes, characteristics and mechanisms of governance which led to these results.

This sub-section provides evidence on the role of coordination and is comprised of four parts. The first part focuses on the coordination within the UK Government Institutions. The second part focuses on the role of networks and their influence on AD deployment across the UK. The third part focuses on the coordination in Scotland. The final part of the sub-section focuses on the differences of coordination between England and Scotland and how Scottish coordination is more inclusive and has contributed to the higher uptake of waste-fed AD. As qualitative evidence is analysed in this chapter, the element of uncertainty is essential when drawing interrelationships among factors and outcomes (Greenwood, 2023). Because of the cross-sectorial nature of waste-fed AD technology, the policy sectors of environment, climate, and waste are devolved and comparison between Scottish Government and Westminster Government can provide insights on their different mechanics of coordination at national level of government. However, the design and delivery of renewable energy policy incentives is a reserved matter, so coordination of this policy area is examined at the UK Government level. Moreover, comparison also involves the role of networks and LAs operating in both nations, along with the role of industry.

In the UK vertical coordination is evident in public administration (Peters, 2006) and this vertical nature of the state can even influence the collaboration of various stakeholders on the waste-fed AD deployment. Effective governance involves interdisciplinary and cross-departmental policy work, characterised by ongoing communication and collaboration among policymakers. Sharing policy approaches, objectives, and learning is crucial in the waste-fed AD sector. These processes are ways of effectively addressing barriers to coordination, which is fragmentation, working in silos and competition of policies. Overall, there is both horizontal and vertical coordination in different policy settings and there are state and non-state actors who have the role of coordinator. Networks have members who collaborate and work on issues of waste, bioenergy, and AD across the UK. There are different networks, whose work is closely related with the waste-fed AD deployment in England and Scotland, but there are also few networks at the regional level to address common needs and challenges of their members.

Coordination within the UK Government institutions

Political support and motivation are essential for changing a situation at local and national level of government (Interview 6Sc and Interview 1Sc). At national level of governance, politics plays a key role in setting and prioritising policies. If renewable energy, greenhouse gas emissions and climate change are viewed as significant issues by politicians, then changes mainly happen in policy with the direction and support of politicians (Interview 1Sc). As stated by the Policy Advisor of DfT, ‘we saw a lot of interesting policy developments where energy, renewable energy, climate change are concerned around the time the Climate Change Act was written into law, which was 2008, I think. Politically then, climate change was an issue that commanded more interest and attention, in the UK than has necessarily been the case in the years that followed the Climate Change Act. So, it comes down to politics’ (Interview 1Sc). Consequently, politics can play a more influential role on setting and implementing ambitious policies for the wider use of AD, renewable energy, and GHGs emissions reduction (Interview 1Sc).

The study presents examples of vertical coordination influencing waste-fed AD deployment, initiated through both top-down and bottom-up approaches. In waste-fed AD deployment, political motivation has been ‘top down’ and taken the form of commitment from the UK Government administration. This ‘top down’ approach is related to the political leadership of a Government Department. Ministers are the political leaders of Government Departments and set policy priorities and objectives for certain initiatives to be implemented, because of specific political reasons, intended outcomes or lobbying (Interview 6Sc). In the case of waste-fed AD, there has been a combination of these factors at a UK-wide ministerial level. Specifically, there was a commitment for the uptake of waste-fed AD in the Conservative manifesto, adopted by the Coalition Government, and this commitment meant that policy officials had to work for the implementation of this commitment (Interview 6Sc).

Bottom-up initiative is also evident in the coordination of targeting waste-fed AD deployment and starts from individuals influencing organisations and decision-makers. A stakeholder or organisation can report an important issue, such as land pollution incidents from contaminated digestate, while asking for effective measures to address it. So, this issue can reach organisations and Ministers, through the regulators and delivery bodies and it can be approached as problem to be solved or as an opportunity to be further explored (Interview 6Sc). Then different options or solutions will be presented, while taking into consideration the wider political climate (Interview 6Sc). Furthermore, AD companies recognise the need for political support and influence of the political agenda in favour of waste-fed AD, while taking actions individually or collectively through their networks, as it is presented further below. For example, AD companies can engage with their local MPs and political party leaders by contacting and inviting them to visit their AD facilities (Interview E1_7). However, it is doubtful how this type of engagement is truly influential on the high-level decision-making as participating in consultations and calls for evidence, which are organised by government departments, is found to be more influential on attracting political support for waste-fed AD. For the launch of a consultation, policy officials inform key stakeholders and can also invite them to a meeting. In this way, it is always possible for the stakeholders to contact policy teams, who can provide essential information to the Chief Scientific Advisor or Ministers directly (Interview E1_8). So, coordination can be top down, but can also be bottom up, depending on the context (Interview 6Sc, Interview E1_7, and Interview E1_8).

Apart from the examples of vertical coordination, there are also cases of horizontal cooperation, which are also recognised as distribution of responsibility and action across government arrangements in the literature on network governance and policy networks (Hanf and Scharpf, 1978; Landau, 1980; Chisholm, 1989). Policy development usually starts within a Ministerial Department, and then a consultation is sent to invite external stakeholders. The policy development cycle enables policies to be reviewed by different Departments to assess potential impacts on them and to ensure consistency in policy proposals (Interview 1Sc, Interview E1_8, Interview 25Sc and Interview 6Sc). For civil servants, stakeholder engagement involves detailed, constant, and ongoing processes of communication with interested parties of different government organisations, agencies, and industry representatives. Every government department has its own goals and objectives and tries to achieve them through their own policy mechanisms and incentive schemes, while also aiming to contribute to overarching and cross-cutting government objectives. In the UK, interdisciplinary work is a common practice even within the same policy team or the same Government Department or across organisations. For example, policy teams engage in mutual communication, evidence sharing, and information sessions on the impacts of AD technology (Interview E1_8 and Interview 6Sc). They occasionally present their perspectives on policy issues to key decision-makers, explaining the rationale behind specific policy actions and exploring alternative options, all under the guidance of top-level decision-making (Interview E1_8 and Interview 6Sc). As presented in this study, there is an actual outcome orientation in coordination processes.

An example of an important target is the 2030 ammonia emissions target which is also related with AD deployment and is an outcome driving processes in government towards its achievement. As already presented in chapter 4, reduction of ammonia emissions is a key challenge for waste-fed AD deployment in the UK, because a potential increase in AD plants may lead to increased ammonia emissions. According to the National Emissions Ceiling Regulations, the UK has to reduce ammonia emissions by 16 per cent compared to emissions is 2005 by 2030 (DEFRA, 2023). Consequently, the importance of reaching these legally binding 'national emissions ceilings' is a motivator for the Air Quality team of DEFRA. They stress the importance of the legally binding targets to convince other teams to consider these commitments and its impacts on their work (Interview E1_8 and Interview 6Sc). Obviously, there is a need for balancing the demands, which originate from different policy teams, the Chief Scientific Advisor and other Government Ministers. One of the challenges was the need to ensure that the renewable energy incentive is aligned with DEFRA's objectives on ammonia emissions (Interview 23Sc, Interview 6Sc and Interview E1_8). DESNZ had to work closely with Defra, WRAP, LAs, Ofgem and EA for the policy review, support policy delivery and undertake studies to enhance policy learning (Interview E1_8, Interview 25Sc and Interview 12Sc). However, having legally binding targets is a strong argument to convince Ministers to take actions in favour of this intended outcome (Interview E1_8). There are also environmental non-governmental organisations, who threaten that the UK Government can face legal challenges if the

UK fails to meet its legally binding targets to reduce air pollutants (Client Earth, 2021; Interview E1_8). This adds additional external pressure to act. Consequently, the relevant UK Government Departments work together with the industry to assess innovative technologies which reduce ammonia emissions, while also acknowledging the negative impacts on air quality and AD, gathering more evidence to address these impacts holistically (Interview 6Sc, Interview 20Sc, Interview E1_5 and Interview E1_8). This type of coordination illustrates the 'positive coordination' of Peters (2006) who describes a 'more active stance' of recognising conflicts between policy programmes, which need to work in parallel, addressing different policy needs and prioritising multiple decisions.

In the UK, regulators are also part of this horizontal coordination as they engage with the Government, industry, and the public as their role focuses on the implementation of regulations and operation of various schemes. As the energy regulator, Ofgem aims to help the industry and public understand the application processes needed for the renewable energy schemes as it is responsible for their delivery in the UK. Ofgem also provides feedback from the industry to DESNZ and shares ideas on possible legislation changes or improvements on the operations of different renewable energy schemes, which are related to AD. DESNZ also provides feedback to the wider operations team of Ofgem (Interview 25Sc). So, they both try to create the links between the operational delivery on the ground and the actual policymaking at DESNZ (Interview 25Sc).

Waste & Resources Action Programme (WRAP) works as a horizontal and vertical coordinator depending on the specific policy setting. In 2011, WRAP had a leading role in the Anaerobic Digestion Action Plan, which enabled the development of the food waste industry (Interview 12Sc). As the SEPA interviewee recognised, 'there is a lot of work done [in the AD sector]. I think it was started by WRAP, when WRAP was UK-wide, and it was continued by Zero Waste Scotland' (Interview E1_6). WRAP also provides information on the annual gate fees, which are charged to LAs for various waste treatment facilities and vary among different nations in the UK (Interview

E1_3). Its strength of vertical coordination lies in its technical expertise and ability to engage with industry and local levels of government across a variety of policy issues. WRAP works with LAs and food supply chain on the consistency, quantity, and quality of their food waste collections, which lead to AD plants (Interview 12Sc). Its horizontal coordination is illustrated by WRAP's engagement with other Government Departments, such as DESNZ and DEFRA, to provide advice on the financial incentives and their impact on the industry (Interview 12Sc).

Although there are strategies which need the joining forces across the UK Government, lack of clear communication and engagement may lead to inconsistencies in addressing cross-cutting policy issues. UK Government Departments have faced financial and recruitment pressures, which also had an impact on their use of resources during the last years (Interview 18Sc and Interview E1_8). Practical issues, such as time and budget pressures, may drive civil servants to work in silos inevitably, because engaging with stakeholders takes more time and resources (Interview 6Sc). Working in silos can cause poor communication and disconnection, which can lead to fragmented policy implementation and inability to achieve overarching strategic goals (Interview 20Sc, Interview 1Sc and Interview 6Sc). These are barriers to policy coordination, which can lead to divergence and eventually to fragmentation in the wider UK environmental policy (Fletcher and Dunk, 2018). Engagement of the different Ministers and Departments in the achievement of certain, common objectives and outcomes is essential to avoid any fragmentation because Departments reflect their ministerial priorities on their work (Interview 2Sc).

It is also important to recognise the challenge in prioritising different policy objectives of the UK Government Departments as there may be a competition with each other in terms of achieving different outcomes of policy delivery (Interview 25Sc, Interview 1Sc and Interview 6Sc). Representatives of industry and trade organisations have observed fragmentation, miscommunication, and competition among different teams of Government Departments, while working with them on the development of renewable energy incentives (Interview 12Sc, Interview 6Sc, Interview 1_8, Interview 1_9). Peters (2006; 2015) observes these situations of policymaking which are characterised by complexity and inconsistency and eventually lead to dysfunctional or even inefficient solutions on the short-term, despite the best intentions of decision-makers.

Despite the potential for any inefficient and inconsistent outcomes of policymaking, coordination can take the form of a 'dynamic process' as characterised by Alter and Hage (1993), because it includes continuous improvement, which integrates policy learning and may bring eventually better outcomes on the longer-term (Greenwood, 2023). An example of dynamic coordination process, which is closely related to waste-fed AD development, ended up with the inclusion of 'sustainability criteria' or 'crop cap' of the RHI. As already mentioned, RHI, a renewable energy incentive, was open to Scotland and Wales and England, but its decision-making was led by BEIS, the predecessor of DESNZ. Initially the introduction of RHI created an unintended conflict between two competing uses of land as there was an increase in growing crops and maize for AD feedstock, while decreasing land use for food production. For example, AD operators were registered to RHI as AD technology processes waste and produces renewable energy, while bringing further benefits; nutrient recycling, farm fertilisers, and reduction of GHG emissions on farms (Interview 23Sc). However, the financial reward of RHI also led to negative practices, including the overgrowing of maize and crops for feedstock of AD plants and use of food waste, which could have been prevented in the first place, while following the Waste Hierarchy (DEFRA, 2011). Nonetheless, the review phase of RHI introduced feedstock requirements, which set the crop cap and significantly limited the demand for crops and the conflicts between the two competing uses of land (Interview 25Sc). Overall, the review of RHI and introduction of crop cap serve as examples of dynamic and effective coordination. This process incorporates policy learning, as evidenced by the adoption of the crop cap by the Green Gas Support Scheme (GGSS). The GGSS is the successor to the RHI and requires that 50 per cent of feedstock originate from food waste. It provides financial support for new AD facilities, which produce biomethane, and promotes the growth of AD industry. As a result of this shift in policy development, various government departments have adopted a high-level, strategic, and consistent approach to shape their policies (Interview 20Sc and Interview 18Sc). Consequently, this also led to the promotion of AD as a waste treatment method and mitigated any disconnections or contradictory impacts from new policy developments (Interview 23Sc and Interview 3_4Sc).

A cross-departmental working group was established in 2010, dedicated to promoting AD in the UK (Interview 2Sc). It is an example of high-level and effective governance, which has a positive influence on AD as the working group was run by representatives of different Government departments, agencies, regulatory and trade organisations (Interview 2Sc and Interview 3_4Sc). As the ADBA Head of Policy supported, 'there was a strategy cross-cutting - all departments and all parts of the industry. Every year there was an update on how it was going [...], so all departments would have been involved in that and different bits of the industry would have been involved. So, it was more coordinated, but that comes from the top (Interview 2Sc). In 2011, the adoption of the AD Strategy was the culmination of this working group's efforts, bringing together government institutions to set agreed actions and a clear vision for successful AD development in the UK. Consequently, the AD Strategy provided clear direction to the industry, leading to a significant increase in newly built AD plants across the UK.

In the UK, there has been coordination between local government and corporate organisations for the location, operation, and development of AD plants, which favoured the deployment of the sector. However, the prerequisite for coordination is national government working in alignment with local government and other state and non-state actors (Corfee-Morlot et al., 2011). Austerity has actively influenced the dynamics between national and local government of the UK and restricted the capacity of LAs (Gray and Barford, 2018) to take the lead in a sustainability transition, such as the use of waste-fed AD. The role of LAs was influential in the negotiations of contracts and planning decisions of the AD facilities (Interview E1_11) and had the capacity to influence the engagement of households in food waste collections. AD investors have worked with LAs to ensure that the plant has been procured and their food waste collection could feed the AD plant (Interview E1_11). As a result, these processes of planning and procurement framed the coordination between LAs and AD companies. In a few LAs there have been more AD plants built than in others. The partnership of LAs with the private sector is essential to be nurtured and further developed. There is also a need for LAs working in collaboration with the private sector to ensure that their waste collection and treatment maximises its benefits (Interview E1_10). A key lesson for LAs is to design systems and processes which enable them to provide a good quality of food waste, which can be used efficiently and effectively by AD operators (Interview E1_10). This ability of LAs to design the right systems and processes is also closely related to their internal capacity, autonomy, and experimentation, which are further explored in the sub-sections 6.2.3 to 6.2.5 of the chapter.

The role of Networks across the UK

As discussed in chapter 5, networks can foster coordination with defined, common goals and rules for their members. They are evident at different stages of the deployment of waste-fed AD in the UK. There are also networks, which are active at different levels of the government in both England and Scotland. However, England and Scotland have distinct networks related to local waste management and treatment, differing in both form and actions. Some actors are better resourced in the network, which in effect gives them more power, which can be legislative, economic, cultural, and social. The role of the networks and the state within them is reflected below in AD deployment of the UK. The role of the state and its influence are highlighted on its power of shaping the behaviour of governing bodies and the practices responsible for policymaking (Bevir and Rhodes, 2010).

Networks constituted by these trade associations, REA, WBA and ADBA, represent the industry's interests and have companies of the AD sector as their members. Apart from businesses, they also have members with a varied background; AD operators, investors, developers, academic institutions, (operational, engineering, electrical and soil) consultants, waste management companies, recycling companies and agronomists. They also work together to collectively respond to a policy or consultation to protect and promote the interests of their members as they are lobbying organisations with the same vision of a prosperous waste-fed AD deployment (Interview 2Sc, Interview 20Sc and Interview E1_21). In England, REA and ADBA were both lobbying for mandatory segregated collection of food waste from LAs, however this has not happened yet in England, despite the need for a more ambitious government policy on food waste (Interview 20Sc and Interview E1_3). Networks also set up forums for different stakeholders to promote dialogue directly and indirectly on the development of AD, while promoting certification schemes and quality protocols (Interview 12Sc, Interview E1_16, Interview E1_4 and Interview 13Sc). Within the AD sector, trade bodies have a good communication with AD industry and aim to share information and lessons learnt for the development of the industry (Interview E1_17).

Communication of the networks with the UK Government Departments can influence policy development positively in favour of AD deployment. However, in decision-making the role of the state is leading, and network members are responding or making proposals to its decision. As Rotmans et al. (2001) argue that stakeholders expect the government to take the lead and the role of state is dominant in different occasions, organised by networks. Actors of networks can also undertake the role of agenda setter in various occasions, while inviting Government representatives to participate in discussions and events to present their organisations' views on the deployment of waste-fed AD. Historically, ADBA organises conferences in Wales, Scotland, and Northern Ireland to address policy development related to AD in devolved administrations. During these events, Ministers and Government officials are invited to talk and provide policy updates, however there may be competing Government priorities which do not usually satisfy industry's needs (Interview 12Sc and Interview E1_5). Furthermore, ADBA offers a certification scheme, extensive resources, official guides on plant operation, investment, and health and safety, and facilitates knowledge sharing among members (Interview 2Sc and Interview E1_5). Networks are also formed for the purposes of information sharing and capacity-building among their members who are encouraged to communicate through the publication of newsletters and reports on AD-related topics, and the organisation of conferences, courses and webinars.

Along with the large networks operating across the UK, there are also some regional networks which are powerful in influencing the government and bringing the industry together. In England, LARAC organises conferences and networking events, where companies get invited and become sponsors. In these events, the waste managers of LAs are invited to exchange ideas and best practices (Interview E1_15). Furthermore, there are also regional networks for waste managers to access them for information on various topics, related with waste-fed AD in England (Interview E1_13). An example is the Waste and Resources Management Group, which has a working group on waste and carbon emissions and is based in the Northeast of England (Interview E1_13). The Northeast Recycling Forum is a collaborative group of LAs and private organisations who meet quarterly with experts to discuss a range of topics from waste management strategies to social inclusion on waste policies and use of AD (Interview E1_15). These organisations have been useful in forging the connections and information sharing between big waste management companies, AD operators and LAs, which use waste-fed AD for their food waste disposal. Given that numerous English LAs do not employ AD for waste treatment, they can benefit from information about segregated food waste collections, the location and capacity of existing AD facilities.

Argyriou, Fleming and Wright (2012) highlight the importance of peer support between UK LAs, which share learning and knowledge in climate policy initiatives, taken in the field of sustainable energy development. LAs also form connections with each other to share important information, so they help and advise each other in issues of waste management, such as organising a trial of food waste collection (Interview E1_15). For example, the Northumberland County Council's waste team consulted with other waste officers who use AD plants. They also gained valuable insights from the Scottish Borders Council regarding food waste collections, environmental protection, processes, standards, equipment, user engagement, and budget (Interview E1_13 and Interview E1_15). They were also in contact with North Lincolnshire to receive their communication material and strategy to engage their residents in the food waste collections (Interview E1_13 and Interview E1_15). As the Waste and Recycling Officer of the East Riding of Yorkshire Council reported, they consulted 'Calderdale Council, which were collecting food waste before us. And managers went to a few AD and IVC facilities, so they have spoken to Councils and facilities, before deciding to add food to the brown bin rather than having a completely separate collection' (Interview E1_26). Moreover, LAs can form a small network with the other councils and waste collection providers, and work together on the adoption of segregated food waste collections and use of AD. An example is the 'mini network' RE3 partnership, which was formed by Bracknell Forest Council, Reading Council Wokingham Council, and FCC environment (Interview E1_27). Through this 'mini network' partnership, waste officers of Bracknell Forest Council spoke to all its members on a regular basis when they were planning to introduce their food waste collections, which feed AD.

During network meetings, members discuss the development of waste policy in the UK, however there are different positions, leading to agreements and disagreements (Interview 20Sc). Each member has different needs and characteristics, and the trade association aims to be in the middle to balance different views, because conflicts are unavoidable (Interview 20Sc). Sometimes there is conflict between some members who want the industry to grow further and other members who are content with the size and status quo of industry. AD operators, who are engaged in food waste contracts with LAs, typically resist the establishment of new AD facilities in the vicinity of their existing plants (Interview 25Sc). This resistance is often manifested in opposition to policy initiatives which incentivise the construction of additional AD plants. However, criticism coming from smaller AD companies is that networks are influenced by the larger organisations, who are the most financially strong in the sector. As the Sales and Marketing Director of a biological engineering consultancy argues 'that the networks are predominantly based around large safe organisations with good balance sheets which can put in the infrastructure. These AD sites are expensive because […] they have multi million pound contracts. And then to reduce that risk, the contracts are five to ten years or maybe even more' (Interview E1_21). Nonetheless, this imbalance of interests needs to be addressed democratically, otherwise it sets the longevity and authority of the network at risk (Esmark, 2007).

Networks have rules and mechanisms, which ensure the participation of their members. Trade unions facilitate or influence the dialogue between industry and Government through their specific working or steering groups (Interview E1_5 and Interview E1_4). Networks also have an advisory and learning role for members and organise them to respond to a policy or consultation and vocalise their interests and criticism towards policy development. They are open to feedback and have dedicated working groups to gather industry's views on policy changes and address any policy issues, technological problems, or perception issues, to decide the best way to address these issues (Interview E1_5). Furthermore, active network members can influence their network's activities more effectively. For example, REA has steering groups, whose representatives are elected by the network members, and they provide feedback on the position of REA and ways of influencing policymaking (Interview E1_4). A lot of companies rely on the trade associations to represent their interests and influence decisions and policymaking (Interview E1_4). A cross-sector response to a policy is always stronger than a single response from an industry lead (Interview E1_7). Network members are informed about new policies and consultations, and their feedback, gathered through organised meetings, is instrumental in shaping the network's stance. This collective position, reflecting diverse opinions due to varying stakeholder types and AD plant characteristics, is then circulated for further feedback before responding to government actions (Interview E1_4 and Interview E1_5). UK Government also hosts stakeholder engagement sessions and trade associations participate while representing their industry's interests (Interview E1_5).

Coordination in Scotland

Scotland follows a similar pattern of coordination, but on a smaller scale, compared to the UK Government. Political support and motivation drive the environmental agenda in Scottish Government which sets ambitious targets on waste and climate. These highly targeted outcomes need coordination between national and local levels of government. Scottish Government is the key decision-maker and works closely with state and non-state actors in the policy issues of waste, bioenergy, and net zero transition. Along with Scottish Government, SEPA and Zero Waste Scotland collaborate with LAs, businesses and AD industry representatives on various issues related with AD deployment and proper implementation of its regulatory and policy framework. There is also a network of LAs operating in the waste sector of Scotland and works under the umbrella of COSLA, which has strong working relationships with Scottish Government.

Ways of working within the policy team of waste in Scottish Government are similar to the waste team of DEFRA (Interview E1_22). They have 'specific working groups' and a 'sector forum', which are 'engagement mechanisms' of Scottish Government with the rest of stakeholders in Scotland and the UK (Interview E1_22). These focus on food waste policy development and are indirectly related to AD deployment. 'Forum' is a more fluid structure of network in terms of collaboration and engagement of stakeholders involved. For example, a forum was established by the Courtauld Commitment 2030, which is WRAP's initiative presented in Chapter 4. Scottish Government is a signatory to WRAP's Courtauld Commitment, a voluntary agreement for collaborative action across the UK (Scottish Government, 2022). Specifically, Scotland aims to reduce food waste by 33 per cent by 2025 and by 50 per cent by 2030 in food production and supply chains (Scottish Government, 2019). As part of the Courtauld Commitment, representatives of the Scottish Government engage monthly with some of the UK's biggest retailers, the Food and Drink Industry, the Devolved Administrations, DEFRA, and WRAP to work together and share views in the effort of meeting the ambitious Scottish targets on food waste (Interview E1_22). Furthermore, as part of the consultation for Route Map to 2025, which aims to deliver Scotland's circular economy, the Scottish Government established a stakeholder forum to discuss the introduction of mandatory public reporting on food waste (Interview E1_22; Scottish Government, 2022). As part of the Route Map development, the Scottish Government held sessions with stakeholders to discuss ways of accelerating progress towards its targets (Interview E1_22). These are the two main fora of stakeholder engagement on food waste policy development (Interview E1_22).

Although there are engagement mechanisms of the Scottish Government for working together with stakeholders of the reuse, management, and disposal of food waste, there are also cases of different competing policy priorities. Competing policy priorities is also a challenge to be faced within Scottish Government (Interview E1_22), as it is the case for the UK Government. As the interviewees of Scottish Government describe it: 'there is a little bit of a push and pull' between food waste and bioenergy policy experts (Interview E1_22). They both aim to prioritise the use of food waste for energy; however, they have different policy priorities and targets to achieve. Waste policy experts also need to adopt mechanisms to ensure that the waste hierarchy is applied in practice, while focusing mostly on the inputs and processes of AD (Interview E1_22). Other challenges which are addressed in policy-making are the following: lack of clarity and stability in regulatory framework, miscommunication among key actors, and fragmented initiatives taken by key institutions and other stakeholders as it is observed in Scotland by Markantoni and Aitken (2015). Processes of coordination are in place to overcome any issues of competition, fragmentation, and miscommunication between different policy teams, as it is described already for the UK Government.

Scottish Government also engages with SEPA on the issues of waste and AD, through various working groups and similar ways as DEFRA engages with EA (Interview E1_22 and Interview E1_6). SEPA is a regulatory authority which engages at the devolved and national levels of government. Apart from maintaining a strong working relationship with Scottish Government, it liaises frequently with EA, Natural Resources Wales, and Northern Ireland Environment Agency (Interview E1_6 and Interview E1_12). In Scotland, the role of SEPA was fundamental in waste-fed AD development during the early phase of its development as a niche. SEPA reviewed technical and scientific evidence to consider carefully all the different options of food waste treatment and the potential of AD, before the roll out of mandatory food waste collections in Scotland (Interview E1_6). This enabled the introduction of waste-fed AD as a reliable waste treatment and disposal method with the adoption of Waste (Scotland) Regulations 2012. It accelerated its use and adoption as a food waste treatment because it gave a clear direction to the industry and LAs. Furthermore, SEPA's work focuses on writing the relevant guidance and providing further clarifications on the policy and regulatory framework, which shapes waste-fed AD deployment in Scotland.

SEPA has also taken initiatives to support local government in the socio-technical transition needed to adopt waste-fed AD, while engaging with the AD industry, farmers, food chain and LAs. It responds to industry's inquiries and feeds in the work of Scottish Government to help revise any policy and regulatory initiatives to the right direction, while sometimes underlining any pitfalls or areas of further improvement (Interview E1_6). It also works closely with Zero Waste Scotland, Food Standards Scotland, Quality Meat Scotland, ADBA, REAL, NFU, retailers and quality assurance groups to ensure that the digestate originating from the waste-fed AD meets certain quality criteria, which are appropriate for the end-user and the food chain (Interview E1_6 and Interview E1_2). SEPA cooperated with REA and Zero Waste Scotland to engage with Scottish LAs to promote waste-fed AD technology and inform them about ways of improving the quality of food waste, which is collected from households and is processed at the AD sites (Interview E1_6 and Interview E1_2). The engagement with LAs involved working with their waste officers, AD plant operators, and contract managers to make stronger and more effective connection and communication between LAs and AD sites. This stakeholder engagement involved various events, conferences, and meetings to help LAs understand the actual needs of AD sites, but also inform AD sites about contamination of food waste and standards of high-quality material (Interview E1_6).

Zero Waste Scotland plays a key role in waste policy development, which is initiated at UK-wide scale by WRAP. They were both instrumental in leading the work on the quality of the digestate and its impacts on the land and food chain as an economical fertiliser, which provides nitrogen and organic matter (Interview E1_6 and Interview E1_2). They also worked with Food Standards Scotland on schemes to ensure the high quality of food products with the use of digestate (Interview E1_6). This inclusive cooperation proved to be very influential in Scotland as it considered the power of the end-user in the Scottish market. Zero Waste Scotland also advises and supports the 32 Scottish LAs, while being in close cooperation with COSLA and Scottish Government to enable this transition of segregation of food waste and use of AD for its disposal. Scottish LAs adopted recycling practices and waste collection services with the advice and support of Zero Waste Scotland, which also assisted them in implementing effective communication and engagement campaigns (Interview E1_10 and Interview E1_2). Zero Waste Scotland supports regional development of the biogas sector by sharing knowledge on waste resources, composition, and feedstock availability, which is essential in creating a value chain system (Attard et al., 2020; Acharya & Cave, 2021). However, this coordination seems to be led by the Scottish Government, which sits at the centre of decision-making. The role of Zero Waste Scotland is to enable policy implementation at the local level, provide feedback to both the centre and the periphery, and foster ongoing dialogue between them (Interview E1_10 and Interview E1_2).

The relationship between the Scottish Government and LAs on the issues of waste policy, management, and disposal is characterised as good by a COSLA interviewee (Interview E1_10). Efficient communication channels are essential to maintain this relationship. In Scotland, there is a waste management network, comprising waste managers from the 32 LAs and COSLA, meets occasionally each year (Interview E1_14 and Interview E1_22). The network has three chairs who work closely with COSLA to develop responses to new policy proposals from the Scottish Government. This network communicates the needs and impacts on the waste management processes of LAs and maintains an open dialogue with the Scottish Government (Interview E1_14). It also receives policy updates covering various issues, including health, social care, and the environment (Interview E1_5 and Interview E1_10). Network members use the platform to share best practices and address common challenges in waste management and disposal. Zero Waste Scotland plays a central role in this relationship between the Scottish Government and the LAs. It provides updates on legislation, mandatory targets, and services, and actively engages with Scottish LAs through this network of waste managers (Interview E1_25 and Interview E1_14).

Coordination as an evaluative criterion of waste-fed AD deployment

In governance, coordination is closely related to the effectiveness of both processes of decision-making and achievement of policy targets (Greenwood, 2023). UK Government works and engages with state and non-state actors in a way which encourages communication and collaboration, despite any competition, fragmentation, or conflict of interests as there are processes and mechanisms to address these. This form of coordination defines and shapes a 'culture of coordination' which directly influences the mode of coordination, which is adopted by devolved administrations. Coordination has proved to be a key governance factor which can lead to different outcomes. This study shows the similarities in coordination between England and Scotland as they are shaped by the UK Government in the reserved areas of policymaking, but there are also some differences in the devolved areas which enabled further the uptake of waste-fed AD in Scotland. This sub-section highlights below the similarities and differences between the two nations.

Division between the jurisdictions of national and local level is clear in both nations. In England, governance is characterised by hierarchy and the division between the national and local level of government is clear. So, the relationship between these two levels of government is vertical and there is a clear direction of influence from national to local level (Kuzemko, 2019). In Scotland this relationship is horizontal and more inclusive as the Scottish Government and SEPA have established a more collaborative relationship with Zero Waste Scotland, COSLA and representatives of LAs, the AD industry and farmers. This type of influence is political, but also financial, although central government grant funding has been sharply decreased since 2010 in English LAs (Muldoon-Smith & Sandford, 2021; Gray & Barford,2018). Three levels of government (national, devolved and local) acknowledge their interdependencies, which require coordination bottom-up and top-down across different government levels and policy areas (Betsill and Rabe, 2009; Markantoni, 2016). These interdependencies become more evident in the role of regulatory, not-for-profit and trade organisations, which facilitate the communication between the national and local level of government.

The ties between the national and local level of government seem to be stronger in Scotland than England. In Scotland, coordination at both levels of government have evolved in parallel with the policy developments in the sector of waste. According to Corfee-Morlot et al. (2011) and Markantoni (2016), multi-level governance is built on three layers or spheres of policy-making: the core, inner periphery and civil periphery. The Scottish model of governance is built on these three spheres, which are also characterised by communication, influence, and collaboration. Scottish Government and Parliament are at the core area of public decision-making. SEPA, Zero Waste Scotland, COSLA, AD industry, trade bodies and NFU are at the inner periphery which interacts with the core to work on waste policy development. LAs, local communities, households, end-users, and individuals belong to the civil periphery, where waste policy is implemented via the use of waste-fed AD or IVC. The main difference with the English model of governance is that the inner periphery in Scotland has a more targeted communication and promotion of waste-fed AD to the civil periphery. COSLA, SEPA and Zero Waste Scotland seem to have enriched and benefited the communication and coordination of the core with the civil periphery on the related issues of food waste and AD deployment. In other words, these organisations had a very influential and effective role in Scotland and even more impactful role than the English counterparts as Scottish LAs were given financial support and guidance to adopt segregated food waste collections. Furthermore, SEPA is more proactive in setting AD as a strategic option of food waste treatment and bringing together key actors, which influenced the uptake of waste-fed AD, whereas EA seems to be more active in the implementation side of the regulations by inspecting AD plants and facilities. Scotland's small size enables SEPA to be fast and agile in setting the AD regulatory framework, while engaging with the AD operators, waste officers of LAs, farmers and end-users of the digestate. Kivimaa (2014) refers to these actors as innovation intermediaries in socio-technical transitions towards environmental sustainability.

Networks play a crucial role in coordinating waste management efforts, within the context of waste-fed AD deployment in the UK. They operate at various government levels and can influence policy design and implementation, while impacting legislative, economic, cultural, and social aspects. Networks are also constituted by trade associations which collaborate with other stakeholders to protect and promote the interests of AD industry members. They have rules and mechanisms to ensure member participation, an advisory role for policy development, and dedicated working groups to address industry views and issues. They play a powerful role in waste management by influencing government decisions and fostering collaboration within the industry. This collaboration is valuable for promoting waste-fed AD, especially in English LAs which may not currently employ this method. Peer support and knowledge exchange among LAs further enhance sustainable waste management efforts. Sharing of knowledge can take place in a more structured and informative way through group or network memberships or relationship building between LAs and other organisations. LAs collaborate by forming small networks with other councils and waste collection providers. Active network members can influence activities effectively, and collective positions are shaped through feedback from diverse stakeholders. While differing positions sometimes lead to conflicts, balancing diverse interests is essential for the network's longevity and authority.

Scotland mandated LAs to collect food waste, which led to AD plants and/or IVC facilities, years before England started considering this option. Scottish Government approaches waste-fed AD as part of the wider circular economy agenda (Interview E1_6, Interview E1_22, Interview E1_14). In England, the policy focus was mainly on the biogas and biomethane production and development of renewable energy subsidies (Interview E1_11 and Interview E1_5). Nonetheless, AD is a technology which interacts with different environmental systems: soil, water, energy, and food. So, it needs a more inclusive approach of governance, which considers the interrelationships among these systems and the relevant stakeholders. In Scotland, governance is more inclusive and joined up as it incorporates coordination across a range of stakeholders who have different responsibilities and interests. However, they share the same goal, which is the development of waste-fed AD. As Sugden et al. (2012) argue there is potential to achieve targets towards a low carbon future in Scotland, but these need political motivation, inter-government collaboration, targeted use of resources and engagement of the public. This research identifies inter-government collaboration, political motivation, targeted and circular use of resources, and stakeholder engagement as coordination factors which favoured the waste-fed AD development in Scotland. Overall, effective governance of AD development needs a more integrated approach that ensures the supply of AD plants, optimises the use of digestate, waste, and existing AD infrastructure and resources, while considering the impacts on habitats and local communities (Interview E1_11 and Interview 13Sc).

6.2.2 Learning and knowledge

Learning and knowledge is a means, but also an outcome of coordination. As already presented in Chapter 5, it is a governance factor closely associated with coordination and plays a key role at the formation of interrelationships among all levels of government and individuals. As policy actors and other stakeholders coordinate through their relationships and collaborations, their skills and knowledge co-evolve (Greenwood, 2023). Learning and knowledge is approached as a process which leads to the deployment of waste-fed AD and involves both the local and national level of government. The importance of knowledge is also associated with the wider public. Vergragt et al. (2016) highlight the important role for education at all aspects of life as it can contribute to a transition to a more sustainable model of production and consumption. The quality of food waste, which is used by AD plants, is associated with knowledge and awareness of the recycling processes, the benefits, and end products of AD. In other words, lack of knowledge and awareness is a barrier for participation in food waste collections, which feed AD plants (Interview E1_12).

This sub-section presents the similarities in the processes and mechanisms of learning and knowledge sharing in the two nations. The smaller size of Scotland and number of LAs enables channels of knowledge sharing and communication to be easier to access and more effective in raising awareness. This sub-section is also comprised of two parts. The first part focuses on the processes of learning and knowledge sharing between the national level of government and other key actors, while drawing evidence from both England and Scotland. The second part summarises the key aspects of learning associated with the use and development of waste-fed AD in England and Scotland.

Learning and knowledge within the UK Government, Scottish Government, and other key actors

Access to information is essential for the adoption of dedicated processes of monitoring, evaluation and learning at different levels of governance (Visseren-Hamakers and Glasbergen, 2007). Both the UK Government and Scottish Government enable processes which support learning and knowledge sharing, which are core factors of evidence-based decision-making. This section aims to explore how learning and knowledge processes have influenced the deployment of waste-fed AD, while providing evidence from both UK and Scottish Governments and their work with other key actors.

Sharing of knowledge and dissemination of information happen within UK Departments and across Scottish Government, as it is an essential part of the policy cycle to examine the evidence and assess any policy implications and adjustments (Gerlak and Heikkila, 2011). Gerlak and Heikkila (2011, p.621) refer to the 'processes' and 'products', which define 'collective learning' in government. In the UK Government, policy evaluation is central to the policy cycle as it is important for policy learning and accountability and it can provide important information 'before, during and after an intervention's implementation' (HM Treasury, 2022b, p.5). Policy evaluation is also embedded in the policy practices of Scottish Government, which values its significant role in evidence-based decision-making. It has also published an evaluation guide for policymakers (Scottish Government, 2018), which is similar, but less extensive than the HM Treasury guidance on evaluation (HM Treasury, 2022b). During the evaluation stage, policy officials continue to work closely with industry on implementation, while looking closely at policy impacts and discussing any concerns they have.

Evidence-based decision-making also involves evidence gathering through communication with stakeholders. Policy design is driven by evidence and civil servants invest a lot of resources and time in communicating with stakeholders and gathering evidence in support of the policy decisions and recommendations to Ministers. As the DfT interviewee argues: 'one of the guiding principles is that any recommendations on the use of taxpayers' money that we make has to be based on the best available evidence' (Interview 1Sc). In the case of waste-fed AD, policy officials also ask for the input of technical advisers, such as WRAP or NNFCC, on issues related with AD technology and engage with industry representatives to get their perspectives on the development of policy initiatives, related to AD (Interview 12Sc, Interview 3_4Sc and Interview 23Sc). Furthermore, at DfT they follow the principle of technological neutrality towards renewable energy technologies (Interview 1Sc).

Policy experts, who rely on established evidence and consultations to gather more information, find it challenging to incorporate emerging evidence (Interview E1_8 and Interview E1_11). Policy officials of the Scottish Government use evidence and data published by SEPA, Zero Waste Scotland and LAs to inform policymaking processes, which are related on waste and resource management. At Defra, there are scientists and expert analysts who are embedded across policy teams and can form expert groups. These groups examine the quality of evidence and conduct research on different topics, such as ammonia emissions from the use of digestate. They also have impact assessment processes to consider the impacts and costs of various policy programmes, regulations, and incentives. At Defra, in the quest of evidence related to waste-fed AD deployment, they also consult the dataset of the National Atmospheric Emissions Inventory System,[38] the Farm Practices Survey,[39] and the National Non-Food Crops Centre (NNFCC) (Interview 6Sc). However, it seems that social science representation is not mentioned in these evidence sources and raises the question of the feasibility of a socio-technical transition to happen successfully without enough social science evidence reflecting the views of different population groups. This was also observed by De Santo (2017, p.38) on another topic of environmental policy, specifically in the design of the UK marine conservation zones, which was 'slower than expected' and did not include any of the proposed sites, indicated by stakeholders during the consultations. Nonetheless, this raises questions on how best evidence is assessed and what the role of scientific expertise is in the interpretation and use of this evidence in policy. Nutley et al. (2012) argue there is no single definition or description of 'good evidence', so the quality of evidence

[38] For more information see here: https://naei.beis.gov.uk/data/.

[39] Results of the Farm practices survey run in February 2022 can be found here: https://www.gov.uk/government/statistics/farm-practices-survey-february-2022-greenhouse-gas-mitigation-practices.

depends 'on what we want to know, for what purposes, and in what contexts we envisage that evidence being used' (Nutley et al., 2012, p. 4; Cairney, 2016; De Santo, 2017). Consequently, 'good evidence' is not a one-size-fits-all concept, but rather a dynamic, complex and context-dependent one.

Before the introduction of the renewable energy subsidies and the adoption of AD strategy, Defra funded research projects focusing on the food waste sector of AD and DESNZ commissioned a research project, which provided useful evidence and focused on the impacts of the whole AD supply chain on GHG emissions savings (Interview E1_11 and Interview 23Sc). There were three key projects commissioned in England; a. the Valley Gas project, which was undertaken by Southampton University, b. the AD plant in Shropshire, and c. the Greenfinch AD plant in Ludlow, which was among the first to digest food waste. In the UK, most waste-fed AD plants digest food waste in combination of other feedstocks and materials (Interview E1_11; NNFCC, 2021). However, the Greenfinch plant proved that the AD of food waste was possible, and the research project provided evidence, which was based on trials of various collection and engagement mechanisms with households. At the same time, the Valley Gas Project was examining research questions related to the biology of AD from a laboratory and practice perspective, in the UK and other European countries. As the Head of Knowledge Exchange and Innovation of a specialist environmental consultancy argues, these projects 'formed a very significant body of evidence', which gave confidence to Defra on the value of AD to provide subsidies to the market (Interview E1_11). Development of the AD industry and infrastructure was initiated by the evidence and knowledge that the AD technology has the capability and capacity to process food waste in a safe, but also beneficial way for the society and the environment (DEFRA, 2011). Without the knowledge and learning, generated by these research projects, there would have been still uncertainty about the potential and future of waste-fed AD in the UK.

Raising awareness, knowledge and learning is illustrated as a key process to reach the targets of Scottish Government in its Zero Waste Plan (Scottish Government, 2010) and its Zero Waste Roadmap for Industry (UKRI and NECCUS, 2023). Scotland's Zero Waste Plan sets a long-term vision, which calls for action in four key areas: 'resource streams, economic opportunity, resource management sector, and education and awareness' (Scottish Government, 2010, p.12). It also stresses the importance of improving data and evidence originating from public and private organisations to inform policy and enhance knowledge of businesses in the waste sector (Scottish Government, 2010). Scotland's Zero Waste Plan recognises the role of all stakeholders in raising awareness, taking responsibility for waste, and changing behaviour and attitudes towards a sustainable waste management. Furthermore, the Scottish Zero Waste Roadmap for Industry stresses the importance of reducing technology costs through research and development, learning-by-doing and economies of scale (UKRI and NECCUS, 2023).

Knowledge and skills are also essential for the development of waste-fed AD in the UK. Companies investing in the AD sector need to have sufficient knowledge, experience, and skilled workforce, before proceeding with any investment (Interview E1_2 and Interview E1_19). As reported by the interviewees of the regulatory authorities, there have been instances where AD sites are operated by individuals who lack the necessary technical skills and knowledge. Unfortunately, this lack of awareness and skills is a key challenge for further development of the AD sector in the UK (Interview E1_19, Interview E1_5, Interview E1_16 and Interview E1_2). There are processes of environmental management, which need to be followed by AD operators on site to ensure that the operation of the plant is safe, without any odour and spillage of wastes. CIWM WAMITAB is an awarding body for qualifications in the waste management industry and the operations of AD[40]. Many of the skills required by AD operators are acquired on the job, which is related to process engineering (Interview E1_19). Previous experience and expertise are essential for the successful

[40] Chartered Institution of Wastes Management - Waste Management Industry Training & Advisory Board (CIWM WAMITAB) Level 4 Medium Risk Operator Competence for AD (MROC5) is designed for AD operators. For more information: https://www.hsecservices.co.uk/WAMITAB-Level-4-MROC5 .

development of an AD plant as lessons learnt from the operation of previous AD plants ensures more efficient operation of the sites in the future (Interview E1_20). On the operation side, there are also health and safety certificates, engineering certificates for the education and professional development of AD operators (Interview E1_21). In-house expertise, knowledge and working experience in the AD sector are key factors, which can influence the decision making of an LA towards the use of waste-fed AD for its disposal of food waste (Interview E1_13). This has been the case for Northumberland County Council to decide the design and delivery of segregated collections because its waste team has environmental engineers who are aware of the technology (Interview E1_13 and Interview E1_15).

LAs also have monitoring processes to track progress of their schemes against their targets and enable them to collect high quality data and evidence. This data enables LAs to ensure that they make robust decisions on the use of their resources and their waste prevention mechanisms are effective in delivering behaviour change of their residents (Sharp et al. 2010). Using a range of well-planned monitoring and evaluation methods is recommended by WRAP's current monitoring and evaluation guide (WRAP, 2023). Monitoring and evaluation of waste management schemes include attitudinal surveys, web statistics, composition analysis and participation surveys. Bespoke waste composition analysis is a method of collecting robust and effective data and three out of six LAs examined conduct this type of analysis (Interview E1_26, Interview E1_13 and Interview E1_22). However, Scottish Government finds the collection and reporting of food waste data by Scottish LAs challenging as food waste is not a routinely reported waste stream and there is not enough data publicly available (Interview E1_22). Zero Waste Scotland has an online knowledge hub, which includes guidance for both LAs and businesses on how to measure and monitor their waste. Furthermore, it has fostered robust partnerships with certain councils, such as South Ayrshire Council, assisting them in implementing segregated food waste collection services and welcoming innovative ideas for waste collection improvements (Interview E1_25). Nonetheless, this is not the case for every Scottish LA as some LAs provide the bare minimum, due to the lack of financial means to provide more (Interview E1_25).

The importance of monitoring and evaluation processes of the food waste collections is further exemplified by Bracknell Forest Council, which assesses the performance of their segregated food waste collections by monitoring data and evidence. Bracknell Forest Council increased the reuse, recycling and composting to 56 per cent, and this is an increase of 13 per cent in one year. They also had the aim to reduce the amount of waste sent to landfill to less than 10 per cent. At the end of the first year of segregated collections, the amount of waste sent to landfill was 7 per cent, a decrease of 9 per cent, compared to the previous years (Interview E1_27). They have also prevented 3.62 million kilograms of carbon dioxide equivalent from entering the atmosphere by ensuring that this waste is processed rather than being sent to landfill. Monitoring processes enabled the waste officers to observe that the amount of food waste sent to landfill has not dropped off significantly, but they observed a slight decline, caused by the introduction of a food waste service (Interview E1_27). The introduction of this service eventually influences residents' amount of food waste as it is a trigger to reflect on measures to restrict or stop wasting food. Overall, the food waste collection service has had a steadily good performance since its introduction (Interview E1_27).

Apart from the inward processes of monitoring and evaluation within the LA and knowledge sharing among LAs and other state and non-state actors, there are also outward processes of knowledge sharing between LAs and their residents. English and Scottish LAs usually have a Waste Education Officer who will be responsible for education and communication programmes. According to the Senior Waste Management officer of Northumberland County Council, the availability of this role 'depends on funding, time and capacity' (Interview E1_15). Waste Awareness Champions or Educators usually talk to schools, local associations, while working closely with the Communications team to promote various messages related to food waste collection and treatment through websites, events, and social media

(Interview E1_15 and Interview E1_26). Scotland's Zero Waste Plan aims to provide support and resources on waste management for education providers to integrate zero waste objectives into teaching and learning at schools in the context of Curriculum for Excellence and sustainable development education (Scottish Government, 2010). Furthermore, in Scotland some AD sites have open days when a community group, local councillors or members of public can visit the sites. The purpose of these visits is to educate people about the collection of food waste, the importance of good quality food waste, the process and value of AD (Interview E1_6).

At the local level, there is also a lot of peer-to-peer learning among farmers. This form of learning and knowledge sharing is common in both England and Scotland. It was initiated and supported by WRAP and Zero Waste Scotland (Interview E1_16 and Interview E1_6). There have been incidents of contaminated digestate injected illegally into the ground and this affected the quality of soil in few Scottish farms and caused distrust towards the use of digestate (Interview E1_23). Zero Waste Scotland has conducted risk assessments, land and field trials, and lab work, which accumulate a lot of evidence on the risks and benefits of the digestate use (Interview E1_2). This wealth of evidence built farmers' confidence on the safe use of digestate on land and this triggered its use (Interview E1_2). Usually, a farmer will trust another farmer and trust is a foundation for learning and exploring new products (Interview E1_6). This building of trust enabled farmers to accept the waste-fed AD technology and especially the use and benefits of the digestate.

Learning and knowledge as an evaluative criterion

In the UK learning and knowledge sharing on waste and AD has taken place since the operation of the first waste-fed AD plants whose efficiency, cost-effectiveness and potential were closely monitored and assessed. Along with these plants, attention of policymakers also focused on the performance and use of waste-fed AD plants in EU countries to enrich their evidence on the future potential opportunities of waste-fed AD. Learning and knowledge sharing is evident at both national and local level of government and it further supported the deployment of waste-fed AD in both nations. Informal and formal mechanisms of knowledge sharing and learning are similar in both the UK Government and Scottish Government. Communication, evaluation, and applied research are ways of collecting evidence which can inform decision-making on waste management and AD. Apart from the national level of government, learning, knowledge, and awareness raising on sustainable waste management and AD involves all stakeholders: waste management businesses, AD operators, farmers, households and even schools (Interview 1_12, Interview E1_26, Interview E1_15).

Existing knowledge and expertise within a LA or even between neighboring LAs, appear to be important factors in adopting separate food waste collections, which subsequently lead to AD. Having a good knowledge and understanding of the AD technology and its benefits enable waste officers of the LA to examine the option of AD more carefully and bring a complete proposal of its use as a waste treatment method to the Council Cabinet. During the empirical stage of the research, the English LAs mainly stressed the importance of peer-to-peer learning, whereas Scottish LAs stressed more the importance of getting guidance and feedback on their waste services from Zero Waste Scotland. There are two main reasons for this difference. Firstly, in England the food waste collections are not mandated, but they are expected to happen in near future, so they expressed the importance of learning in the preparation of this change. Bracknell Forest Council has already segregated food waste collections which feed AD, so their focus is on monitoring and evaluation of this service. Secondly, Scottish LAs are mandated to collect food waste, so their need in learning focuses more on improving or extending the existing service. However, Scotland is a smaller nation with only 32 LAs and this enables the channels of communication to navigate knowledge and learning in a more efficient and targeted way, so this leads to a higher development of waste-fed AD.

6.2.3 Internal Capacity

As already presented in this chapter, coordination, learning and knowledge are governance factors, which are influential at both local and national levels of government. The other governance factors are internal capacity (section 6.2.3), autonomy (section 6.2.4) and local experimentation (section 6.2.5). These three factors refer to the local level of government. Insights on local governance are analysed from the selected three English LAs (East Riding of Yorkshire Council, Northumberland County Council, Bracknell Forest Council) and the three Scottish LAs (East Lothian Council, South Ayrshire Council, and Renfrewshire Council).

Internal capacity is an evaluative factor of the local level of governance, such as city, municipality, local authority or even community. In Chapter 5 of the analytical framework, it is defined as the LA's ability to achieve its policy objectives, while making the best use of its own resources independently, without having to rely on other actors for resources (Holgate, 2007; Matthews, 2012; Eckersley, 2018). The role of LAs as stakeholders of the energy system depends on their internal capacities for policy development and implementation (Bulkeley and Kern, 2006; Eckersley, 2018; Emelianoff, 2014; Hawkey, 2015; Kelly and Pollitt, 2014; Tingey and Webb, 2020). The possession and effective management of resources enable policymakers to make effective decisions on the use and deployment of waste-fed AD. Due to austerity and budgetary constraints they faced during the last decade, food waste collection seems to be a lower priority (Banks et al., 2018; Purnell, 2019; Acharya and Cave, 2021).

In the study, internal capacity of LAs is also related with their ability to deal with costs and constrained budgets, while managing their waste collections. In the case of Scottish LAs, funding was provided to enable them to make this transition and adopt waste collections, so the management and adoption of these funds enhance their internal capacity to adapt to change. Moreover, political leadership of the Council, which supports more environmental-friendly solutions for waste disposal, is a characteristic of internal capacity. Provision and operation of food waste collections reflects in practice the internal capacity of LAs to make the best use of their resources, which includes access to the infrastructure of an AD plant and to the essential equipment of segregated food waste collections. The internal capacity of an LA is influenced by the equity of the service provision as it depends on the level of inclusion of its geographical areas and socio-economic background of residents. The quality of the service provision is also related with the LA capacity as it depends on the frequency and methods of collection, impacts on wider cleanliness and plastic contamination of food waste collections. Consequently, the equity and quality of the food waste collection service affects engagement of LA residents through communication mechanisms of the LA, which can enhance further public acceptability towards segregated food waste collections and use of AD. Overall, Scottish LAs have a proportionally higher capacity compared to English LAs, which exhibit a range of internal capacities.

Internal Capacity in England

The national level of government plays a key role in shaping and implementing policy, but LAs are the key decision-makers in planning and use of local amenities, waste management and disposal (Interview E1_21). Planning sits within the responsibilities of LAs which can influence the location of waste-fed AD plants (Interview E1_10). The introduction of the draft Waste Management Plan for England states that planning policy should complement the work towards a zero-waste economy. However, it also sets the 'traditional waste planning axiom'; provision of sufficient opportunities for new waste management facilities, which need to comply to the requirements of the right type, place, and time (Interview E1_13). Furthermore, Tingey and Webb (2020, p.5) argue that some LAs across the UK 'developed clean energy in niche areas but lack resources to shape meso-scale planning and innovation'.

Political support is important prerequisite for a socio-technical transition to happen at the local level. The local communities have their own decision-makers and political mechanisms, which also influence the deployment of AD. Political support influences the decision-making and broader acceptance of AD sites in local communities (Interview 13Sc). At the local level, the support of the Councilors is essential for the adoption of food waste collections and the use of IVC or AD. In the case of Bracknell Forest Council, there was political support from the Council Leaders and residents to adopt a weekly food waste collection service (Interview E1_27). As the waste officer of the Council recognises ‘It looks like public demand there was for it, so we know our residents wanted food waste collections’ (Interview E1_27). So, it is a bottom-up and top-down interrelationship between LA leadership and the public. During the decision-making process, the Waste Team of Bracknell Council gave different options of food waste collection services to the Senior Council Members to decide on the frequency, size, and type of the collections (Interview E1_27). After considering different proposals, the executive members of the Council decided the best available route and there was a Council meeting to inform Councilors on their decision, which was confirmed and made by their Executive Group (Interview E1_27).

There are financial and environmental issues related with waste-fed AD at the local level, which can gain political support from the leader and members of the Council. The Council’s capacity to adopt low carbon practices is largely due to its competent leadership, which recognises the environmental advantages of this sustainability transition. In Northumberland County Council, the elected members and the portfolio leader have been keen on environmental issues, such as waste and recycling. The waste team has never struggled to get any environmentally related decision through the Executive Committee as climate change is a politically strong area and at the top of the Council’s priority list (Interview E1_15 and Interview E1_13). The decision on food waste collections and the use of AD plant, which was approved by the Service Director and the Cabinet, led to trials and segregated collections (Interview E1_13). The environmental and economic benefits of this decision, including reduced residual waste, improved carbon footprint, and local bioenergy production, were communicated and promoted to residents, making the segregated food waste collections more appealing and encouraging their participation (Interview E1_13).

Infrastructure is an important resource for LAs to initiate and maintain food waste collection and disposal at waste-fed AD plants. Building and maintaining waste-fed AD plants have positive impacts on economy and employment at the local level through job creation (Interview 18Sc). As the interviewee of Local Partnerships –

DEFRA observes in England, ‘there are quite a few examples of LAs, Oxfordshire, Kent, where the authorities have entered a complex procurement to […] effectively build their own AD facility. This is a slightly more complex procurement than relying on [existing] merchant capacity of AD’ (Interview E1_9).

Communication is an essential element of the LAs’ internal capacity as it can encourage public engagement and acceptability of food waste collections. The communication and promotion of segregated food waste collections is also part of the LA’s internal capacity. LAs use their human and financial resources to inform and promote the benefits of food waste management and treatment, as they aim higher levels of public engagement and acceptability. Northumberland County Council’s communications strategy was crucial in supporting residents to collect food waste during a trial, ensuring key messages were effectively conveyed and addressing any exclusions to prevent disappointment (Interview E1_15). Bracknell Forest Council also launched a major communications campaign using events, press releases, emails, local newspapers, their website and magazine, social media, and advertisements to inform and motivate residents to participate in food waste collections (Interview E1_27). As the Council’s officer states, ‘we have different events and virtual talks to local community groups, parish councils, town councils and when we delivered the caddies [… with] an information leaflet, which explained all about the service [and] the benefits of food waste. So, any channel that we could find, basically we tried to use it for communication’ (Interview E1_27).

Public engagement in food waste collections may be affected by their satisfaction, originating from the frequency of waste collections at the local level (Interview E1_13). Pro-environmental behaviour and pro-recycling attitudes are important factors which can influence public engagement in the recycling of food waste (Interview E1_15 and Interview E1_28). There is also the sense of pride-in-place when residents of LA feel that their council outperforms in environmentally friendly initiatives, such as recycling activities. At Bracknell Forest Council, the residents demanded a food waste collection service, because they felt that their Council was underperforming in this sector, while being in comparison to the other neighbouring councils (Interview E1_27). As reported by the waste officer of the Bracknell Forest Council, 'people were actively asking for it and additionally, where Brokenborough council, [..] Windsor Council and other neighbouring councils were all doing food waste collections. We were almost lagging behind the neighbouring councils. And people were asking for it. They were really the driving factors for it' (Interview E1_27).

Internal Capacity in Scotland

As already presented in the previous sub-section, political support has shaped the internal capacity of Scottish LAs. Specifically, the three Scottish Councils, explored in the research are cases which had received support for the adoption of waste-fed AD and segregated food waste collections from their Council leaders. For example, there has been a strong political and leadership support for the recycling of East Lothian Council (Interview E1_24). Food waste is part of its recycling provision, but there has been no adverse reaction to the food waste collection, and it is seen as a positive service to encourage the residents to engage with it (Interview E1_24). Moreover, Scottish energy and climate planning were more advanced, compared to the other devolved nations (Heidrich et al., 2013; Tingey and Webb, 2020), so there is a more supportive policy environment focusing on circular economy in Scotland. Consequently, this also enabled a greater proportion of LAs to embrace innovative ways of food waste management and treatment, which leads to a higher deployment rate of waste-fed AD in Scotland, compared to England.

The Scottish Government aims to fund capital upgrades and develop LA facilities to accelerate Net Zero targets, by supporting waste-fed AD and addressing the climate emergency and carbon management goals (Interview E1_10). In Scotland, £154 million was allocated between 2008 and 2011 to support the implementation of the Zero Waste Plan, enhancing the capacity of LAs to transition to food waste collections (Interview E1_2; Cole et al., 2014; Scottish Government, 2010). This transition required significant funding, incentives, and support from the Scottish Government and Zero Waste Scotland. In addition, a key difference of Scottish LAs is that the provision of waste collection services is retained in-house by the LAs and these services are not contracted to companies as is the case with most English LAs. The equipment, staffing and collection vehicles is one of the biggest costs to be addressed by Scottish LAs, which needed the funding to adopt this transition to food waste collections (Interview E1_24, Interview E1_25 and Interview E1_28). In addition to these costs, there are also fees that LAs must pay for the food waste treatment at a licensed IVC or AD plant. A five-year, £70 million recycling improvement fund enables LAs to bid alone or in partnership with commercial or third sector partners for the improvement of their recycling services (Scottish Government, 2021). However, the usage of this funding depends on the internal capacity of LAs to use these financial resources efficiently for the improvement of existing facilities and provision of services.

Scottish LAs adopted segregated or commingled food waste collections, with the exemption of rural areas, following the Scottish Waste Regulations 2012 and legal obligation to ensure that management of bio-waste promotes high-quality recycling (SEPA, 2016). Consequently, this regulatory change brought a significant change in food waste tonnages (Interview E1_23), so there was an increased demand for AD facilities close to the LAs. In Scotland, there are only two LAs, the Western Isles and Fife Council, who own their AD facility (Interview E1_10 and Interview E1_4). Fife Council built an AD plant to deal with its own communal commingled waste, which can be processed following a dry digestion process. This process is similar to composting, but the produced gases run through combined heat and power (CHP) (Interview E1_23). The idea of an AD plant, owned and operated by an LA, can become a great asset of waste management and energy production, which address its own needs, but in practice the dry AD process is challenging and can cause problems in the operation and efficiency of the plant, while affecting its load (Interview E1_23). In Scotland most of the AD plants have a wet digestion process, which is generally mixed with waste, originating from milk, meat and food producers and sludges (Interview E1_20).

East Lothian Council is a small, semi-rural authority of Scotland, but it was able to provide the food waste collection to the whole Council, which uses AD for food waste disposal. All residents of the Council are given the same option of waste disposal, and it is at the residents' discretion to engage in this service. East Lothian Council has adopted a completely different approach, compared to Bracknell Council in the previous sub-section. The Waste Manager of the Council argues that 'we were able to provide this to the whole Council and I think for me having worked at a few other authorities, that is probably the best type of solution because it does not leave any inequality of service. So, you have got that standardisation across [the Council] whether people choose to engage or not is at their discretion. But you give everybody the same option' (Interview E1_24). East Lothian Council has implemented a 'one pass system' and provides a separate collection system for all recyclable materials (food waste, paper, cartons, card, glass, plastics, and cans) on a weekly basis, enabling the capture of a high quantity and quality of these materials for sale as commodities (Interview E1_24). Overall East Lothian Council is one of the best six Scottish LAs in recycling and aims to improve their performance on waste disposal and recycling (Interview E1_24).

Plastic contamination is a challenge for waste-fed AD plants, which process food waste from Scottish LAs. According to the AD plant operator, food waste contamination is a challenge for bigger and urban LAs, where there is a higher concentration of population in high rising buildings (Interview E1_23). There are Scottish LAs who collect higher quality of food waste than others. East Dunbartonshire Council was illustrated as an exemplary case during an interview with an AD plant operator. Specifically, East Dunbartonshire Council started recycling of food waste, and was measuring their tonnage of food waste collected to examine how successful they were in food waste recycling and management, based on their coverage of areas and population (Interview E1_23). They were also able to check which areas suffered from plastic contamination in food waste, and they would host educational events to inform households of these areas on ways of food waste collection and disposal for its treatment by an AD plant. In other Scottish LAs, contamination of food waste has been decreased over the years as it is the case of Renfrewshire Council (Interview E1_28).

Scottish Government acknowledges public participation in the food waste collections as a key issue (Interview E1_22). Scottish Government aims to address the issues of communication and information of the public in the next Food Waste Reduction Action Plan (Interview E1_22). Residents' participation and engagement need to be further incentivised with communications mechanisms, which seems to be a key issue for most LAs in both England and Scotland. South Ayrshire ran a household participation survey because around half of its residents were participating in food waste collection (Interview E1_25). The household participation survey was open to the same properties for a duration of four weeks and this survey gave them a starting point for designing a communications plan to enhance awareness and achieve stakeholder engagement (Interview E1_25). South Ayrshire Council was in cooperation with Zero Waste Scotland, which helped them design their communications plan. Zero Waste Scotland is eager to collaborate with the Councils and conduct research on food waste collection services, as it would provide them with concrete evidence on household participation rates (Interview E1_25 and Interview E1_28). Both East Lothian Council and South Ayrshire Council had communication campaigns of food waste collections which used their collection vehicles for advertising and aimed to increase participation rates in food waste collections (Interview E1_24 and Interview E1_25). Their advertising campaign was based on key messages communicating the importance of the food waste collection service.

Internal Capacity as an evaluative criterion

Internal capacity is an evaluative criterion which explores the ability of LA to achieve its targets, while making the best use of its own resources independently. The section explores how the access to funding, guidance and infrastructure can influence the LA capacity to implement separate food waste collections and use AD. Furthermore, the provision and operation of service, which forms part of the internal capacity, are also influenced by the equity and quality of the service and the levels of public participation in the service. Political leadership and support can influence the decision making of LAs and the use of communication strategies, which can eventually enhance the public acceptability and engagement towards the segregated food waste collections and use of AD.

Having political leadership and support for the adoption of food waste collection is a key similarity between the Scottish and English LAs, which are examined in the research. Policies and political motivation are not sufficient to run and sustain a service by LAs, however funding is a critical factor for the future of projects or services (Interview E1_15). Austerity led to budgetary constraints of LAs in the UK since 2010. Funding is a key resource along with access to infrastructure, technology, and learning, which were provided to Scottish LAs to adopt food waste collections and use of waste-fed AD facilities. This is a key difference between English and Scottish LAs as the Scottish Councils were backed up by different funding opportunities and guidance from Scottish Government and its delivery body, Zero Waste Scotland. In the waste-fed AD deployment, English LAs seem to 'sit somewhere between government and operators' (Interview E1_21), whereas Scottish LAs seem to work more closely with AD operators (Interview E1_18), because Zero Waste Scotland was cooperating with both LAs and AD operators. Consequently, Scottish LAs seem to be more advanced in the food waste collections and the use of AD as they are more experienced compared to the English LAs.

At the local level, stakeholder engagement in food waste collections can happen through communication strategies and provision of incentives, which can motivate the public to engage successfully in food waste collections, feeding AD plants (Interview E1_24 and Interview E1_27). There is more public acceptance of using food waste and AD in Scotland, compared to England (Interview E1_7). However, low participation rates seem to be a challenge for both English and Scottish LAs (Interview E1_15 and Interview E1_24).

6.2.4 Autonomy

As presented in Chapter 5, autonomy refers to the freedom and initiative of LAs to decide on the use of waste-fed AD as their method of food waste disposal. Policies and regulations are adopted at the national level of government and influence how the LAs contribute to the implementation of policy and regulatory framework, by taking a passive, reactive or even proactive role. As Kuzemko (2019, p.80) recognises, LAs can play a more important role than being the 'takers of global or national rules'. Evidence shows that LAs decide on the interpretation and adoption of these rules, while considering their sustainability strategies, costs, and regulation changes. Eckersley (2018, p.141) refers to autonomy as 'the degree of freedom from central direction'. However, at the local level, the degree of freedom is always dependent on a patchwork of duties and entitlements, originating from the national level of governance. It is also important to avoid any confusion with internal capacity, which is already explored.

The research indicates that autonomy arises due to a lack of funding, guidance, and regulations. English LAs enjoy significant autonomy to adopt targets, strategies, and initiatives for their food waste management, but have been constrained by a lack of resources, clarity in regulations and/or funding. The internal capacity of LAs has decreased due to austerity during the last ten years in the UK (Gray and Barford, 2018). Increased autonomy may be a constraining factor for targeted action, which leads to a specific sustainability transition. It may also lead to reduced internal capacity for service delivery of LAs, potentially increasing dependence on external actors to achieve its ambitious targets (Eckersley, 2018). For example, Scottish LAs received sufficient funding and guidance to direct their actions towards Scotland's Zero Waste targets. So, they are less autonomous to adopt their own initiatives alone, but they seem more capable in adoption of food waste collections and the use of waste-fed AD, as explained in sub-section 6.2.3. This section explores the waste recycling targets and strategies, motivations, and reasons of LAs to adopt segregated food waste collections, while comparing the English to the Scottish LAs selected as cases.

Autonomy of English Local Authorities

The adoption of diverse waste recycling targets by English LAs illustrates their autonomy in setting their own objectives. LAs have adopted various waste recycling targets and this fact underlines their autonomy to set their own recycling targets. As already presented in chapter 4, the EU Waste Framework Directive 2008/98/ EC (WFD) had influenced the adoption of recycling targets in the UK and the Devolved Administrations. According to DEFRA (2020), England did not meet the 2020 target of 50 per cent recycling waste from households and its future targets on municipal waste recycling rates are still under development. In 2019, the recycling rate of household waste was 45.5 per cent, whereas it decreased to 44 per cent in 2020, due to COVID-19 pandemic (DEFRA, 2020). Although England had its own recycling targets, these were not cascaded to its LAs, who were left to decide how to incorporate these targets into their environmental and waste strategies. Resources & Waste Strategy for England (DEFRA, 2018) plays a pivotal role in encouraging English LAs to implement weekly food waste collections (Interview E1_27). Specifically, the interviewee of Bracknell Forest Council stated: 'we were asked to explore the options of introducing a weekly food waste collection service, driven by the time and by DEFRA's intentions, to mandate a weekly separate food waste collection from 2023 in its Resources and Waste Strategy. [..] By recycling food waste, it would allow us […] to reach the government target of 50 per cent recycling rate' (Interview E1_27).

Designing and adopting their own Waste Management Strategy is an example of initiative related with the autonomy of English LAs. English LAs were autonomous in deciding how to design their own Waste Management Strategy, even join forces with other neighbouring LAs to take actions towards common goals. The mode of waste collection service aims to be in alignment with their Waste Strategy or Climate Change Strategy, so it can contribute to the bigger environmental and climate change goals of the LA. For example, Target 45+ is a Joint Sustainable Waste Management Strategy, which was developed in partnership by Kingston upon Hull City Council and the East Riding of Yorkshire Council (Interview E1_26). Both Councils worked together towards the implementation of this Strategy, while adopting a high recycling target of 45 per cent, but the implementation of the Strategy has happened differently in the two LAs (East Riding of Yorkshire Council and Hull City Council, 2012). Target 45+ set out clearly the aims for both councils' targets of waste collection, recycling, and disposal over a fifteen-year period from 2006-2020 and replaced the joint strategy established in 1999 (East Riding of Yorkshire Council and Hull City Council, 2012). Waste Strategies of English LAs influence their decision-making on the system and service of food waste collections. Northumberland County Council created a long-term waste management plan, which aimed to divert more than 60 per cent of waste or 20,000 tonnes of waste from landfills (Stantec and Northumberland County, 2014). This plan was split on stages of short-, medium- and longer-term implementation and Northumberland County Council aimed to be a frontrunner and adopt the food waste collections before the introduction of future Waste Regulations mandating the food waste collections of English LAs (Interview E1_15).

In England, the absence of mandatory food waste collections made LAs more autonomous to decide and act on the management and disposal of their food waste. In 2021, 41.4 per cent of municipal collected waste was recycled (DEFRA, 2020). According to LGA (2018), more than half of English LAs provide a form of food waste collection and around 97 per cent of English LAs offer garden waste collection. There are two main reasons why English LAs want to collect food waste separately. Firstly, food waste collections complement their existing recycling services, so it will improve the dry recycling collection system as it contributes towards the 50 per cent recycling target of England. However, the 50 per cent recycling target is not mandatory. Many LAs aspire to reach their own recycling rates and even achieve a higher recycling rate and this is one of the drivers for food waste collections (Interview E1_9 and Interview E1_4). An example is Bracknell Forest Council, which managed to increase its waste recycling performance to 56 per cent and within the first year of segregated food waste collections, they collected 6,031 tonnes of food waste, which was 34 per cent above their initial target (Bracknell Forest Council, 2022). According to Bracknell Forest Council (2022), during 2020 - 2021 its recycling rate increased from 13 to 56 per cent and this increase is recorded as a *‘monumental achievement’*. By collecting and recycling food waste, Bracknell Forest Council was able to reach England’s recycling target of 50 per cent and be aligned to Defra’s intentions to mandate a forthcoming weekly separate food waste collection as stated in the Resources and Waste Strategy (Interview E1_27) Secondly, LAs do their own carbon assessments, which contribute to the declaration of carbon emergency, while taking into consideration the tonnages of different types of waste and their method of treatment and disposal (Interview E1_9). For example, the segregated food waste collection and use of AD for food waste disposal enable Northumberland County Council to set its Low Carbon plan in action (Interview E1_13). These are the two reasons, which motivate LAs to provide food waste collections, despite a lack of regulatory framework, guidance, and funding from the central government (Interview E1_9, Interview E1_4 and Interview E1_15). The interviewee of Local Partnerships - DEFRA argues that ‘the LAs, who actually deliver on the ground, are the ones who have decided whether they do it or not, and they had the discretion themselves to do it’, as there is no enforcement mechanism (Interview E1_9).

Procurement is a mechanism of decision-making on service provision in the LAs of the UK. LAs follow procurement procedures to make decisions and choose contractors to collect food waste. In England the majority of LAs have tended to use existing merchant capacity for their food waste disposal and the LAs, who prefer AD as a food waste disposal method, use existing plants (Interview E1_9). As the interviewee of Local Partnerships – DEFRA argues ‘the AD plants are already in place and what the local authority has to do, whether it wishes to collect food waste separately. […] It is quite easy then, to arrange contractually, the services to those AD plants. It is a little bit more difficult where they are in a location, which might be remote from merchant AD capacity, [then] their option is not to collect food waste, so many adopted that approach, if they do, they will have to build their own AD capacity' (Interview E1_9). Bracknell Forest Council has the freedom to decide their collection method and company, but they use existing AD capacity from the RE3 Partnership for waste disposal (Interview E1_27). Because of this partnership, Bracknell Forest Council entered a contractual arrangement with Reading Borough Council for their food waste collection and disposal in 2021. The contract, initially established between Wokingham Council and the Severn Trent AD plant before the entry of the other two councils, simplified the internal decision-making processes of these two councils (Interview E1_27). The existing contract of the RE3 partnership with the AD plant of Severn Trent simplified their internal decision-making processes (Interview E1_27). The collection service, initially reaching 43,000 households, expanded to include food waste collection for about 20 per cent of the Council's flats (approximately 1800 properties), while maintaining a consistent participation rate of around 80 per cent (Interview E1_27). However, this finding raises the issue of equity in service provision by an English LA as it seems that only few areas of the LA and certain parts of the population get benefited by the provision of food waste collection. In other words, it brings a division between participating and non-participating neighbourhoods of LAs, which can cause dissatisfaction to residents.

There are significant costs for food waste collections, and these also depend on the type of residual waste treatment (Interview E1_4). Having weekly collections of food waste, and wet or dry residues is not cost-effective. A more cost-effective option is collecting food waste separately from dry and residues on a two-weekly basis. Around half of the LAs, who do not collect food waste, decided that food waste could be collected from the residual bins and can be diverted from landfill, through the process of energy from waste, but not through AD (Interview E1_9). It is expensive to adopt segregated food waste collections and rearrange the rest of the collection systems, so they prefer to find a way to integrate it in the existing waste collection system (Interview E1_9). Cost also influences their decision to transition from a weekly to a fortnightly collection system of food waste.

Overall, LAs are free to make the choice of the technology treatment, while considering the processes and the wider environmental benefits of their choice (Interview E1_10). Their decisions are often driven by costs as it may be less expensive to them from a collection perspective to collect food and garden waste together rather than having two separate collections. For example, the cost of having separate garden and food waste collections was the main reason for East Riding of Yorkshire Council to choose commingled collection feeding an IVC plant. The cost of having two separate collections was higher than having commingled collections of food and garden waste (Interview E1_26). Apart from the cost reduction, they also aimed to reduce methane emissions from landfilling household and municipal waste, so they initiated the commingled waste collections to reduce the amount of food waste ending to landfills (Interview E1_26). As the waste officer of East Riding Council explains, 'the fact that the IVC was local [it] was a big factor in us choosing them, because it reduced our fuel costs and our environmental impact. Because the actual compost itself […] is produced to quality PAS 100, we give that back to residents. […] Residents could see that they are contributing towards something good. So, that was a big factor as well, the fact that we could get the compost back and give it to our residents' (Interview E1_26). Nonetheless, in this case, there is less benefit occurring from the IVC, because the energy, which could have been produced by an AD plant, is lost.

In England the mandate of weekly separate food waste collections and provision of efficient and consistent recycling measures would increase the available food waste tonnage from 400,000 tonnes to 1.5 million tonnes of food waste collected, based on modelling projections (Interview E1_9). However, this supply increase can cause chain disruption, if it is not planned carefully, as half of the English LAs need to purchase collection vehicles and come to agreement with AD plants for their waste disposal at the same time (Interview E1_9). There might also be a mid-term change of contracts as LAs have a seven-year cycle for their collections, which also affect the waste trucks (Interview E1_9, Interview E1_13 and Interview E1_15). Mandating LAs to have separate waste collections by 2025 creates practical issues as a few contracts of LAs with waste management companies cannot be ended or changed to address this mandate and, in some cases, contracts will only have a couple of years to complete their contracted time (Interview E1_9). A lot of LAs requested more clarity and guidance on the adoption of food waste collections, before taking any further action (Interview E1_4). Consequently, the lack of clarity on forthcoming regulations restricts their autonomy in decision-making and tacking actions (Eckersley, 2018).

Autonomy of Scottish Local Authorities

Scottish LAs were guided and supported to consider the EU Waste Framework Directive and Scotland's recycling targets (Interview E1_11). Scotland adopted the Zero Waste Plan, which included a 60 per cent recycling target of household waste collected by 2020 and a 70 per cent recycling target of household waste collected by 2025 (Scottish Government, 2010). The Net Zero targets, adopted by the Scottish Government, started driving different decisions based on the use of AD or IVC by the LAs. Scotland has introduced a ban on biodegradable municipal waste going to landfill by 2025 (Scottish Government, 2022). Consequently, the adoption of these recycling targets was a very influential initiative for the local level of government. The two Scottish LAs explored here, East Lothian Council and South Ayrshire Council, already use waste-fed AD for the disposal of their food waste and have already taken practical steps towards to the achievement of the Net Zero targets. Fewer waste officers of LAs realise the environmental benefits of using separate food waste collections and waste-fed AD in Scotland as there is a tendency to use commingled waste collections and IVC, because of lower costs (Interview E1_23). While the Scottish Government continues to advance the Net Zero agenda through various initiatives and discussions, these efforts can prompt additional decisions and actions by LAs regarding food waste collection and disposal, enabling them to establish their own ambitious targets (Interview E1_23).

South Ayrshire is an exemplary case which has set a ten-year waste management plan which incorporates their climate, waste, and sustainability targets, while describing in detail the food waste management and treatment at the contracted AD facility. South Ayrshire Council has a ten-year Waste Management Strategy and a Sustainable Development and Climate Change Strategy, which are related to national and international objectives (South Ayrshire Council, 2020). The Council's Sustainability Plan and the Climate Change plan include all their actions and targets, which are related to single-use plastics, sustainability, fleet management, food waste, beach management and electric vehicles. According to its Waste Management Strategy (South Ayrshire Council, 2020), the Council adopted climate policy which integrates the national targets of reducing emissions by 75 per cent by 2030 with net zero emissions by 2045 (against the 2014/15 baseline). Furthermore, the Council has set the ambitious target of reducing Scotland's food waste by 33 per cent by 2025 against the 2013 baseline (South Ayrshire Council, 2020). South Ayrshire collects food waste, which is transferred to an AD plant. In 2019, 2,556 tonnes of food waste were collected, and this is a 33 per cent reduction on 2018, however there is still substantial amount of food in the household waste stream (South Ayrshire Council, 2020).

The Waste (Scotland) Regulations 2012 mandated Scottish LAs to take action to collect food waste and decide its disposal and treatment method; either AD or IVC. Scottish LAs had to respond effectively to this mandate, motivating them to set and reach their targets. According to an interviewee and AD operator (Interview E1_23), the problem was that there were no penalties for a few LAs who were still sending food waste to landfill, after the introduction of the Waste (Scotland) Regulations. As it has been the case in England, the choice between IVC and AD proved to be mainly a cost-driven decision, despite the plethora of environmental benefits that waste-fed AD provides. For example, East Lothian Council supports businesses and schools to collect food waste for composting or AD. Since the adoption of its Waste Strategy in 2014, East Lothian provided weekly food waste collections to each household (East

Lothian Council, 2023). In East Lothian Council, collected food waste is on average around 3500 to 4000 tonnes per annum (East Lothian Council, 2023). The cost per tonne of waste residual disposal is much higher than it is for the food waste disposal. So, the Council aims to motivate more people to engage actively in the food waste collection service because it would reduce the amount and cost of total residual waste (Interview E1_24). It also transitioned the service frequency of all recycling materials to a weekly basis to encourage more people to use their waste collection services (Interview E1_24). As the service manager of East Lothian Council argues the 'frequency of collection is key. So that weekly service takes place because people don't want food waste building up, they don't want to be storing it too much' (Interview E1_24).

Some Scottish LAs made initial decisions on how to manage and treat their food waste collections before the adoption of the Waste (Scotland) Regulations. They seemed to be proactive towards central decision-making as they needed time to plan their actions. Regulatory changes work as a stimulus for action. An example is Renfrewshire Council who submitted a joint bid with its neighbouring LAs, East Renfrewshire and Inverclyde, for early stages of the funding available by the Scottish Government (Interview E1_28). Their aim was to take advantage of the forthcoming changes, while being able to provide the service to all the residents. They also engaged with Zero Waste Scotland on the processes of bid submission and administration of the fund (Interview E1_28). There were also Scottish LAs who were slow in making effective decisions and averse to change, which is externally imposed (Interview E1_23), but they managed to adopt food waste collections. Before the introduction of Waste (Scotland) Regulations, the 2013 gate fees of food waste AD were slightly higher than the gate fees of commingled waste, so the option of commingled waste and use of IVC proved to be cheaper than segregating food waste with separate collections and vehicles for many LAs to adopt them (Interview E1_23). All these practical issues and challenges of this transition which were created by the adoption of segregated food waste collections, were addressed with clear guidance and funding opportunities, provided by the Scottish Government and Zero Waste Scotland.

In Scotland, local government funding has decreased during the last decade. Reducing overall funding of LAs disempowers their leadership and decision-making (Interview E1_14). Furthermore, it seems that there is more control by the Scottish Government on the sectors which receive and absorb funding at the local level (Interview E1_14). Costs restrict the autonomy of LAs to make the most environmentally beneficial decision on their food waste collections and disposal method as they eventually choose less expensive processes of food waste collection. This is the case for both English and Scottish LAs. Furthermore, autonomy also includes the flexibility of an LA to change from one type of food waste management to another. This is also related to its internal capacity to initiate and adopt this change successfully.

For some Scottish LAs, Waste (Scotland) Regulations 2012 were perceived as an opportunity for commingling food and garden waste as this is not prevented by law (Interview E1_28). For example, Renfrewshire Council decided in 2015, which was the last year of their grant period, to move from separate food waste collections and use of AD to commingled waste collections. In 2013, segregated food waste collections were provided to 86,000 households of Renfrewshire Council and AD was used for food waste disposal (Interview E1_28). As the Waste Solutions & Sustainability Manager describes: 'By the end of 2016 we had 60,000 households on a commingled collection service. We were collecting both food and garden waste in the one container, so that allowed us to go to IVC for all that material. So, the remaining 26,000 households remained on a weekly food waste collection service' (Interview E1_28). However, the food waste of the remaining households was collected with garden waste by the collection vehicles, as it was feeding the same IVC plant (Interview E1_28). In 2021 they transferred 16,000 of those households on a co-mingled service and they anticipated the completion of this transition by 2023

(Interview E1_28). However, a decision based on costs does not lead to the optimum use of waste, resources, and environment.

Autonomy as an evaluative criterion

Autonomy is an evaluative criterion which explores the choices and actions of LAs, dependent on their freedom. As a criterion, it reflects how LAs decide to set their own targets and address effectively problems, despite any regulatory and financial constraints. The section explores the waste recycling targets and strategies, motivations, and reasons, which lead to the adoption of food waste collections and use of waste-fed AD by LAs, their decision-making processes, and the role of costs on the choice of food waste collection and disposal.

English LAs had the freedom to decide whether and how they divert food waste from landfills, whereas the Scottish LAs had to respond effectively to the mandate of food waste collections. In Scotland, LAs had more restricted degrees of freedom. However, both English and Scottish LAs, who collect food waste, are free to choose the type of food waste disposal (IVC or AD), the contractor, the type, and frequency of the service, while following certain procedures of procurement and decision-making. LAs have responsibility, but also the freedom to consider the choice of different collection methods, the potential of AD, and different waste management companies to ensure how the whole process of waste collection and treatment can maximise economic and environmental benefits. However, cost of the service is prioritised and can lead some LAs to change their waste collection model, from AD to IVC as it is the case of Renfrewshire Council in Scotland.

English LAs are characterised by more degrees of autonomy in terms of setting their own strategies, targets, and food waste management, but they have been constrained by lack of clarity in the forthcoming waste regulations and funding. Despite the autonomy of English LAs, they faced lack of funding and guidance, which constrains or slows down their capacity to adopt food waste management collections. By contrast, Scottish LAs received funding and guidance from Zero Waste Scotland to align their strategies and actions towards Scotland's Zero Waste targets and international targets on climate change. They are less autonomous, but they seem more efficient in the implementation of food waste collections. Consequently, the deployment of waste-fed AD per capita is higher in Scotland, compared to England. Furthermore, Scottish LAs are already ten years ahead in the provision of food waste collections and use of IVC and AD as waste disposal methods, compared to English LAs.

6.2.5 Local experimentation

Voß and Schroth (2018, p.100) define experimentation as 'the deliberate production of experiences for finding out what works'. They also refer to the politics of experimentation as the decision-making processes which start from a plethora of alternatives through a process of learning, thinking, and reflecting, then decisions are taken (Voß and Schroth, 2018). In the research, it is associated with trials and experiments used by some LAs to identify the uptake of food waste collection services and the use of waste-fed AD. At the local level of governance, performance indicators, data and evidence are collected to analyse the results and impacts of the trials and inform decision-making for further actions. Contamination rates of waste and composition analysis are both used at LA level to assess performance of the food waste collection service (Interview E1_26 and Interview E1_13). For example, a positive impact of a food waste collection trial is the reduction of food in the amount of residual waste ending to incineration. Funding is a key fuel of trials and influences the end products of service provision (Interview E1_15).

The three English LAs have adopted forms of experimentation in the food waste collections and the use of waste-fed AD through the adoption of trials or the provision of collection to certain areas of the LAs. These trials focused on certain areas or neighbourhoods within the LAs, where the waste collection service was provided, while economic and environmental data was being collected for monitoring and evaluation purposes (Interview E1_15, Interview E1_13, Interview E1_27, Interview E1_26). East Riding of Yorkshire Council and Northumberland County Council are two English LAs who used trials for the provision of food waste collection services. Bracknell Forest Council provided the service to certain areas and population groups of the Council. These processes enabled the evidence-based decision-making process of the LAs on taking further actions on food waste management and treatment: IVC or AD. Northumberland County Council and Bracknell Forest Council sent their collected food waste to an AD plant. The three English LAs initiated these 'local experimentations' with food waste collections, while using the Councils' financial resources without any external funding programme (Interview E1_15, Interview E1_13, Interview E1_27, Interview E1_26). None of the Scottish LAs proceeded with food waste trials, instead the 3 Scottish LAs provided the food waste collection service which covered most or all its population from the beginning. For example, Renfrewshire Council did not adopt any trials or short projects, which do not cover most of its households or population. The waste manager of Renfrewshire Council argues that the provision of fortnightly food waste collection delivers positive results on the public, environment, and wider services of the Council, so it needs to be 'Renfrewshire-wide' (Interview E1_28). They take actions which are, and aim to be 'council-wide', such as the service provided to Renfrewshire's households (Interview E1_28).

Out of the three English LAs examined, the East Riding of Yorkshire Council provide food waste collections, which feed an IVC plant since 2010. The Council conducted a successful six-month food waste collection trial in a small area, leading to the gradual provision of food waste collection services to all properties in 2011 (Interview E1_26). Collected food and garden waste of the Council is used and processed by an IVC facility, which is located within the East Riding of Yorkshire (Interview E1_26). Northumberland County Council is another interesting example as it is experienced in the implementation of trials in the collection, recycling, and disposal of different waste materials, with the aim of collecting data and evidence to inform decisions on the feasibility of service expansion across the Council. In 2022 Northumberland County Council started designing the trial of food waste collection, which would feed an AD facility (Interview E1_13 and Interview E1_15). As the assistant project manager of the Council states: ‘it is going to be done quite similarly to our glass recycling trial. […] We are going to do it in the similar style to the food waste collection, but it will be weekly and cover around 4800 properties and split into about four areas of the county’ (Interview E1_13). Despite the similarities, there are also differences between the trials as the food waste trial has different operational characteristics, compared to the glass trial (Interview E1_15 and Interview E1_13). Furthermore, they do not include the Council’s poorest areas as they usually contaminate the waste, so the areas included in the trial are richer than the average areas (Interview E1_15). Data and evidence of the trials would enable them to decide whether they sustain, modify, or stop the provision of the waste collection service and the use of AD or IVC (Interview E1_15 and Interview E1_13). Nonetheless, insufficient funding may be a reason for terminating a trial or restricting its size by limiting the participating areas or population of the LA (Interview E1_15).

There are also LAs which do not implement any trials or pilots to check the feasibility and effectiveness of programmes or services before a wider roll out. They may provide a particular service to certain areas of LAs and check the results of this service provision. However, this is another form of local experimentation. The examination of the participation rates in food waste collections enables them to explore further ways of increasing residents’ participation over the next few years (Interview E1_27). Based on the evidence of the waste composition analysis, Bracknell Forest Council did not decide to go for a trail, instead they provided the service to all households and gradually to 20 per cent of flats in 2023 (Interview E1_27). As the waste and recycling manager of the Council argues: ‘at the moment, we are trying to introduce it to flats […], but we would not intend to introduce it to all flats in the borough, unless that was made mandatory’ (Interview E1_27). This decision is made on the fact that many flats across the council may not have the right equipment or knowledge to participate efficiently (Interview E1_27). They can encourage residents’ participation in food waste collections ‘through door knocking campaigns, events and any communication methods’ (Interview E1_27).

Local experimentation as an evaluative criterion

In the research, the three English LAs examined, provide the food waste collection service to specific geographic areas within their territories, whereas the food waste collection service covers the whole territories of the three Scottish LAs. Out of the three English LAs, East Riding Council has collected food waste for IVC treatment and provides this service to all the households for more than ten years. Northumberland County Council and Bracknell Forest Council are the other two English LAs, who are still exploring further the results of their experimentation in food waste collections, feeding AD plants.

In the research findings, it is evident that there is an interrelationship between autonomy and local experimentation. The more autonomy English LAs had to decide on food waste collection and treatment, the higher their degree of local experimentation. Despite this freedom of choice, English LAs did not have funding, guidance, and clarity in forthcoming changes in regulations. So, it seems that this autonomy gave space to self-initiatives of LAs to experiment with food waste collections and waste-fed AD to learn further and decide based on the results of these 'experiments', which were funded by their own means. This is a key difference compared with Scottish LAs who were able to adopt food waste collections for their whole population from the beginning, without any 'trials' or 'restricted provision of the service'.

6.3 Economic factors

6.3.1 Market

Market is a key economic factor in influencing the progress of sustainability transitions. The influence of market in the governance of waste-fed AD is further explored in this section and aspects of networks and multi-level governance are identified. AD market development is dependent on the multi-level influence of the UK governance: the national level regulates and provides financial incentives for investors and local government provides contracts to AD facilities for their food waste disposal and treatment. The role of regulation on the market development of waste-fed is fundamental. Regulation also further evolves as more learning becomes available to ensure health and safety from the operation of AD facilities. In the UK, the market of waste-fed AD has responded positively to the regulations, policies and renewable energy incentives. Collaborations among LAs, farmers, AD operators and supermarkets form a network of market actors in England and Scotland. While corporate entities appreciate the clear long-term direction set by Scotland's devolved government (Cowell et al., 2020), the same sentiment is not echoed in England.

In the private sector, large retailers, and supermarkets have an important role to play in waste management as they can ensure that their food waste is segregated in a beneficial way for AD operators (Interview E1_10). They produce a lot of food waste and can have a greater influence on the promotion of AD sector than the waste management companies. Contamination of food waste coming to AD plants is still a challenge. The processing facilities have installed the appropriate technologies to deal with it, but there is still a cost they face for the plastic removal from food waste. Competition, a key characteristic of market in network governance, is evident between waste-fed AD plants and IVC facilities. As already presented in previous sections, some LAs have transitioned from segregated food and garden waste collections to commingled waste collections, which are used by IVC facilities. Consequently, this had an impact on the amount of food waste being used as a feedstock by AD plants.

In Scotland, the market has been created and further developed with the introduction of legislation mandating food waste collections by LAs. The Waste (Scotland) Regulations 2012 brought changes which mandated any commercial business to recycle more than 50 kilogrammes of produced food waste amount per week in non-rural areas. They also influenced the capacity of the waste-fed AD plants. Consequently, in 2014 the LAs saw a massive influx of people collecting food waste, which increased tonnage significantly. Most of the waste-fed AD plants doubled their size and capacity because there was so much food waste in Scotland due to the 2012 Waste Regulations (Interview E1_23). In 2016, this amount decreased meaning that urban food businesses which produced over 5 kilogrammes of food waste on a weekly basis have also to sperate food waste for collection. Investors and companies made investments in AD plants, while lobbying Scottish Government and having projections of feedstock and food waste, coming from different LAs (Interview E1_23). Consequently, investors have built AD plants, while being confident in securing tonnes of food waste as input for their sustainable operation. Initially, the waste-fed AD plants were operating at full capacity. Reaching full capacity of AD plants means that the extra amount of food waste needs to be transferred to other AD plants (Interview E1_23). As the operations manager of a Scottish AD plant explains: 'before all our plants had invested in extra capacity, there was too much food waste to go out around. If you had too much food waste in your own plant, [..] you had to take it to a plant because their capacity was filled up. So, we were still making money at that, and we are sending things down South to process. That no longer happens, to be fair' (Interview E1_23).

In both countries, the wider usage of AD products can provide further opportunities for the waste-fed AD deployment. Industry is dealing with the issues of digestate use and the market development of digestate. The digestate can be fully utilised in the farming sector, while following the PAS110 standards as this is essential for the sustainability of the market. By adopting AD, rural areas can achieve energy autonomy, which benefits the local community through waste recycling and self-sufficient energy production and supports local farmers by enabling them to utilise digestate. In Scotland, capital grants influenced the market development of AD and increased confidence in the use of its products, which are the biogas and digestate. At the initial stage of the market development, the creation of this market would not have been feasible without the funding of capital grants (Interview E1_2). It also happened concurrently with the policy initiatives and regulations of the Scottish Government. Furthermore, the development of the first AD plants provided important feedback to the development of policies which influence the AD sector.

This approach was strategic; however, the focus now is on the support and building of the biogas sector as most of the rural areas are off the grid (Interview E1_2).

Partnerships among LAs, AD operators, farmers and supermarkets are influential for waste-fed AD deployment as they form a unique network of market actors in both countries. An REA interviewee suggests that the development of AD industry in Scotland was successful, despite the challenges it faces (Interview E1_4). In Scotland, there are a few waste-fed AD plants which process whiskey and distillery waste, whereas in England there are more crop-fed AD plants (Interview E1_19). These links with the whiskey and distillery industry provide further assurance for the quality of the produced digestate as distillery waste has almost no plastic contamination (Interview E1_6). In both nations the links between the AD industry and farming sector are evident. The agricultural sector in Scotland has stronger links with waste-fed AD and there has been coordinated efforts from Zero Waste Scotland and SEPA to promote and support the safe use of digestate by farmers. Large retailers and supermarkets struggle with the contamination of waste they produce when they change food waste operators (Interview E1_10). However, there is a reluctance to demand the perseverance of high-quality waste as there is the risk of losing business and partners (Interview E1_10). While supermarkets supply AD plants with substantial amounts of food waste, campaigns aimed at reducing food waste also decrease the amount of waste available for use as feedstock in these plants (Interview E1_23). LAs have the potential to collaborate with supermarkets, which often leverage their environmental initiatives for marketing purposes rather than maximising waste collection and segregation. Therefore, a partnership between supermarkets and LAs can lead to a more unified message about food waste usage. As the recycling manager of Zero Waste Scotland argues: ‘if supermarkets and local authorities join up to give a consistent message to food waste, then we can get better messages around food waste prevention, minimisation, segregation and utilisation at the AD plants’ (Interview E1_10).

Regulatory oversight plays a pivotal role in the waste-fed AD industry, exerting influence which transcends market forces. As our knowledge of the technology deepens, these regulations continue to evolve, ensuring the health and safety aspects of operating AD plants are upheld. Industry representatives argue that policies and regulations restrict the industry to use only certain technologies to have access to financial reward mechanisms, without allowing enough space for innovation and experimentation (Interview E1_5 and Interview E1_21). During the last ten years, regulations have changed significantly to include the knowledge and learning on potential problems and risks, associated with the operation of waste-fed AD plants (Interview E1_4). As a result, there are now more regulatory requirements for the safe and efficient operation of these plants than ten years ago (Interview E1_7 and Interview E1_4). For example, building an AD plant needs proper containment and storage for digestate and these were not requirements of building the first AD plants in the UK (interview E1_4). AD plants need to operate efficiently, while using the right technology, equipment, management, and inspection. These aspects need to be a prerequisite for viable business and environmental objectives (Interview 13Sc).

As the industry grows and capacity of AD plants increases, there is the ambition that the AD industry and market will eventually become self-sustaining and then the UK Government would withdraw the financial support. Both the capacity of industry and market have improved, due to RHI and GGSS, but they are not yet self-sustaining (Interview 1Sc, Interview E1_11 and Interview E1_21). Overall investments in AD plants have brought positive impacts on the economy by improving existing infrastructure and creating jobs (Interview 18Sc and Interview 2Sc). Scotland has achieved a higher rate of waste-fed AD deployment compared to England. Both England and Scotland have significant potential to expand the waste-fed AD sector in the future, by systematising food waste collections, improving the efficiency and quality of AD facilities and supporting further the development of markets for digestate and biogas. However, three industry representatives argue that the future of AD is co-digestion, which is not currently allowed due to the existing regulatory framework in England and Scotland (Interview E1_11, Interview 1_7 and Interview E1_5). Specifically, anaerobic co-digestion may provide a more sustainable solution of waste treatment in the future as it uses multiple feedstocks from different waste streams and produces more bioenergy and richer nutrient value of the co-digestate (Karki et al., 2021; Mu et al., 2020).

6.4 Geographical factors

Internal capacity, autonomy, and local experimentation of LAs is also dependent on geographical factors. As already mentioned in chapter 5, the rural and urban typology of LAs influences proximity to a waste treatment facility (AD or IVC). As these two factors define the needs and traits of LAs, they are considered in their decision-making and governance procedures on various service provisions. As I compare the two nations, it is worth noting that Scotland has sparsely populated areas and space availability for waste-fed AD plants. As it is presented in the Net Zero Roadmap for Scottish Industry (UKRI and NECCUS, 2023), there are important technical and historical connections to energy production in Scotland, where decarbonising industry is innovative in the development of alternatives to fossil fuels. Furthermore, Scotland's population density is low, averaging 65 people per square kilometre, but this figure conceals two extremes (Scottish Government, 2012). The country is highly urbanised in the central belt and along the east and west coasts, with 82 per cent of the population residing in areas with 3,000 or more people (Scottish Government, 2012). In contrast, the north and northwestern regions are among the UK's least populated, with densities as low as 8 people per square kilometre (Scottish Government, 2012). These demographic patterns pose unique challenges for waste management, particularly in rural areas where the long distances and travel times for waste collection and transportation can escalate financial and environmental costs.

6.4.1 Urban and rural typology

LAs have different socio-demographic and spatial characteristics, which may contribute to facing different needs and challenges in food waste collections. The

Scottish Government has defined certain regions as 'rural areas' to aid in the creation of zero waste policies and regulations which consider geographic and population trends (Scottish Government, 2012). This rural/non-rural distinction guides the development of area-specific policies and regulations to address unique technical, economic, and environmental challenges (Scottish Government, 2012). The Waste (Scotland) Regulations 2012 mandate separate food waste collections by LAs and businesses, except in rural areas. A similar rural urban classification exists in England and areas are considered rural if they are not part of settlements with a population exceeding 10,000 residents (DEFRA, 2016). According to this classification, there are four urban and six rural categories, which represent the type and size of the LA (DEFRA, 2016). However, this classification is not related yet with waste management in England as English LAs are not mandated to collect food waste separately.

The topographic characteristics of the LAs can also influence the type, quality and quantity of food waste collections and the choice of the food waste disposal method. The city centres of LAs may face issues of waste contamination from flats, tenants, and residents as they are densely populated and there may be a single large bin dedicated to a couple of properties for waste disposal (Interview E1_23). As the operations manager of a Scottish AD plant argues, 'the contamination is a challenge and there is no education for that' (Interview E1_23). In cities, high-rise apartment buildings may grapple with the issue of plastic contamination when managing various waste and recycling containers (Interview E1_23). Both Edinburgh and Glasgow initially faced challenges with the quality and volume of segregated food waste collections when they were first adopted. Over time, they were able to redesign their food waste collection processes and explore avenues for improvement of food waste collections, feeding AD plants. As articulated by the operations manager of a Scottish AD plant, Edinburgh has improved its performance, although this progress required a considerable amount of time (Interview E1_23). Glasgow City Council has been in cooperation with their AD plant to address effectively any issues related with tonnage and contamination. Its city centre has segregated food waste collections, but the wider Glasgow area has commingled waste collections as there are houses with gardens, so they incorporated garden with food waste (Interview E1_23). Gradually, Glasgow City Council started having an increase in tonnages, surpassing the food waste recycling target. However, approximately 20 per cent of food waste still ends up in household residual waste (Interview E1_23).

In contrast, rural LAs have more houses with gardens and space for effective waste management, while using different containers (Interview E1_14 and Interview E1_9). These topographic and household characteristics enable LAs to have food waste collections which are not plastic contaminated. East Ayrshire, a Scottish LA, has rural areas with substantial and high-quality food waste tonnage. The Council exerts significant influence over the management of collected food waste, ensuring its proper disposal, treatment and quality (Interview E1_23). Renfrewshire Council, encompassing urban and suburban areas along with a few villages, has diverse infrastructure needs. These needs are considered in the implementation of commingled food waste collections, which lead to IVC facilities (Interview E1_28). Consequently, this has an impact on the quantity and quality of food waste, which is sent to waste-fed AD plants. In England, very few LAs provide full geographical coverage of their food waste collection service (Interview E1_9).

Proximity to a facility is one of the key reasons why a certain AD plant or IVC facility is chosen by a Local Authority for purposes of food waste disposal and treatment (Interview E1_13 and Interview E1_15). The location of AD sites influences the maximisation of benefits the AD technology can offer to local community. The closer the LA is to an AD plant, the more cost-effective and environmentally friendly choice it is for the LA (Interview E1_12). For example, Northumberland County Council chose an AD plant which is located around 50 miles away from the city centre (Interview E1_13). The search for the ideal facility focused on local AD plants which were experienced in the household collections of food waste, even though in the area there are mainly farm-fed AD plants (Interview E1_13). Waste Officers of Northumberland County Council felt that it was easy to approach AD facilities and identify the right one for their needs as there are AD plants which are active in the wider region (Interview E1_13). LAs will choose the closest facility to the LA as the proximity reduces transportation costs of waste and their environmental footprint (Interview E1_25, Interview 1_24 and Interview E1_26). This has been the case for South Ayrshire Council, East Lothian Council and East Riding of Yorkshire Council.

Identifying the right location of AD plants can be a challenge for investors as they need to be part of a wider system. They need to be located close to food waste and feedstock suppliers, but they also need connectivity to the gas grid for injecting the outputs of biomethane and biogas. They also need designated land where the produced digestate can be disposed and spread. However, their location may face connectivity issues on getting inputs and providing their outputs to secure their successful operation (Interview E1_8 and Interview E1_10). In England, during the early years of AD deployment, there was preference for AD plants to operate in the areas of Hertfordshire and Hampshire which have very sensitive habitats with rich biodiversity (Interview 13Sc). The presence of AD plants in proximity to sensitive habitats can lead to increasing loads of nitrification and acidification, even in breach of permitted levels (Interview 13Sc). Moreover, most AD facilities are situated in the most densely populated regions of Scotland, so decision-making on the location of waste-fed AD plants needs to be further improved (Interview E1_10). As the interviewee from Zero Waste Scotland expressed their desire: 'we want the rural areas as well as the urban areas to be able to access AD facilities and we want these facilities operating at close to maximum capacity. So that we have the right capacity in the right locations' (Interview E1_10).

In Scotland, there is need for the network of facilities, so the extra tonnage of food waste does not need to be transported in big distances. AD facilities are also essential for the islands to avoid any transfer of food waste to the mainland (Interview E1_10). However, AD facilities need support mechanisms to generate renewable electricity, particularly in remote areas of Scotland, such as the Orkney Islands (Interview E1_10). Co-location of activities is also important because an AD facility, which is located next to farms or to energy from waste facilities and can feed into the heat network. The strategic placement of activities is crucial, particularly for an AD facility. When an AD plant is situated adjacent to farms or waste-to-energy facilities, it can effectively contribute to the heat network. Creating a network of facilities is a crucial element for successful deployment of AD at a national level. However, most of the AD sites are in central Scotland and mainly between Edinburgh and Glasgow, but there are fewer in North Scotland. Consequently, tonnes of food waste must travel a long distance to come to get to the facilities (Interview E1_10). Assessing the locations, requirements, and national coverage of key waste management facilities is vital for identifying optimal sites, with the aim to reduce waste transportation and improve the distribution of waste-fed AD plants (Interview E1_10).

The internal capacity, autonomy, and local experimentation of LAs are shaped by geographical factors, with rural and urban typologies influencing proximity to waste treatment facilities and decision-making processes. The topography and socio-demographic characteristics of LAs affect waste management practices, with urban areas facing contamination issues and rural areas dealing with logistical challenges. Rural LAs benefit from more houses with gardens, reducing plastic contamination in food waste collections. Scotland's low population density and historical ties to renewable energy production present unique waste management challenges and opportunities. The Waste (Scotland) Regulations 2012 mandated separate food waste collections, except in rural areas, effectively addressing these challenges. In contrast, England's classification of rural and urban areas does not align with food waste collection practices, and few LAs offer comprehensive services. Proximity to AD or IVC facilities is crucial for cost-effective and environmentally friendly waste management, as seen with Northumberland County Council's choice of a nearby AD plant. Identifying optimal locations for AD plants is challenging due to the need for proximity to food waste suppliers, gas grid connectivity, and designated land for digestate disposal. Early AD deployment in England favored areas with sensitive habitats, raising environmental concerns. In Scotland, most AD facilities are in densely populated regions, necessitating improved location strategies to ensure access and operational efficiency. A network of facilities is essential to minimise waste transportation distances, especially for remote areas, such as the Orkney Islands. Co-location with farms or waste-to-energy facilities can enhance the heat network, highlighting the importance of strategic placement for AD facilities.

6.5 Conclusions

The role of governance is instrumental in the sector of waste-fed AD in the UK. In the chapter, I examined the influence of governance in England and Scotland on the deployment of waste-fed AD, while exploring a range of governance criteria, economic, and geographical factors which can influence a socio-technical transition. Evaluative criteria of governance are coordination, learning and knowledge, autonomy, local experimentation, and internal capacity. The first two refer both to the national and local levels of government and their interactions, whereas the rest mainly refer to the roles and initiatives taken by the local government. The role of market is also explored, along with the urban and rural characteristics of an LA and its proximity to a facility. Local governments are conceptualised as influential actors in the development of AD technology in the UK, after the initial strategy setting and decision-making at the national level of government. Further evidence is drawn from the selected cases of the research, which are the following LAs: East Lothian Council, South Ayrshire Council, Renfrewshire Council (Scotland) and East Riding of Yorkshire Council, Northumberland County Council, Bracknell Forest Council (England).

Scottish governance is characterised by a more inclusive and flexible formation of government, which is smaller in size and aims to keep closer ties with different stakeholders. It responds more holistically and inclusively to top-down and bottom-up requests for the development of waste-fed AD. UK Government is bigger in size and has more actors so their coordination is mainly centre-led and faces challenges of competing policy priorities, fragmentation and miscommunication. Moreover, Scottish LAs have a better performance on food waste collection and disposal, compared to English LAs, because they have higher targets, which are set in cooperation with the Scottish Government. In both England and Scotland, robust stakeholder engagement on all levels of governance has proved to be essential. Coordination and communication of stakeholders are parts of their wider engagement which depends on various circumstances and seems to be at the core of governance. Learning and knowledge is another criterion for assessing further the effectiveness at all levels of governance and influences waste-fed AD deployment. Overall Scotland is a smaller nation with only 32 LAs and has more efficient channels of communication to navigate knowledge and learning to different stakeholders. This contributes to a higher deployment rate of waste-fed AD.

Autonomy, local experimentation, and internal capacity are three criteria which are interrelated and used for the comparison between English and Scottish LAs and their performance in the use of segregated food waste collections and AD. English LAs are more autonomous in taking initiatives related to waste-fed AD, but they are constrained by lack of clarity in the forthcoming waste regulations and funding. Scottish LAs received funding and guidance from Zero Waste Scotland. They seem less autonomous compared to English LAs, but they took better planned and efficient actions related to food waste collections and use of waste-fed AD. The three English LAs explored in the research had the autonomy to experiment and self-organise with food waste collections and use of IVC or AD as they did not have clear guidance and funding. They experimented with food waste trials or with provision of this service to some areas of the LA. Scottish LAs were more advanced in the use of waste-fed AD and provision of food waste collections, which covered their whole territory. They are more experienced compared to the English LAs and have higher levels of internal capacity in the implementation and operation of food waste collections, which led to an AD facility.

Market and geography are two factors of governance effectiveness influencing both the national and local levels of government. The role of the market is explored as an economic factor which plays a crucial role in the development of waste-fed AD in the UK, including national regulations and local government contracts. Regulations and policies have positively impacted the AD market, fostering collaborations among LAs, farmers, AD operators, and supermarkets. The availability of food waste feedstock for AD plants is affected by competition with IVC facilities, alongside persistent issues such as food waste contamination. Despite significant regulatory changes and improvements in industry capacity, the AD market in the UK is not yet self-sustaining, though it has positively impacted the economy. Geographical factors are urban and rural differences and proximity to a facility, which also explain differences in waste-fed AD deployment of both nations, while considering the needs and nature of the technology. Rural and urban typologies of LAs influence proximity to waste treatment facilities and decision-making processes of food waste management practices. Scotland is characterised by more advantageous terms in the geography and location of AD plants, compared to England. However, there is need for creation of networks which have different facilities completing each other in the same location.

Chapter 7 Comparative Analysis

7.1 Objectives and Structure of the Chapter

The research has a strong comparative element, and the previous chapter uses the evaluative criteria and explanatory factors of the analytical framework to illustrate the differences and similarities in the waste-fed AD deployment of England and Scotland. The purpose of this chapter is to discuss further the variation between England and Scotland in the deployment of waste-fed AD. This comparative analysis provides the basis for deriving conclusions about the importance of governance in the transitions literature and the resulting implications for its key frameworks and concepts in the use of waste-fed AD. Section 7.2 illustrates the importance of the policy and regulatory framework for the development of AD as Scotland has been leading the way in waste regulations, which mandated the collections of food waste. Furthermore, section 7.3 illustrates how Scottish Government is shown to perform better in the evaluative factors of coordination and learning and knowledge, which contribute to the higher levels of waste-fed AD deployment in Scotland. Similarities and differences between the LAs of the two nations are discussed in relation to the following: autonomy, local experimentation, internal capacity, market, proximity to a facility, urban and rural differences. Section 7.3 also seeks to answer clearly the last two sub-questions of the research, while highlighting the strengths and weaknesses of the analytical framework of the research. Section 7.4 summarises the key points of the chapter and the core factors explaining the success of English and Scottish LAs in the use of waste-fed AD plants. Overall, the key finding is the importance of governance in the deployment of waste-fed AD, which is also influenced by the initiatives and actions of LAs.

7.2 Policies and regulations in place

One of the research objectives is to explore the role of LAs in a sustainability transition associated with the deployment of waste-fed AD in the UK, while comparing the governance effectiveness in the uptake of AD in England and Scotland. In Chapters 4 and 6, policymaking at the devolved level is shown to be a contributing factor to different deployment rates of AD in England and Scotland. Furthermore, there are also other factors which can influence the different performances in waste-fed AD and this chapter discusses further how these factors are interrelated and influence differently the deployment of waste-fed AD. First of all, policy is a key factor for the uptake of waste-fed AD deployment in the UK and this is in agreement with the MLP and TIS, which set policy as a key political factor of a socio-technical transition and innovation pathways. However, policy development depends on the engagement and coordination of institutions and organisations on how it is implemented. Policies evolve over time and are end-products of the ongoing governance processes and dynamics. The role and effectiveness of governance is explored further in the analytical framework, presented in Chapter 5. In the UK, most waste-fed AD plants are situated in England and Scotland, but Scotland has achieved a higher rate of waste-fed AD deployment per capita than England. This section provides a comparative analysis of the policies and regulations, which favoured the development of AD in Scotland and England.

Scotland has been leading the way in the adoption of policies, regulations, and initiatives in the sectors of climate and waste since 2008. Table 7.1 presents the comparison between England and Scotland in key policies, initiatives and regulations of climate, renewable energy, and waste policy streams. It presents the key incentives, initiatives, strategies, and regulations in chronological order. These are selected from Section 4.2.3 of Chapter 4, which explores in-depth the wider policies and regulations of these sectors at an international, European, national, and devolved level. Table 7.1 summarises the most influential policies, regulations, and initiatives of each sector as these three policy sectors are also the most important for the deployment of waste-fed AD in both England and Scotland.

Compared to England, Scotland developed a more supportive policy and regulatory framework in the sectors of climate and waste, which influenced the development of AD since 2008 (Table 7.1). However, the development of policies, initiatives and regulations in these policy sectors approached marginally the technology and

Table 7.1 Key policies, regulations and initiatives adopted in England and Scotland since 2008		
Policy sectors	England	Scotland
Climate	UK Climate Change Act (2008) Low Carbon Transition Plan (2009), National Emission Ceiling Regulations (2018), Net Zero Strategy (2021),	Climate Change (Scotland) Act (2009), Climate Change Bill (2018) Climate Change (Emissions Reduction Targets) (Scotland) Act (2019); - Citizens Assembly, -Scottish Nitrogen Balance Sheet, -Just Transition Commission
Renewable energy	Energy Act 2010, Energy Efficiency Strategy 2012, Community Energy Strategy 2012, Energy Act 2013, Renewable Energy Strategy 2009, Renewable Energy Roadmap 2011, Bioenergy Strategy 2012, Feed in Tariffs (FiTs), Renewable Obligation Certificates (ROCs), Climate Change Levy, Renewable Heat Incentive (RHI), Renewable Transport Fuel Obligation (RTFO), Green Gas Support Scheme (GGSS), Biomass Strategy 2023	
Waste	Waste Management Plan for England (2013) Resources & Waste Strategy for England (2018) Waste Management Plan for England (2021) Environmental Bill (2021) Environment Act (2021)	Scotland's Zero Waste Plan (2010) -funding of 154 million (2008-2011) Waste (Scotland) Regulations 2012 Making things last – a circular strategy for Scotland (2016) Circular Economy (Scotland) Bill (2018) Ban on biodegradable municipal waste going to landfill by 2025 (2022)
	AD Strategy (2011), PAS 110 Composting Process, PAS 110 Anaerobic Digestion	

development of AD. These policies, initiatives and regulations did not target specifically the development of waste-fed AD sector, but their adoption influenced positively the uptake of waste-fed AD. AD Strategy, published in 2011, was the only fundamental strategy, which focused on the benefits, opportunities and targets associated with the development of the technology in the UK. Since the adoption of the AD Strategy, the development of AD was positively influenced by FiTs and non-domestic RHI (DEFRA, 2021). Since 2020, the GGSS provides tariff support for biomethane, which is produced via AD and injected into the gas grid. The development of renewable energy policies, regulations and initiatives influenced equally both nations as the Scottish Government has limited ability to shape the energy policy. So, there were the same renewable energy incentives, which favored the uptake of waste-fed AD plants.

Climate policies, regulations and initiatives are widely influential in setting the direction and actions of the national government to achieve the reduction of GHG emissions, such as methane and ammonia emissions. Ammonia emissions are associated with AD development in two ways. Firstly, the disposal of food waste, which ends up in landfills and is not processed by AD, produces pollutant emissions, such as methane. Secondly, ammonia emissions are related with the use and spread of an AD output, which is the digestate and requires specific technological equipment to prevent any ammonia emissions in the air. Comparing Scotland to England in climate regulations and policies, it is evident that both nations have adopted very high ambitious climate targets since 2008 (Table 7.1). The breakthrough towards climate legislation was initiated by the UK Climate Change Act 2008, which expressed the UK-wide commitment to 80 per cent GHG emissions' reduction by 2050. Since then, both nations have set even higher climate targets. Net Zero Strategy (2021) sets the UK-wide ambition of net zero emissions by 2050, whereas the Climate Change (Scotland) Act 2019 set the same target by 2045. However, the difference is not only that Scotland has adopted a shorter-time frame, but also that Scotland's climate legislation is supported by incorporating the elements of 'citizen and stakeholder engagement' and 'just transition' (Table 7.1). The societal factor is recognised as an essential ingredient for the success of the net zero and socio-technical transition in Scotland as it is important to influence the human behaviour to lead the behavioural change as part of this transition. The approach of the Scottish Government is differentiated from the Net Zero Strategy adopted in England. The Net Zero Strategy focuses more on the industrial and economic transition required to happen to achieve the net zero emissions, without embracing the stakeholder coordination to achieve this goal in a greener and fairer way.

Scottish policy and regulatory framework proved to be more ambitious, by setting higher targets and stricter standards, which influenced the development of the waste sector and AD. It was also more supportive of waste-fed AD, which was officially considered as a solution to promote the mandated separate food waste collections. In England there was no similar mandate and English LAs were only advised to adopt these collections. Since the adoption of the Zero Waste Plan in 2010, Scotland strategically set policies, initiatives, and actions in the waste sector a lot earlier than England. The key difference between England and Scotland is that Scotland has adopted food waste legislation. Specifically, Waste (Scotland) Regulations 2012 mandated both Scottish LAs and businesses to adopt separate food waste collections, and this mandate entered into force in 2014. Although both the Environment Act (2021) and Environment Bill (2021) refer to the need of English LAs to provide segregated food waste collections to households, however they do not enforce LAs to take this action. It is also worth noting that the waste regulations, targets, policies, and initiatives are set and adopted by Scottish Government in a more holistic, and inclusive manner, while the same policy instruments were concurrently being discussed through Plans and Strategies in England (Table 7.1). Scottish Government responds more inclusively and holistically to requests and issues for the development of waste-fed AD, while involving and engaging with stakeholders from different sectors. Consequently, Scotland is leading the way in food waste disposal and treatment, due to its waste policy and regulatory framework and policy narratives.

Furthermore, Scotland has developed a design-driven circular economy action plan (Whicher et al., 2018) as there are several companies using organic and food waste to produce biogas through AD process. Circular economy is a central element of the policy discourse surrounding AD.

The above review of policies and regulations provides the key outcomes of governance, which is essential for evaluating further the processes of governance in the use of waste-fed AD. The Scottish Government has adopted a more ambitious and comprehensive regulatory and policy framework in the sectors of waste and climate. In Scotland, waste-fed AD is part of the wider Circular Economy agenda. As a result, Scottish Government had a higher uptake of waste-fed AD deployment per capita, compared to England. Nonetheless, high, and ambitious targets are also adopted in England, but the 'mandate' and 'inclusivity' are missing. The lack of enforcement delays the adoption of waste-fed AD, which can contribute to a certain extent to the achievement of policy targets in waste and climate. Furthermore, there is need to develop a more integrated policy thinking in the sectors of energy, climate, and waste to encourage the use of AD technology which can contribute to the targeted socio-technical transition to 'zero waste' and 'net zero emissions'. An updated version of the AD Strategy is deemed necessary to contribute to the bigger vision of this net zero transition in the UK as the last version of AD Strategy was published in 2011. For the future of waste-fed AD development, the role of science and evidence is crucial to encourage innovation to enable the best use of AD on the ground and a policy framework which supports the uptake of AD to flourish. Specifically, there is need for further scientific evidence on the positive effects of co-digestion for the environment and economy as there are industry representatives who argue that co-digestion is the future of AD technology. However, co-digestion is not allowed within the existing regulatory framework of England and Scotland.

7.3 Governance of AD deployment – Comparing England to Scotland

The previous section illustrates that there is a cross-sectorial influence of different policy streams on AD. Policy sectors of environment, climate, and waste are devolved, but the design and delivery of renewable energy policy incentives is a reserved matter, so coordination of this policy area is led at the UK Government level. It highlights the need for the adoption of a multi-dimensional theoretical approach, as the urban sustainability transitions literature has not explored in depth the governance of these transitions. As already presented in the analytical framework of Chapter 5, key elements of the literatures on multi-level governance, urban climate governance, network governance and policy networks are brought together to enrich further the transitions literature. So, the research explores 'the governance of transitions', while identifying evaluative criteria of governance, economic and geographical factors (Table 7.2). Table 7.2 illustrates the role and potential of governance in the case of waste-fed AD as a sustainability transition of England and Scotland, while recognising other economic and geographical factors and examining to what extent they contribute to their outcomes. In the case of waste-fed AD, the outcome examined is the deployment rate of waste-fed AD per capita. The role of governance is assessed by the following criteria: coordination, learning and knowledge, internal capacity, autonomy, and local experimentation (Table 7.2). Coordination and learning and knowledge are criteria for assessing further the effectiveness of both national and local governance, which influenced waste-fed AD deployment in the two nations. Internal capacity, autonomy and local experimentation are evaluative criteria of local governance in both nations. Market and geography influence both the national and local level of governance. Moreover, urban, and rural differences and proximity to a facility are geographical factors which influence the uptake of waste-fed AD. Overall, Scotland is characterised by aspects of inclusive governance, which embraces both local and national government.

<table>
<tr><td colspan="3">Table 7.2 Key criteria for assessing waste-fed AD deployment in England and Scotland</td></tr>
<tr><td></td><td>England</td><td>Scotland</td></tr>
<tr><td colspan="3">Governance factors</td></tr>
<tr><td>Coordination</td><td>- Hierarchy & division between national and local levels of government
- Networks
- Vertical coordination between national and local level of government</td><td>- Inclusion of all stakeholders early in the decision-making processes
- Networks
- 3 peripheries working together: core, inner and civil periphery.
- Smaller in size</td></tr>
<tr><td rowspan="2">Learning and Knowledge</td><td>- Peer-to-peer learning & support between LAs</td><td>- Guidance from Zero Waste Scotland to LAs</td></tr>
<tr><td colspan="2">- Evidence-based decision-making, monitoring & evaluation, waste composition analysis.
- Networks for information sharing & communication.
- Peer-to-peer learning between farmers & building of trust.</td></tr>
<tr><td>Autonomy</td><td>- English LAs are free to decide whether they provide separate food waste collections.
- Lack of clarity, guidance & funding from national government.
- Autonomous to self-experiment on food waste collection and treatment.</td><td>- Scottish LAs are mandated to collect food waste.
- Funding and guidance provided to LAs by Zero Waste Scotland and Scottish Government.
- Autonomous to decide the method of food waste disposal; IVC or AD.</td></tr>
<tr><td>Local experimentation</td><td>- Use of trials or provision of segregated food waste collections to certain areas of LAs.
- Monitoring & Evaluation of these services
- Use of own financial resources</td><td>- No experimentation
- Provision of segregated food waste collections covering the whole LA.</td></tr>
<tr><td rowspan="2">Internal Capacity</td><td>- No funding provided by UK Government
- Provision of food waste collections in certain areas causes inequity.</td><td>- £154million provided by Scottish Government
- Provision of the service covers the LA widely.</td></tr>
<tr><td colspan="2">- Political leadership & support.
- Use of communication strategies for public engagement.
- Access to resources and infrastructure.</td></tr>
</table>

Other factors		
Market	- Renewable energy schemes have been the same	
	- Future Waste Regulations	- Waste (Scotland) Regulations & funding
	- Crop-fed AD plants are more than waste-fed AD plants	- More AD plants which use food waste as the main feedstock
	- AD industry links with farming and food industry	- Market maturity & waste-fed AD as part of circular economy - AD industry links with whiskey & distillery industry.
Geography	- Urban and rural areas - More densely and heavily populated urban LAs.	- More rural, sparsely populated areas. - Path dependency in the development of renewable energy.
	- Agglomeration, due to spatial concentration of economic activity in some regions. - Urban & rural differences and proximity to a facility.	

7.3.1 Coordination

As presented in Chapter 5, coordination is at the core of governance mechanisms and involves communication, engagement, and networks of stakeholders, working with the industry and LAs. It is associated with the effectiveness of two elements: processes of decision-making and achievement of policy targets (Greenwood, 2023). It can also be both horizontal and vertical and explain the processes of national and local level of governance, which contributed to the uptake of waste-fed AD in both England and Scotland. Overall, the UK public administration is characterised by vertical coordination (Peters, 2006), which influences the collaboration of important stakeholders in waste-fed AD deployment. However, state, and non-state actors also play the role of horizontal and vertical coordinator in different policy processes and settings, influencing the waste-fed AD deployment in the UK. Networks are groups of organisations which communicate, coordinate, and collaborate 'to deliver services, address problems and opportunities, transmit information, innovate, and acquire needed resources' (Kenis and Provan, 2009, p.440). Networks are both active in the promotion of waste-fed AD either directly or indirectly in both England and Scotland, but there are also smaller networks at the regional level to address common needs and challenges of their members. The research did not evaluate the networks and their influence on the policymaking of AD, however networks are perceived as important stakeholders who promote industry's interests and the use of AD technology.

Comparison between Scottish Government and Westminster Government provides key differences of coordination at the national level of government. Table 7.2 summarises the differences and similarities in coordination between England and Scotland as they are shaped by the reserved and devolved areas of policymaking, which enabled further the uptake of waste-fed AD in Scotland. In England, hierarchy, and division between the national and local levels of government is clear and the national level has the central role in governance. England's model of coordination seems to be more hierarchical, whereas horizontal coordination takes place across the different government departments. The relationship between national and local levels of government is vertical and the national level of government is more powerful and influential than the local level in both political and financial terms (Kuzemko, 2019). In Scotland, the ties of these two levels of government are stronger as they worked effectively to embrace policy and regulatory changes of the waste sector, which were influential for the waste-fed AD deployment. The Scottish model of governance is founded on the following three elements: communication, influence, and collaboration. Scottish Government is at the core of decision-making, which is surrounded by the inner periphery and civil periphery (Corfee-Morlot et al., 2011; Markantoni, 2016). Regulators, not-for-profit organisations, trade bodies belong to the inner periphery, whereas LAs, communities, households and individuals form the civil periphery. The core and two peripheries work with each other for the development of waste-fed AD in Scotland. Furthermore, the Scottish actors of inner periphery had a more strategic communication of waste-fed AD, while having a clear vision of its development. Compared to their English counterparts, these organisations had a more influential role in the guidance and support of Scottish LAs to transition their waste management.

Effective governance entails cross-organisational decision-making, which is associated with ongoing communications and collaboration among different stakeholders, as it is important to share views, objectives, and learning in the sector of waste-fed AD. This type of governance is evident at different stages of the waste-fed AD development in Scotland, from strategy setting of considering AD as an important technology to the adoption of Scotland's Zero Waste Plan (2010) and workshops of Zero Waste Scotland with SEPA and farmers' representatives to consider digestate as nutrient fertiliser. During the different stages of the socio-technical transition, these processes of communication and coordination are ways of effectively addressing any barriers to collaboration among different stakeholders. UK Government has a bigger size and a plethora of stakeholders, so the coordination is mainly centre-led by government. Both Scottish and UK Government face the same challenges, which can become barriers to coordination: competing policy priorities, working in silos, fragmentation, and miscommunication. Scottish coordination is characterised as more inclusive and 'joined-up' because various state actors participate to reach targeted outcomes. These processes of coordination reveal the potential of Scotland to achieve targets towards a low carbon future, but these also need political motivation, targeted use of resources and engagement of the public (Sugden et al., 2012). In Scotland, this type of inclusive and joined-up coordination contributes to an effective model of governance, which led to a higher uptake of waste-fed AD, compared to England. Moreover, Scotland's smaller size is also a contributing factor to inclusive coordination as there are significantly less stakeholders than their English counterparts, so it is easier and quicker to collaborate with each other.

7.3.2 Learning and Knowledge

Learning and knowledge is closely related to coordination because it is both a process and outcome of coordination. In policy, different stakeholders collaborate and build their relationships, while their skills and knowledge co-evolve through this collaboration (Greenwood, 2023). Learning and knowledge is essential for the evidence-based decision-making in the development of waste-fed AD, while forming interrelationships among all levels of government and different stakeholders in both nations. In the UK, the development of AD industry was initiated using scientific evidence on the capacity, efficiency, and cost-effectiveness of its technology. Learning and knowledge is also associated with raising awareness about waste-fed AD and involves educating the wider public, schools, communities, farmers, and households on key issues, such as food waste quality, recycling processes, and the benefits and end products of AD. Increased public awareness can raise participation in food waste recycling and acceptance levels of waste-fed AD. Table 7.2 also presents the similarities and differences in learning and knowledge processes in England and Scotland.

Informal and formal mechanisms of learning, communicating, and sharing knowledge are similar in both the UK Government and Scottish Government (Table 7.2). Formal mechanisms of learning and knowledge are processes and mechanisms of monitoring and evaluation, which are adopted both by the national and local level of government and can inform decision-making on food waste management and AD. Waste composition analysis enables waste officers of LAs to check the composition of biodegradable waste and the amount of food waste, which is sent to landfill. Informal mechanisms of learning and knowledge sharing are communication between waste officers of LAs, peer-to-peer learning among farmers and site visits of waste-fed AD plants. In England, sharing of knowledge and information among LAs is effective as it supports adoption of segregated food waste collections and waste-fed AD. This communication and information sharing can happen in a more structured and organised way through network memberships or relationship building among LAs, trade bodies and not-for-profit organisations. Having waste officers with expertise, knowledge and experience in the AD technology is an important factor for English LAs to adopt separate food waste collections, which feed AD facilities.

In Scotland, the inner periphery has a critical role in coordination (as already noted above) and in the learning and knowledge sharing of the civil periphery, which includes communities, households, individuals, and the wider society (as defined in Markantoni, 2016). Scottish LAs highlighted the importance of getting guidance and feedback, which is provided by Zero Waste Scotland, on the adoption of separate food waste collections and use of AD. Zero Waste Scotland is a not-for-profit organisation and belongs to Scotland's inner periphery, which includes non-departmental public bodies and government agencies, the private and the third sector (Markantoni, 2016). Furthermore, Scotland has a smaller number of LAs, which are only 32, compared to 317 English LAs, consequently, this enables Scottish LAs to navigate knowledge and learning in the issues of food waste and AD more quickly, easily, and efficiently (Interview E1_14 and Interview E1_25). This access of information through networks and other communication channels of Scottish LAs have also contributed to a higher development rate of waste-fed AD. English LAs highlighted the importance of peer-to-peer learning because the food waste collections have not been mandated yet, so they expressed the importance of learning from neighbouring LAs in the preparation for change. Both English and Scottish LAs who have implemented segregated food waste collections and used AD, focus on monitoring and evaluating their services to assess effectiveness and make improvements. Scottish LAs are already ahead in the mandated food waste collections, so their needs in learning focus more on improving or extending the existing service.

7.3.3 Autonomy

Coordination, learning and knowledge are governance factors, which influence both local and national levels of government. Autonomy, local experimentation, and internal capacity are governance factors which influence mainly the local level of government. The comparison between the selected Scottish and English LAs shed light on these three evaluative criteria of local governance and their influence on the uptake of waste-fed AD technology (Table 7.2). Autonomy of LAs is defined as 'the degree of freedom' from central government, which defines the powers, entitlements, and responsibilities of local government (Eckersley, 2018). It is an evaluative criterion which explores the freedom, choices and actions of LAs on food waste management and use of waste-fed AD and their contribution to the implementation of policy and regulatory framework, adopted by the national government. As a criterion, it reflects on the decision-making of LAs to set their own targets and take initiatives to effectively address problems, despite any regulatory initiatives and financial constraints, imposed by the national level of government. The autonomy of LAs is constrained by the lack of resources, regulatory clarity, and funding. Both English and Scottish LAs have different levels of autonomy which illustrate their different approaches in collecting food waste separately and their motivations in the use of AD or IVC for its disposal and treatment. The high levels of autonomy led to high levels of local experimentation in the English LAs as the next section illustrates further.

Both English and Scottish LAs, who collect food waste, are free to choose the type of food waste disposal (IVC or AD), the contractor, the type, and frequency of the service, while following certain procedures of procurement and decision-making. LAs have responsibility, but also the freedom to consider the choice of different collection methods, the potential of AD, and different waste management companies to ensure how the whole process of waste collection and treatment can maximise economic and environmental benefits. Another sign of LA autonomy is following procurement procedures to make decisions on their contractors to collect and dispose food waste. Overall, LAs are free to make the choice of the technology treatment, while considering the processes and the wider environmental benefits of their choice.

Autonomy also includes the flexibility of an LA to change from one type of food waste management and disposal to another. Nonetheless, cost of the service is a key decision-making factor and can lead some LAs to change their food waste collection and disposal model. Before the introduction of Waste Scotland Regulations, the 2013 gate fees of food waste AD were slightly higher than the gate fees of commingled waste, so the option of commingled waste and use of IVC were cheaper than separate food waste collections, feeding AD, for many Scottish LAs. High costs of having separate food and garden collections can also be the reason to adopt commingled waste collections and to choose IVC, while reducing methane emissions from sending less amounts of food waste to landfills. The frequency of waste collections depends on both the costs and environmental targets of LAs. Costs restrict the autonomy of LAs to make the best environmental decision on their food waste collections and disposal method as they eventually choose less expensive processes of food waste collection. This is the case for both English and Scottish LAs.

In England, the absence of mandatory food waste collections made LAs more autonomous to decide and act on their food waste management and disposal. England had set the 2020 target of 50 per cent recycling household waste, and its future targets on municipal waste recycling rates are still under development (DEFRA, 2020). Nonetheless, budget reductions from national government and the wider financial austerity have affected the relationship between English LAs and national government (Gray and Barford, 2018; Pike et al., 2018). English LAs enjoy significant autonomy to decide how to incorporate environmental targets into their waste strategies and set their own initiatives for their food waste management. With reference to food waste management, English LAs had the freedom to decide whether and how they divert food waste from landfills. Some are interested in collecting food waste separately, because these collections will supplement their existing recycling services and contribute to the national recycling targets of England. Furthermore, LAs undertake their own carbon assessments which contribute to declaration of carbon emergency and towards the UK's 2050 Net Zero greenhouse gas emissions target, while considering different methods of treatment and disposal of their waste (LGA, 2021). Compared to Scottish LAs, English LAs are characterised by greater levels of autonomy in terms of setting their own strategies, targets, and food waste management, but they have been constrained by lack of clarity in the forthcoming waste regulations and funding (NAO and Defra, 2023). Despite the autonomy of English LAs, the lack of funding and guidance constrains their capacity to adopt food waste management collections and use of waste-fed AD more widely. Uncertainty from national government undermines strategic and coordinated actions of local government. Consequently, a few LAs, who have not already segregated food waste, requested more clarity and guidance on the adoption of food waste collections, before taking any further action.

Scotland has adopted the Zero Waste Plan, which included a 60 per cent recycling target of household waste collected by 2020 and a 70 per cent recycling target of household waste collected by 2025 (Scottish Government, 2010). Furthermore, the adoption of Net Zero targets and the ban of the biodegradable municipal waste going to landfill, initiated further decisions and actions on food waste collection and the use of AD or IVC by the LAs, so they can adopt their own ambitious strategies. The adoption of ambitious waste, recycling and climate targets was a very influential initiative for the LAs by the Scottish Government. Consequently, Scottish LAs had to respond effectively to the mandated food waste collections, while receiving sufficient funding and guidance from Zero Waste Scotland to align their strategies and actions towards Scotland's Zero Waste targets, the EU Waste Framework Directive and international climate change targets. Specifically, the provision of funding to Scottish LAs enabled them to face costs of adopting segregated food waste collections and using waste-fed AD. Compared to English LAs, Scottish LAs had more restricted degrees of freedom as they had to take actions and initiatives in food waste within a specific regulatory, policy and financial framework set by the Scottish Government, as illustrated in Chapter 4. As a result, the deployment of waste-fed AD per capita is higher in Scotland, compared to England, and Scottish LAs have been already ten years ahead in the provision of food waste collections and use of waste-fed AD as a waste disposal method.

7.3.4 Local experimentation

Local experimentation is one of the evaluative criteria of the analytical framework and is associated with trials implemented by some LAs to identify the uptake of food waste collection services and the use of waste-fed AD. At the local level of governance, performance indicators, data and evidence are collected to analyse the results and impacts of the trials and inform decision-making for further actions. Contamination rates of waste, composition analysis and participation rates are used at LA level to assess performance of the food waste collection service and to explore further ways of improving residents' participation. For example, a positive impact of a food waste collection trial is the reduction of food in the amount of residual waste, ending to incineration. Funding is a key ingredient of trials and influences the end products of service provision.

In the research, three English LAs (Bracknell Forest Council, East Riding of Yorkshire Council and Northumberland County Council) adopted experimentation in the food waste collections through the adoption of trials or the provision of the collection to certain geographic areas. These trials focused on certain areas or neighbourhoods within the LAs, where the waste collection service was provided, while economic and environmental data was being collected for monitoring and evaluation purposes. These processes enabled evidence-based decision-making process of the LAs on taking further actions related to food waste management and treatment: IVC or AD. Out of these three English LAs, one English LA collected food waste for IVC treatment, whereas the rest have adopted separate food waste collections which feed AD plants. Furthermore, two English LAs used trials for the provision of food waste collection services for both IVC and AD. One English LA provided this service to certain areas and population groups, without any trial first. Some LAs base their food waste management strategies on their waste composition analysis and evidence of other councils, bypassing trials or pilots, and design their waste collection and disposal systems to achieve specific outcomes. Overall, these three English LAs undertook 'local experimentation' with food waste collections using their own financial resources without any external funding programme. On the contrary, the three Scottish LAs (South Ayrshire Council, East Lothian Council and Northumberland County Council) provided separate food waste collections to a wider coverage of household types. None of the Scottish LAs adopted food waste collection trials, as they provided the food waste collection service which covered most or all its population from the beginning.

The research highlights the strong interrelationship between the two factors of local governance: autonomy and local experimentation. The more autonomy English LAs have in the design and adoption of their food waste collection and treatment, the higher their degree of local experimentation is with modes and coverage of waste collection, management, and treatment. Although LAs had high levels of freedom in decision-making, they faced lack of funding, guidance, and clarity in forthcoming legislative and policy changes, imposed by the national government. This autonomy enabled LAs to experiment and take initiatives with food waste collections and waste-fed AD plants and decide based on the results and learning of these experiments, which were funded by their own means. English LAs are perceived as 'active sites of experimentation' (Jordan et al., 2018) which encourage innovation in governance and food waste collections through AD and IVC. Compared to English LAs, this is a key difference for Scottish LAs who were able to adopt food waste collections for their whole population from the beginning, without any experimentation (Table 7.2). The provision of separate food waste collections and the use of waste-fed AD as a waste treatment by Scottish LAs contributed to the higher uptake of waste-fed AD deployment per capita. Despite their lack of experimentation, Scottish LAs managed to provide food waste collections which covered most of their households and this secured the feedstock essential for the operation of waste-fed AD plants.

7.3.5 Internal Capacity

As presented in Chapter 5, internal capacity is an evaluative criterion of the local level of governance and explores the ability of LAs to achieve its targets, while making the best use of its own resources, without any dependence on other actors for resources (Holgate, 2007; Matthews, 2012; Eckersley, 2018). LAs are important stakeholders of the energy system, which depends on their internal capacities for policy development and implementation (Bulkeley and Kern, 2006; Eckersley, 2018; Emelianoff, 2014;

Hawkey, 2015; Kelly and Pollitt, 2014; Tingey and Webb, 2020). In the research, internal capacity also includes the different levels of LA capacity to adopt food waste collections and use waste-fed AD plants as a disposal method. This type of internal capacity depends on the role of political leadership and support, funding availability, use of infrastructure, resources and communication strategies, the provision and operation of food waste collection services. The internal capacity of LAs in the implementation of food waste collections and use of waste-fed AD is reflected on the equity and quality of the service and the levels of public participation in the service.

Since 2010, LAs faced austerity and budgetary constraints, which decreased their internal capacity, but also increased inequality and territorial injustice between LAs (Gray and Barford, 2018). Because of these financial constraints, food waste management became a lower priority issue for LAs (Banks et al., 2018; Purnell, 2019; Acharya and Cave, 2021). Autonomy and internal capacity are interrelated. The ability to experiment is also associated with internal capacity of an LA and its political, legal, and socio-economic context which allows LAs to use trials (Nejaime, 2009; Heijden, 2019). However, having more autonomy does not necessarily equate to having more internal capacity to meet specific national targets and provide a particular service to their residents (Eckersley, 2018).

There are differences and similarities in the internal capacity of LAs, as each LA has its own characteristics. Financial resources are very important for the adoption of food waste collections as they enable access to infrastructure, technology, and learning. A key difference between English and Scottish LAs is the provision of funding for the adoption of food waste collections and use of waste-fed AD as a waste disposal method (Table 7.2). Compared to English LAs, Scottish LAs were provided with funding of £154 million and guidance from Scottish Government and Zero Waste Scotland. The management and use of these funds reflect the internal capacity of Scottish LAs to take advantage of funding opportunities and adapt to change set by the national regulatory and policy framework. Furthermore, internal capacity of LAs is also reflected in the ability of English LAs to deal with costs and constrained budgets, while implementing food waste collections and using waste-fed AD. In this case there are different interpretations of LA internal capacity, however they cannot be examined in isolation of the wider national and political context. In addition, Scottish LAs worked more closely with AD operators, because Zero Waste Scotland encouraged cooperation with both LAs and AD operators. Consequently, Scottish LAs seem to be more advanced in the food waste collections and the use of AD as they are more experienced compared to the English LAs.

Another key difference is the operational side of food waste collections by LAs and its results on equity and quality of the service provision (Table 7.2). Operation of food waste collections is related with the internal capacity of LAs to make the best use of their resources to provide this service in a cost-efficient and environmentally friendly way. It also includes access to the infrastructure of an AD plant, equity and quality of the service provision and the engagement of its residents in the waste collection service through communication mechanisms of the LA. For the English LAs examined, trials and pilots are used at the initial stages of this transition, however these first stages have impact on equity as only a few areas of LAs have access to this service. As already mentioned, Scottish LAs proceeded with food waste collections which cover their households widely from the beginning of this transition, while enabling equity and inclusivity across its residents. Both English and Scottish LAs face the challenge of plastic contamination in the food waste collections and the digestate produced. Because English LAs are at the early stages of food waste collection and use of waste-fed AD, they have more issues related with the plastic contamination and its presence in the digestate produced. Compared to English LAs, Scottish LAs are more experienced as they have adopted measures to tackle contamination of food waste effectively, based on learning and communication with AD operators. Overall, there are proportionately more actions undertaken by Scottish LAs, which are the result of their internal capacity. The plethora of actions taken by Scottish LAs are related with the higher uptakes of waste-fed AD in Scotland.

Having political leadership and support for the adoption of food waste collection is important for both Scottish and English LAs and is examined as a key characteristic of their internal capacity (Table 7.2). Firstly, political support and leadership have been stronger in Scotland than England to enable a socio-technical transition to happen at the local level, such as the use of waste-fed AD by LAs. LAs' political leadership, who supports environmental-friendly solutions for waste disposal, is essential for the uptake of AD technology. Nonetheless, policies and political leadership are not sufficient to run and sustain a service by LAs, and need to be supported with funding, guidance, use of proper infrastructure, communication strategies and proper operation of the services. Secondly, stakeholder engagement is essential in the wider uptake of waste-fed AD through communication strategies and provision of incentives, which eventually motivate the public to engage successfully in food waste collections, feeding AD plants. Low participation rates in the food waste collections seem to be a challenge for both English and Scottish LAs. Residents' participation and engagement need to be further incentivised with communication mechanisms and seems to be a key issue for most LAs in both England and Scotland. Both Scottish and English LAs had communication campaigns and advertisements targeted to increase participation rates in food waste collections. The use of communication strategies is more recent and intense amongst English LAs at the initial stages of this transition to ensure public engagement and participation in food waste collections. Because of the ten-year mandated food waste collections and the increasing use of AD technology in Scotland, the public acceptance of food waste collections and AD is higher than England.

7.3.6 Market

Market is an evaluative criterion related to the national and local levels of government. There are few similarities and differences in the waste-fed AD market of England and Scotland, and these are illustrated below. Key similarity is that the same renewable energy incentives, such as FiTs, RHI and GGSS, were accessible to both nations. However, the AD market has some differences in Scotland and England, because of waste management regulations and strategies, food waste availability, and financial characteristics, such as market maturity and strong links with other industries. Overall, the market adapts to the changes caused by regulations and policies, which shape opportunities for further growth. In the sector of waste-fed AD, the market is mostly influenced by the national level of government. Local level of government is influential in the negotiations of the contracts and locations of the AD facilities. AD operators have worked with LAs to ensure that the procurement procedures and planning permissions are in place for the construction and operation of the AD plants, which use the food waste of LAs as their feedstock.

The sector of waste-fed AD was developed by a combination of factors, but it has been mainly driven by the energy subsidies, since 2010. The market of AD responds positively to the renewable energy incentives which were the same in both England and Scotland and supported the creation of waste-fed AD plants. These subsidies allowed various types of businesses to take the risk to invest in AD, and build waste-fed AD plants, because they were certain on the type of subsidy for renewable energy production and the price of produced gas. These tariffs were important for market response when the use of waste-fed AD is still innovative. Specifically, FiTs and RHI were successful as they managed to boost the sector development. However, the dependence of AD industry on subsidies makes its long-term deployment inefficient.

In Scotland, the market has been initiated and further developed with the introduction of legislation mandating food waste collections by LAs and businesses. Waste (Scotland) Regulations 2012 strengthened the market in Scotland and led to availability of more food waste to be used as feedstock for the waste-fed AD, as in England there is more crop-fed AD. This reflects the different availability and demand of feedstocks in each country as Scotland has higher availability of food waste for AD plants and a higher deployment rate of waste-fed AD, compared to England. Furthermore, the Scottish Government has also offered specific programmes, grants or incentives to the businesses related with waste-fed AD plants operating in Scotland. This is a key difference from England where similar support has not been provided to the market. In Scotland, grant funding favoured the development of AD sector, so private investors built AD plants to process food waste. This regulatory and financial framework provided stability and certainty to AD investors and developers on the profitability of the investment and availability of feedstock for the sustainable operation of AD plants. Feedstock availability is very important for the efficiency and sustainability of the sector but can differ between England and Scotland. There are factors, such as agricultural practices, use of the digestate on land and national waste management strategies, which cause these differences. Scotland has a significant agricultural sector which can work both as a source of feedstock and a consumer of digestate. Investors have built AD plants, which would use food waste as an input for their operation. After the adoption of Waste (Scotland) Regulations 2012, the waste-fed AD plants were operating at full capacity and the extra amount of food waste had to be sent to other AD plants of Scotland. However, there was competition among waste-fed AD plants in finding sources of food waste and securing enough feedstock. Due to the lack of mandated food waste collections in England, there is not the same food waste availability for AD plants, compared to Scotland. Moreover, there are cases of Scottish LAs who transitioned from segregated food and garden waste collections to commingled waste collections which are used by IVC facilities and not AD plants. Consequently, this had an impact on the Scottish market of AD, because the total amount of available food waste was reduced as it also fed IVC facilities.

The AD market has different levels of maturity in Scotland than England. Scotland has been more proactive in the promotion of renewable energy, the adoption of waste regulations and provision of relevant funding to promote the development of waste-fed AD sector, which is more mature. In England, AD development is mainly crop-fed and has strong links with the farming sector, but in Scotland, waste-fed AD is more dominant and the links with agriculture sector became stronger to ensure the safe use of digestate on land and its impacts on food chain. Apart from the farming and dairy sectors, the sectors of renewable energy and whisky production have a stronger presence in Scotland, compared to England. In Scotland there are also strong links between the AD industry and the whisky and distillery industry as there are a few AD plants which process whiskey and distillery waste. AD is recognised as part of the circular economy in Scotland. Consequently, Scotland has a relatively higher number of AD plants per capita compared to England and more availability of experienced AD operators and suppliers.

7.3.7 Geography

Geography is an explanatory factor of the differences in the deployment of waste-fed AD between England and Scotland. In this research, geography sets spatial considerations, which are considered in governance both at local and national level. As presented in Chapter 5, geographical factors are examined, drawing key insights from the literature on sustainability transitions and referencing definitions from multi-level and urban climate governance literature. The research provides evidence of the need for spatially sensitive conceptualisations of transitions research (Truffer and Raven, 2015). In this research, there is a key place-specificity issue of waste-fed AD deployment in England and Scotland and is the following: the urban and rural typology of LAs. This typology can also influence the accessibility and proximity of the LA to a facility. This place-specificity issue also highlights the importance of technological and industrial specialisation of space within the geography of sustainability transitions (Hansen and Coenen, 2015). Studies focusing on local technological and industrial specialisation often argue that geographical clusters are catalysts for the innovations required for transitions to sustainability (Hansen and Coenen, 2015; Bridge et al., 2013; McCauley and Stephens, 2012). In line with other technologies, green innovations are spurred by the benefits of economic concentration, which include access to a skilled workforce, the support of intermediary organisations, and the presence of academic and research institutions (Hansen and Coenen, 2015; McCauley and Stephens, 2012).

Scotland and England have distinct geographical features which influence the deployment of waste-fed AD. Compared to England, Scotland is smaller, but has sparsely populated areas, which are advantageous for the installation and operation of AD plants as they need space to operate efficiently. However, waste-fed AD plants need to be located in areas which can provide them with sufficient amounts of feedstock. In both nations, there are industry concentrations in different places. Furthermore, most of the AD sites are in central Scotland and mainly between the two biggest cities of Edinburgh and Glasgow. Fewer are situated in Northern Scotland. Some AD plants process waste from Scotland's big distilleries and breweries, so there is a proximity between these two industries as their interrelationship contributes to the country's circular economy. This interrelationship creates a co-location of activities which are vital for the operation of waste-fed AD plants and builds networks of facilities which complement their process and operation. In England, most AD plants are situated in the South West, West Midlands and the East Midlands (NFCCC, 2021), close to other medium and high-tech industries (ONS, 2021). In both nations, there are regions with increased agglomeration and local development, due to spatial concentration of economic activity in these areas. In Scotland, there is path dependency in the wider sector of renewable energy production as there are technical and historical connections between the decarbonisation of industry and use of alternative sources to fossil fuels. However, in both nations, there are issues of connectivity between some waste-fed AD plants with the sources of transported food waste and the National Grid. Consequently, there have been cases where tonnes of food waste had to travel a long distance to reach the AD facilities. The role of planning regimes can be influential on the choice of locations for waste-fed AD plants to create better connections with LAs, businesses and National Grid, while reducing GHG emissions from the transport of waste.

At the local level, location, topography, size, and density of population are all characteristics which influence the type, quality, and quantity of food waste collections. In other words, these spatial characteristics of the LAs can influence the internal capacity of an LA to implement separate food waste collections and locate an AD facility nearby. The spatial and socio-demographic characteristics of LAs can influence their internal capacity, but also their autonomy and local experimentation to design how they collect and dispose food waste in a commingled or separate mode. Overall different socio-demographic and spatial characteristics may create different needs and challenges in food waste collections, which need to be considered in the waste and climate strategies of the LAs, but also in the design and delivery of the waste services.

Rurality gives a comparative advantage as it enhances the internal capacity of the LA to provide segregated food waste collections, while having lower risk of plastic contamination. City centres of LAs may face issues of waste contamination from flats, tenants, and residents as they are densely populated and there may be insufficiency of waste disposal bins. Furthermore, condensed populations in high-rise buildings make the separation of food waste collections challenging and residents need specific instruction and equipment to participate efficiently. A rural LA has more houses with gardens, where there is enough space for handling waste effectively. An LA can provide different modes of food waste collection in its different areas to accommodate the different characteristics of residents in the food and garden waste collections. The comparison between English and Scottish LAs shows that both rural and urban LAs can adopt waste-fed AD as a waste disposal method.

Internal capacity, autonomy, and local experimentation of LAs is also related with their proximity to a waste treatment facility (AD or IVC). Proximity to a facility is one of the key reasons why a certain AD plant or IVC facility is chosen by an LA for purposes of food waste disposal and treatment. The facility, which is closest to the LA, tends to be the first choice for the LA's food waste disposal because proximity to a facility also reduces transportation costs of waste and their environmental footprint. The location of AD sites influences the maximisation of benefits the AD technology can offer to local community. Rural areas are used for the installation of AD plants as they need enough space for successful operation. However, there are rural LAs who may prefer to provide commingled collections of garden and food waste, which are processed by IVC. The adoption of separate food waste collections and the use of waste-fed AD is mainly a cost-driven decision by LAs, despite the environmental benefits provided by this type of waste management.

7.4 Conclusions

This research explores the important factors of governance effectiveness in sustainability transitions as this is theme is not explored deeply in the literature. In the research, I compare the governance of England and Scotland and their influence on the deployment rates of waste-fed AD. Governance criteria, influenced by market and geography, contributed to the higher rate of waste-fed AD development in Scotland. Evaluative criteria of governance are coordination, learning and knowledge, autonomy, local experimentation, and internal capacity.

Policy is an influential political factor for the uptake of a certain environmental technology, such as AD. Compared to England, Scotland has achieved a higher rate of waste-fed AD deployment per capita, because of its ambitious and comprehensive regulatory and policy framework in the sectors of waste and climate. These sectors are devolved, so different initiatives, policies and regulations have been adopted by Scottish Government. However, the renewable energy policy is a reserved matter, so both nations were influenced by the same renewable energy incentives and policies. In England, the policy focus remained mainly on the biogas and biomethane production through the adoption of renewable energy subsidies. In Scotland, higher policy targets and ambitious regulations are also supported by a model of holistic and inclusive governance, coordinated by the centre, while responding to the requests of different stakeholders in the peripheries surrounding the central government. Furthermore, in Scotland the ties of both national and local governments are stronger as they worked together to implement policy and regulatory changes in the waste sector which led to a higher uptake of waste-fed AD.

In England and Scotland, there are key differences in coordination, learning and knowledge, market, and geography, which influence differently the development of waste-fed AD in both nations. Coordination and learning and knowledge are key evaluative criteria of governance both at the local and national level. Through enabling stakeholder engagement in governance processes, Scottish coordination not only facilitated the achievement of targeted outcomes but also fostered an inclusive and joined-up approach, thereby enhancing Scotland's potential to meet its low carbon future targets. In England, the vertical coordination creates a division between national and local level of government. Both nations implement monitoring and evaluation mechanisms to inform their decision-making in the sector of waste and use of environmental technologies, such as AD. However, Scotland has more efficient channels of communication for sharing of information and knowledge among different stakeholders and these enable further the deployment of waste-fed AD. The research also identified market differences in these two nations as in Scotland there are waste regulations mandating the separation and collection of food waste. Consequently, there is more availability of food waste as a feedstock for the operation of waste-fed AD plants and market is more mature in Scotland as the AD industry has strong links with whiskey and distillery industry as part of its circular economy action plan. Last but not least, geography can influence decision-making processes at both the national and local level of government. Scotland has more rural and sparsely populated areas which can be ideal for the operation of waste-fed AD plants, but it is also characterised by strong path dependency in the use and deployment of renewable energy.

Scottish LAs are more experienced and advanced in the food waste collections, compared to English LAs. Overall, Scottish LAs perform better in food waste collection, and most of them use or have used AD for disposing their food waste. Scottish LAs have been more proactive in food waste collection and disposal, compared to English LAs, because they were given financial support, guidance, waste regulations and higher targets, which are set in close coordination with the Scottish Government. The contributing factors to the success of Scottish LAs in the food waste collections and use of waste-fed AD plants are coordination, learning and knowledge, internal capacity, urban and rural typology, and proximity to a waste-fed AD facility.

Specifically, Scottish LAs have higher levels of internal capacity in the implementation and operation of food waste collections, which provide more feedstock to AD plants. Furthermore, the spatial and socio-demographic characteristics of LAs can influence their internal capacity to provide certain waste services so the urban or rural typology and the distance from the closest AD plant are factors to be considered.

Autonomy and local experimentation are two evaluative criteria of governance which are interrelated. Costs and environmental benefits influence the decisions of LAs in the management and disposal of food waste. Compared to English LAs, Scottish LAs are less autonomous to adopt their own initiatives alone, but they seem to be more capable to operate within a regulatory and policy framework set by the Scottish Government. English LAs experimented with food waste collections, while using the Council's financial resources, without any external funding programme. However, local experimentation raises issues of inclusivity and equity as these food waste collections were open to certain types of households and areas of LAs. Overall English LAs seem more autonomous and inclined to undertake pilots and experiments to identify what really works in food waste collection, management, and disposal. However, Scottish LAs were able to transition to separate food waste collections to their territories, without any experimentation and trials.

Chapter 8 Conclusions and Reflections

This thesis set out to build a better understanding of the active role local government can play in sustainability transitions and its relations with the national level of government. The contribution that this thesis has made is that much greater consideration is needed of the role LAs play in governance processes influencing sustainability transitions. Specifically, governance effectiveness in the sector of waste-fed AD is related with the processes of coordination and learning between national and local levels of government, along with the factors of local capacity, market, and geography. Sustainability transition is the shift from the contemporary carbon-intensive economy to a more sustainable and lower carbon systems of production and consumption. AD is not an innovative environmental technology, but its specific usage of food waste disposal by LAs is relatively recent and can be considered as a sustainability transition. Consequently, there are different deployment rates of waste-fed AD in the four devolved nations. This research explores the reasons behind these differences in the waste-fed AD deployment, while focusing on the two nations with the highest rate of waste-fed AD deployment per capita: Scotland and England. More specifically, this study has explored the following research question: *to what extent and why is the deployment of waste-fed AD in England different from Scotland?* To address in-depth this key research question, the following sub-questions were generated.

A. What is the role of the UK environmental governance on the deployment of waste-fed AD?

B. What is the impact of the devolved and local levels of governance on waste-fed AD in the UK?

C. What are the core factors explaining the success of English and Scottish Local Authorities (LAs) in the use of AD plants for food waste management and renewable energy production?

At the beginning of this chapter, I have addressed again the questions of this research. In this chapter I provide the answers to these questions by discussing further how the policy and regulatory framework, governance, market and geography have influenced differently the deployment of waste-fed AD in England and Scotland. I also provide important insights into the factors which influence more the deployment of a low carbon technology and facilitate sustainability transitions in the two nations. In addition, I illustrate the contribution the study has made, while acknowledging its limitations and proposing future lines of enquiry on the governance of waste-fed AD.

The thesis started by highlighting the research gap of governance processes in the sustainability transitions literature, within the context of waste-fed AD deployment as an example of sustainability transitions in England and Scotland (Chapter 1). The literature on sustainability transitions refers to the steering of governance processes which emerge in transition arenas, transition scenarios and transition experiments. In Chapter 2, I review the sustainability transitions literature and present a key criticism on this literature, which is also raised by other academic scholars. Sustainability transitions are often related to innovations and illustrate sustainable development as a long-term system change (McCrory et al., 2020). However, sustainability governance is not explored in depth in the Urban Sustainability Transitions research (Mourato and Wit, 2022). Although recent Sustainability Transitions research refers to the 'governance of transition processes' (Loorbach et al. 2017), it does not explore deeper the role of policy, regulations, and processes of decision-making, coordination, and multi-level interdependences. The sustainability transitions literature also underlines the importance of coordination in the governance of these transitions, in which a variety of actors and institutions need to work together to implement strategies for a climate-resilient future (Greenwood, 2012; Markantoni, 2016). Multi-level Perspective (MLP) and Technological Innovation Systems (TIS) are both socio-technical frameworks used to evaluate governance in sustainability transitions. However, they do not explore the interactions and jurisdictions of stakeholders at different levels, such as the national and local levels of government in terms of decision-making, authority, and power, and how these are influential on the sustainability transitions.

The governance in sustainability transitions requires more attention than what the current scholarship assumes to get a more complete picture about factors influencing the governance processes. For this reason, Chapter 2 explored how environmental governance is approached in the literatures on multi-level governance, urban climate governance, network governance and policy networks approach. Chapter 2 concludes with the identification of key factors which influence the interplay between sustainability and governance, thereby laying the foundations of the analytical framework, presented in Chapter 5.

The goal of this thesis was to apply an interpretivist epistemological lens to explore the intricacies of a multifaceted political and regulatory environment. Qualitative methods, including a policy review and semi-structured interviews, were employed to explore the impact of the national and devolved levels of governance on the deployment of waste-fed AD (in Chapter 3). The comparative research design led to the selection of six cases to investigate further the role of local government in the interface between waste-fed AD plants and local communities in England and Scotland. The selected case studies are East Lothian Council, South Ayrshire Council and Renfrewshire Council in Scotland and East Riding of Yorkshire Council, Northumberland County Council and Bracknell Forest Council in England.

The policy landscape of waste-fed AD deployment in the UK is explored in Chapter 4. This chapter focused on the policy and regulatory framework of AD in the UK, while exploring the different policy narratives, streams and initiatives, key actors, and levels of government, influencing the uptake of AD in both England and Scotland. Compared to England, Scotland has a more ambitious and comprehensive policy and regulatory framework in the sectors of waste and climate. This framework has enabled the higher deployment of waste-fed AD in Scotland. Specifically, the Waste

(Scotland) Regulations 2012 provided an ideal window of opportunity to Scottish LAs and businesses to take initiatives in food waste management and disposal as they were given mandate, but also guidance and financial support.

In Chapter 5, the factors of the analytical framework possess evaluative power in terms of governance impact on waste-fed AD deployment, related to the ability to take initiatives as part of the overall progress towards waste and net zero targets. These also enabled the researcher to interpret governance processes, while considering the national and local levels of government, the market and geography, and their contribution to higher uptake of waste-fed AD in Scotland. The local level of government plays an active role in the socio-technical transitions towards sustainability. The ambition of LAs to respond to climate change challenges is clear and motivates them to take actions and initiatives as it is illustrated in the literature on urban climate governance, explored in Chapter 5. Governance factors are coordination, learning and knowledge, autonomy, local experimentation, and internal capacity. Furthermore, the factors of market and geography are also introduced to assess the difference in the deployment rates of waste-fed AD in England and Scotland. Specifically, geographical factors are the urban and rural differences and proximity to a facility. Overall, the chapter set the factors which encouraged the sustainability transition towards the adoption of waste-fed AD at a local and national level.

Based on the evidence from the interviews and the review of policy and academic literature, in chapter 6, I elaborated further on the factors, which encouraged the transition towards the development of waste-fed AD at both national and local level. This thesis brings a more holistic approach of embracing the public and private sector, while highlighting the importance of coordination as a key governance aspect. The governance factors of coordination and learning and knowledge refer both to the national and local levels of government and their interactions, whereas the factors of autonomy, local experimentation and internal capacity refer to the roles and initiatives taken by the local government. These three latter governance factors are used for the comparison between English and Scottish LAs and their performance in the use of segregated food waste collections and AD.

Case studies demonstrated that the different LAs have adopted different waste strategies and approaches to AD, depending on their internal capacity. The thesis has shown that greater emphasis is needed on the role of the state in empowering LAs to take environmentally friendly actions, such as segregated food waste collections, which increase the uptake of waste-fed AD technology. Specifically, LAs needed a mandate, funding, and guidance to be successful in the uptake of waste-fed AD. These are three key elements which are essential for the usage of waste-fed AD by LAs. Chapter 6 shows that LAs, when in a financially favorable position through their own resources or external funding, are empowered to take actions which positively influence the development of waste-fed AD. Core factors explaining the success of Scottish LAs in use of waste-fed AD plants are coordination, learning and knowledge, internal capacity, urban and rural typology, and proximity to a waste-fed AD facility. Spatial characteristics of LAs can influence their internal capacity to provide certain waste services. LAs with rural areas can achieve more easily a better quality and quantity of segregated food waste collections, feeding AD facilities. In addition, proximity to a waste-fed AD plant is also a key factor of success in the waste-fed AD uptake as it increases its ease of accessibility, while decreasing GHG emissions from food waste transfer.

Chapter 7 highlights two distinct governance approaches in England and Scotland, underscoring the indispensable role of local government in fostering the development of this environmental technology. The Scottish model of governance includes an ambitious national government which guides and funds the local level of government to take initiatives essential for the achievement of these objectives. In Scotland, higher policy targets and ambitious regulations are supported by a well-coordinated governance, which is also characterised by a more inclusive and holistic formation of government. Nonetheless, the importance of inclusive and holistic governance has been overlooked in the developing literature on sustainability transitions. The Scottish model is different from the English model of governance where the regulatory framework is missing along with specific guidance and funding. English LAs are more autonomous in taking their own initiatives to participate in the socio-technical transition of using waste-fed AD. However, they were constrained by lack of clarity in the forthcoming waste regulations and funding. They had the autonomy to experiment with food waste trials or with provision of this service to specific areas within the LA and self-organise with food waste collections and use of IVC or AD. In Scotland, the ties of both national and local government are stronger as they worked together with governmental and non-governmental organisations to implement policy and regulatory changes in the waste sector which led to a higher uptake of waste-fed AD. This form of holistic and inclusive governance with high levels of coordination led by the centre is shown to successfully support a sustainability transition, in particular the deployment of the waste-fed AD. In Scotland, there is also close cooperation of AD industry with other industries, such as farming, whisky, and distillery industry, as part of the wider effort to embed circular economy on the ground. Scottish LAs are less autonomous to adopt their own initiatives alone, but they seem more capable in the implementation of food waste collections, use of waste-fed AD and undertaking their assessments of GHG emissions, while contributing to the effort of achieving the national targets of Scottish Government.

The research focuses on the particularities of LAs in England and Scotland. Due to the centrality of context-specific factors in the research design, findings from the cases selected in England and Scotland cannot be fully generalised and they only tell a part of the story. Not every LA is identical and the examination of six LAs provided only specific evidence on their influence on the market development of waste-fed AD. The small sample of LAs also confines any generalisation of findings in terms of other market and geographical characteristics of LAs, which may influence the uptake of waste-fed AD. The case selection strategy has its own limitations, which need to be acknowledged. For example, the inclusion of LAs, who own AD plants, in the research design and fieldwork may have provided additional insights in the interrelationships of LAs with the market of AD. Moreover, the study did not yield additional evidence regarding variations in local demand for AD products, namely biogas, heat, electricity, and digestate. The demand for these products may vary in different local communities, however the analysis of the interviews and document review did not provide enough evidence to map any local trends in either nation. It is also important to highlight that the perspectives of farmers, who were not among the interviewees, have not been considered in understanding how the revenues and profitability from waste-fed AD projects shaped the market dynamics in both countries.

Further research exploring additional LAs would provide further evidence on the role of market and geography as it provides an opportunity to address the above limitations of the study. This would also draw additional insights gleaned at the local level and enhance our understanding about the factors which encouraged LAs to engage more effectively in food waste collections, feeding AD facilities. Qualitative evidence from these experiences can guide future waste-fed AD strategies of devolved nations, particularly in terms of structuring robust and transparent scientific advisory systems, and mitigating socioeconomic pressures, opposing to the socio-technical transition of AD.

Another interesting research question to be explored is why the deployment of waste-fed AD is different in England, compared to Wales and Northern Ireland. This can explore the role of devolution in the socio-technical transition with a qualitative research design, which includes a review of policy documents and expert interviews across these devolved nations. Evidence would give further information on the status quo of waste-fed AD in the UK and provide lessons, which will be critical for developing further the future of AD strategy in the UK. Furthermore, the exploration of the local level can be undertaken with the creation of system maps – one for an LA which uses waste-fed AD in each devolved nation. This will enable the mapping of all stakeholders involved in the use of AD as a waste disposal method, while illustrating any dynamics, interdependences, and feedback loops among these stakeholders for each LA. However, this research design is challenging as stakeholders' willingness to participate in the research is essential and they may need to be provided with incentives to contribute to the project. Evidence from the system maps of the four cases will provide further information on the role of waste-fed AD market from both the supply and the demand side.

The research approach has been designed to be transferable to investigate cases outside of the UK. Comparative research can also be used to compare the waste-fed AD sector in the UK and Germany, which has the highest number of AD plants in Europe (Edwards et al., 2015). The analytical framework of the current research can also be used in the exploration of the role of environmental governance in the waste-fed AD deployment of an EU and non-EU country. Evidence from their experiences can help inform policies and governance of waste-fed AD by other European countries.

This study has focused on a specific use of the environmental technology, so another future direction would be to look at other types of environmental or energy technology, perhaps in a comparative manner. Low carbon technologies in the sectors of transport or energy over which LAs have relatively high levels of involvement would be likely candidates. In these types of environmental or low carbon technologies, local and national governments are in close interaction. The more we understand about this interaction, the greater confidence we can have in the ways LAs engage in the broader national strategies. Furthermore, the research methodology, which includes document review, interviews, and comparative analysis, can also be applied to other empirical cases of sustainability transitions (Chapter 3). This thesis contributes to a widening of the debate on urban sustainability transitions, to add understanding of how local government responds when it is given space to do so or needs to respond to a mandate.

By virtue of its novelty, the development of AD has attracted only limited academic discussion in the field of social sciences, mainly in reviewing the development of policies which influence the uptake of the technology, so the role of local government and the importance of governance have been lightly touched upon. The thesis has made two important contributions: one empirical and one theoretical. On the empirical front, it has significantly increased our understanding of the waste-fed AD agenda in the UK, with a clear focus on England and Scotland. There had been no previous attempts at codifying local initiatives, and fewer attempts at mapping the actions and initiatives of national governments in the waste-fed AD sector. From that perspective a great deal has been learnt about the characteristics of local involvement in the waste-fed AD deployment. On the theoretical front, this study has made significant inroads by adopting a framework to further analyse the interactions between national and local governments, thus responding to the highlighted gap in the sustainability transitions literature. Overall, the results of the present study indicate that more attention should be given to the local level of government and its contribution to the central governments' targets to enable sustainability transitions happen on the ground. This model of inclusive and holistic governance is led by the national government and empowers the local government along with public and private organisations to become active agents in the transitions towards sustainable development.

Appendix I

List of interviews at scoping and empirical stage

Table 1 List of interviews at the scoping stage		
Code	**Organisation**	**Job role**
18Sc	University of Southampton	Co-manager of AD Network & owner of an AD firm
13Sc	EA	Project Manager- National AD Project EA, West Midlands Area
12Sc	WRAP	OBE Specialist Adviser
2Sc	ADBA	Head of Policy
3_4Sc	DEFRA	Policy Adviser and Head of Waste Collection & Recycling Team (incl. AD)
23Sc	BEIS	Policy Adviser (Strategic Heat Team)
25Sc	Ofgem	Senior Policy Manager, Non-Domestic Renewable Heat Incentive
6Sc	DEFRA	Policy Adviser, Air Quality
20Sc	REA	Head of Biogas
1Sc	DfT	Policy Advisor

Table 2 List of interviews at the empirical stage		
Code	**Organisation**	**Job role**
E1_1	NNFCC Ltd	Company Director, Lead Consultant
E1_2	Zero Waste Scotland	Project Manager
E1_3	University of Southampton	Co-manager of AD Network & owner of an AD firm
E1_4	Association for Renewable Energy and Clean Technology (REA) - Scotland	Organics Recycling and Biogas Groups Manager
E1_5	ADBA	Lead Analyst - Environment and Agriculture
E1_6	SEPA	Expert in waste management policy and regulation
E1_7	Future Biogas Ltd	Sustainability Manager
E1_8	Defra	Policy Advisor - Air Quality and Industrial Emissions
E1_9	Local Partnerships - Defra	Project Director at Local Partnerships & Defra

E1_10	Zero Waste Scotland	Recycling Manager
E1_11	AquaEnviro	Head of Knowledge Exchange & Innovation
E1_12	Environment Agency	Senior Advisor for Biowaste Treatment
E1_13	Northumberland County Council	Assistant Project Manager - Climate Change Team
E1_14	COSLA	Policy Manager (Waste, Carbon, and Climate Change)
E1_15	Northumberland County Council	Senior Waste Management Officer
E1_16	Ofgem	Senior Operations Manager, Data and Payments
E1_17	Severn Trent	Bioresources Commercial Manager
E1_18	Severn Trent	Bioresources Strategy & Commercial Manager
E1_19	AlpsEcoscience	Senior Anaerobic Digestion Engineer
E1_20	Green Gas Certification Scheme	Scheme Manager
E1_21	AlpsEcoscience	Sales & Marketing Director
E1_22	Scottish Government	Zero Waste Policy Managers
E1_23	Scottish Water Horizons - AD plant	Operations Manager
E1_24	East Lothian Council	Service Manager Transport and Waste
E1_25	South Ayrshire Council	Coordinator -Waste Strategy
E1_26	East Riding of Yorkshire Council	Waste and Recycling Officer
E1_27	Bracknell Forest Council	Waste & Recycling Manager
E1_28	Renfrewshire Council	Waste Solutions & Sustainability Manager

Appendix II

Participant Information Sheet

PhD Research:

The Governance of Anaerobic Digestion in the United Kingdom: Insights from England and Scotland

WHAT IS THE RESEARCH ABOUT?

In my PhD research, I am exploring how cross-sectorial stakeholders with different jurisdictions coordinate together and influence the deployment of Anaerobic Digestion (AD) in the UK. Policymaking at the national and local level seems to be a contributing factor to different deployment rates of waste-fed AD in the UK. I also aim to explore the reasons why there are differences in the deployment of waste-fed AD in England and Scotland. So, it is essential to take into consideration experts' views and work experiences in this area for the benefit of this research.

This PhD research is funded by the University of Westminster and linked to the UK's Centre for the Evaluation of Complexity Across the Nexus (CECAN). CECAN is a multi-disciplinary research centre hosted by the University of Surrey, established to transform policy evaluation to make it fit for a complex world. CECAN is funded by the ESRC and NERC in collaboration with Defra, BEIS, the Environment Agency and the Food Standards Agency.

WHY SHOULD I TAKE PART?

Your involvement will help me to understand the current policy and institutional landscape influencing the deployment of waste-fed AD in the UK. The research will have an impact by contributing to academic knowledge and informing further policy development. Your participation will be valuable and make this possible.

You have been identified through research as having expert knowledge or experience in the field of waste-fed AD in the UK.

DO I HAVE TO TAKE PART?

No. Your participation is voluntary, anonymous, and confidential. No individuals or participants will be named and revealed to the CECAN funders or to anyone else. Any direct quotations used or published will be anonymised and I will not identify you unless you request otherwise. Anonymity and confidentiality are maintained at all stages of the research.

We can stop the interview at any time and we can move on if you do not want to answer a question. There are no wrong or right answers to the questions. During the interview, I may address some obvious questions to you, however the reason for this is to hear your experiences and views in your own words.

What Does Taking Part Involve?

The interview will last around 45 - 60 minutes. It can be a face-to-face, telephone or online discussion. You can express your preference regarding time, date, location and mode of the interview.

With your permission I would like to record the interview. Recording means that I have an accurate record of what was said. The recording will be kept securely in accordance with the Data Protection Act (2018) and the General Data Protection Regulation (GDPR) helps me focus on the flow of the discussion, rather rushing to write down notes.

What Will Happen to the Findings from the Research?

The recordings will be transcribed and the transcripts will be analysed by me. Your views will be combined with the views of others who take part in the interviews. The findings from the discussions will be included in my PhD thesis and other academic articles I write on the topic. The findings will be anonymous – no individuals will be identifiable in any of the publications.

How Do I Find Out More About the Research?

If you have any questions or concerns about the research, please contact:

Anna Kaxira
PhD Researcher | School of Social Sciences
University of Westminster, 309 Regent Street, London, W1B 2HW
07766599401
a.kaxira@my.westminster.ac.uk

In case you have any complaints about the research project, please contact:

Professor Dibyesh Anand
Head of School | Social Sciences
University of Westminster, 32/38 Wells Street, London, W1T 3UW
02079115000 ext 65159
D.Anand@westminster.ac.uk

Interview Consent Form

PhD Research:

The Governance of Anaerobic Digestion in the United Kingdom: Insights from England and Scotland

I agree to participate in an approx. 40 – 60 minute interview as part of the PhD Research. This interview is being led by Anna Kaxira, a PhD Researcher of the University of Westminster.

I have read the participant information sheet provided, and understand the aim of the study, and how my input will be recorded and used in accordance with the General Data Protection Regulation (GDPR) and the Data Protection Act (2018).

☐ **I give permission for the interview to be recorded and transcribed** (please check the box)

Details below can be filled in electronically and returned via email

Name	
Signature	
Date	
Email	
Phone number	

Appendix III

Topic Guide- Scoping Stage

The following guide lists the discussion phases, key themes, sub-themes and the prompts and probes to be used for each interview at the scoping stage. The Researcher is not tied to phrasing the questions as they are exactly presented in this topic guide – these are mainly for guidance.

A. Introduction

- Thank them for agreeing to be interviewed.
- Purpose of interview.
- Permission to record.
- If yes, START THE RECORDING

B. Background section

Aim: To learn about their job, background, and experience in the Anaerobic Digestion (AD) governance

1. What is your role/ position in your organisation?
    - o Describe the setting you are in.
2. Could you please tell me a bit about your work in the AD sector?

C. Existing policy landscape for AD

Aim: To Identify key elements of the policy landscape for the AD in the UK, with the focus on key stakeholders, policy landscape, policies, and the potential of AD.

3. Who are the key stakeholders involved? How would you describe the range of actors in the AD?
    - o Agencies and departments involved in the AD governance and management.
    - o Any key strategies of different institutions influencing these policies?
    - o How do key stakeholders work together on the policies of AD?
4. Please provide a brief description of the UK policy landscape influencing the AD (in your own words).

- What are the key policies influencing the AD?
- Any existing policy mechanisms, incentives, or tools? (ex. FITs, RHI)
- Are there enough? Their results?

5. What is the policy scheme with the biggest influence on the deployment of AD and why?

D. Working in the sector of AD

Aim: Identifying the ways of working in the policymaking of AD aims to unpack the existence of complexity and nexus in the governance. The researcher aims to discover how they manage policy, go through the policy cycle and how they identify impacts and address any problems or challenges.

6. How do you feel working in the sector of AD?
7. How do you manage policy? How has policy evaluation progressed in the field and to what extent?
8. What is working well in the policymaking of AD?
    - Any operational issues worth mentioning in any areas of AD?
    - Any best practice examples in the policymaking of AD in the UK?
    - Any examples when things were much more delivered than expected?
9. What is not working so well in the policymaking of AD?
    - Any operational issues
    - Do you think that there are particular needs to be addressed in the policymaking processes influencing AD?
    - Any changes? What would you change if you could? What do you think needs to change?
10. What do you think makes AD important/ beneficial to the UK?
11. How do you foresee the future of AD in the UK?
    - What about the future of land use in the UK? How could this influence AD deployment?
    - What about the potential use of food waste and bio waste?

Topic Guide – Empirical Stage

A. Introduction

- **Thank them** for agreeing to be interviewed.
- **Purpose of interview.** At this stage of the PhD research, it is important to understand to what extent the deployment of waste-fed AD is different in England to Scotland. The purpose is to understand experts' views on the impact of the national level of governance on waste-fed AD in the UK.
- **Permission to record.** Recording means that there is an accurate record of what was said. The recording is kept securely in accordance with the Data Protection Act (2018) and the General Data Protection Regulation (GDPR) helps me to focus on the flow of the discussion, rather rushing to write down notes.
- **Any questions.** Including any concerns, they have.
- If yes, START THE RECORDING

B. Background section

Aim: To learn about their job, background, and experience in the AD governance

1. What is your role/ position in your organisation?
2. Could you please tell me a bit about your work in the AD sector?

C. Stakeholder engagement in governance

3. Which actors comprised the network of the waste-fed AD in the UK?
4. Which of those actors were the most important in this network? What about Scotland?
5. What resources did they possess for the deployment of waste-fed AD?
6. Are there any processes of learning been used to facilitate the adoption of waste-fed AD plant at the local level?

D. Effectiveness

7. What is the effectiveness of governance in the AD sector? How do key stakeholders perceive it?

8. How would you define success in AD deployment and governance? (Both at the national and local level).
9. How is the successful use of waste-fed AD technology by a Local Authority defined by you? On what terms can we define its success?

E. Coordination, interaction, and cooperation

10. On what terms and within what parameters do you think that stakeholders from different levels of government interact for the adoption of waste-fed AD?
11. How do you see the coordination between the local level of government with the national level? How do they cooperate?
12. How do you see the coordination between the devolved level of government with the national level?
13. How is the cooperation between the public and private authorities for the adoption of waste-fed AD plants at the local level? What factors did enable this cooperation?

F. Policy context/ Autonomy/Local experimentation

14. Please provide a brief description of the UK policy landscape influencing the AD (in your own words). What are the key policies influencing the waste-fed AD at the local level? Describe the way different policies operate.
15. For the uptake of waste-fed AD, which policy initiative has been the most influential on the deployment of waste-fed AD? And why? What was its impacts?
16. What are the key initiatives or policies taken at the national level which also influenced the deployment of waste-AD?
17. What are key initiatives and policies at the devolved or local level influencing the deployment of waste-fed AD?
18. What are the opportunities and challenges for the waste-fed AD sector?

Appendix IV

Case study protocol

- **Overarching Case Study questions**

What is the effectiveness of governance in the AD sector? How do key stakeholders perceive it?

What has changed since the waste-fed AD plant installation? On what terms?

How would you define success in the waste-fed AD deployment and governance? (Both at the national and local level).

What are the opportunities and challenges for the waste-fed AD sector?

- **Background questions**

What is your role/ position in your organisation? Describe the setting you are in.

Could you please tell me a bit about your work in the AD sector?

- **Coordination**

On what terms and within what parameters do you think that stakeholders from different levels of government interact for the adoption of waste-fed AD?

How do you see the coordination between the different levels of government? How do they cooperate?

Did the Local Authorities communicate with other Local Authorities which were already using waste-fed AD successfully?

How do Local Authorities coordinate with waste management companies and waste-fed AD plant owners?

How was the cooperation between the public and private authorities for the adoption of the waste-fed AD plant at the local level? What factors did enable this cooperation?

How do local actors cooperate and communicate together for the installation and use of food-waste AD plants within a local authority?

Who was the key actor for the installation and use of the waste-fed AD plant in the Local Authority? What was its role?

- **Stakeholder engagement & Networks**

Which actors comprised the network of the waste-fed AD in the UK? Which of those actors were the most important in this network?

What resources did they possess for the deployment of waste-fed AD? How did councillors and officers depend upon those resources?

Which governance strategy was employed by the local authority in the policy making process?

Did the Local Authorities have enough resources to embrace this change of waste management?

Was there any economic benefit after the adoption of the waste-fed AD plant? On what terms?

Are there any networks formed at the local/city level influencing the deployment of waste- fed AD? Which actors comprise these networks?

How did households and the public react to the use of the waste-fed AD as a waste-management option?

What efforts were made to increase the environmental awareness of councillors, officers, actors, and the public?

- **<u>Learning and knowledge/ Internal capacity</u>**

Did the Local Authority share expertise or knowledge with other Local Authorities, who are interested in the installation and use of AD plants for waste management purposes?

Have other processes of learning been used to facilitate the adoption of waste-fed AD plant in the territory of a local authority?

Did the Local Authority have the required skills, qualifications and learning for the adoption and usage of a waste-fed AD plant?

- **<u>Policy context/Autonomy/Local experimentation</u>**

How influential was the role of the ruling party in the decision of adoption and use of waste-fed AD plants? What was the reaction of other parties to this decision?

Please provide a brief description of the UK policy landscape influencing the AD (in your own words). What are the key policies influencing the waste-fed AD?

For the uptake of waste-fed AD, which policy initiative has been the most influential? And why? What was its impacts?

What are key initiatives and policies at the devolved or local level influencing the deployment of waste-fed AD?

Was waste-fed AD deployment part of wider sustainability strategy of the Local Authority? Are there any initiatives taken at the local level to address sustainability?

Appendix V

Dataset of English and Scottish LAs with waste-fed AD plants

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
SC	South Ayrshire	Council Area	1	300000	112,610	52,639	19,428	7200	2009	Brewery waste
EN	Barking and Dagenham	London Borough	2	190000	212,906	86072	18,928	1900	2013, 2017	Food waste
EN	Fenland	Non-metropolitan District	2	165000	101,850	39407	17,958	4263	2005, 2011	Food waste, waste starch
EN	Doncaster	Metropolitan District	1	160000	311,890	134848	17,001	5000	2011	Food waste
SC	Moray	Council Area	4	157450	95,820	47,186	19,319	5000	2013, 2010, 2015	Brewery waste & distillery wastes
EN	Aylesbury Vale	Non-metropolitan District	3	143000	203,219	61076		5014.7	2013, 2016	Organic fraction of MSW & C&I waste,

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
										Dairy effluent, Commercial food waste
SC	Fife	Council Area	2	135000	373,550	174,977	18,518	6640	2013	Food waste & green waste & brewery waste
EN	Braintree	Non-metropolitan District	2	130000	152,604	59862	22,179	3694.4	2014, 2017	Food waste, Organic fraction of MSW
SC	North Lanarkshire	Council Area	2	130000	341,370	149,977	17,391	4600	2010, 2011	Food waste, organic fraction of MSW & C&I waste

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	Shropshire	Unitary Authority	4	128900	323,136	157970	20,732	6549	2006, 2012, 2014, 2015	Maize & food waste, Grass silage, poultry manure & food manufacturing waste, slurry, potato waste, sludge, leachate, poultry litter
EN	Redcar and Cleveland	Unitary Authority	1	125000	137,150	56747	16,882	5100	2017	Maize, wheat chaff, slurry, food waste, garden waste, animal by-

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
										product & glycerol
EN	Cannock Chase	Non-metropolitan District	1	120000	100,762	38079	18,096	6000	2011	Food waste
EN	Halton	Unitary Authority	1	120000	129,410	56820	17,907	500	2014	Food waste
EN	Selby	Non-metropolitan District	5	118125	90,620	36066	21,994	1000	2008, 2012, 2014, 2016, 2015	Brewery waste, Vegetable outgrades & grass silage, Food waste & green waste

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	Wiltshire	Unitary Authority	3	110000	500,024	213220	23,179	3859.66	2012, 2014, 2016	Food waste & animal by-products
EN	Basildon	Non-metropolitan District	1	107000	187,199	77360	21,435	4380	2015	Organic fraction of MSW & C&I waste
EN	South Ribble	Non-metropolitan District	1	105000	110,788	40471	19,528	1900	2010	Organic fraction of MSW
EN	East Riding of Yorkshire	Unitary Authority	2	102000	341,173	168664	20,516	6676	2011, 2017	Food waste, Edible oil processing waste & glycerol
EN	Sedgemoor	Non-metropolitan District	2	102000	123,178		20,340	3140	2009, 2013	Food waste
EN	Gedling	Non-metropolitan District	1	100000	117,896	42478	19,250	4999	2014	Food waste

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
SC	Glasgow City	Council Area	1	100000	633,120	252,148	16,345	4000	2016	Food waste
EN	West Suffolk	Non-metropolitan District	1	97000	179,045		20,224	4800	2016	Sugar beet processing waste
EN	North Warwickshire	Non-metropolitan District	2	95000	65,264	26612	20,109	4950	2014, 2015	Organic fraction of MSW & C&I waste & energy crops, food waste
EN	County Durham	Unitary Authority	2	90400	530,094	225842	16,617	2010	2014, 2013	C&I food waste, Animal slurry, grass silage & animal processing waste
EN	Horsham	Non-metropolitan District	1	90000	143,791	50455	27,522	4200	2017	Organic fraction of MSW

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	West Lindsey	Non-metropolitan District	1	90000	95,667	38617	18,709	4800	2015	Food waste & animal processing wastes
EN	Blaby	Non-metropolitan District	1	86000	101,526	34912	19,145	1140	2013	Pig slurry & food waste
EN	Hambleton	Non-metropolitan District	1	80000	91,594	33698	23,487	449	2015	Potato waste, soya waste, creamery waste & brewery waste
EN	Kingston upon Hull, City of	Unitary Authority	2	80000	259,778	105308	14,908	1100	2005, 2018	Bakery waste, Organic fraction of MSW & C&I waste

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	Manchester	Metropolitan District	3	80000	552,858	155619	15,322	4500	2010, 2012, 2005	Brewery waste, Organic fraction of MSW
EN	Torridge	Non-metropolitan District	1	80000	68,267	24671	18,974	3900	2002	Food waste & animal processing wastes
EN	Mendip	Non-metropolitan District	1	75000	115,587		22,146	495	2013	Animal slurry & cheese processing waste
EN	Wyre	Non-metropolitan District	2	75000	112,091	41286	18,459	3800	2010, 2011	Organic fraction of MSW, Food waste & abattoir waste

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	Dorset	Unitary Authority	2	70000	378,508	196709	22,613	1750	2012, 2011	Food waste & pig slurry, Waste water from dairy plant
EN	South Kesteven	Non-metropolitan District	1	70000	142,424	53199	21,522	1415	2012	Waste starch
EN	Basingstoke and Deane	Non-metropolitan District	2	69000	176,582	58435	25,458	2622.3	2013	Food waste & animal slurries, energy crops
EN	Mid Suffolk	Non-metropolitan District	1	68500	103,895	68778	21,280	500	2015	Brewery waste
EN	Broxbourne	Non-metropolitan District	1	66000	97,279	35232	23,109	2855	2015	Organic fraction of MSW

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	Cheshire West and Chester	Unitary Authority	1	65830	343,071	162328	22,301	6200	2016	Organic fraction of MSW & C&I waste
EN	Daventry	Non-metropolitan District	2	65000	85,950	30676		4240	2007, 2017	Food waste
EN	East Northamptonshire	Non-metropolitan District	1	65000	94,527	29421		2900	2009	Food waste
EN	Wakefield	Metropolitan District	1	65000	348,312	149002	17,329	2304	2016	Organic fraction of MSW
EN	Allerdale	Non-metropolitan District	1	60225	97,761	41187	18,968	465	2016	Dairy effluent & whey permeate
EN	Cherwell	Non-metropolitan District	2	60000	150,503	60508	24,115	2350	2010, 2013	Food waste, coffee waste

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	East Suffolk	Non-metropolitan District	2	54000	249,461		20,364	600	2013, 2014	Food waste & brewery waste, Animal processing waste
EN	South Staffordshire	Non-metropolitan District	1	51500	112,436	43662	20,463	500	2016	Organic fraction of MSW & C&I waste & crop silage
EN	Bedford	Unitary Authority	2	50650	173,292	72369	22,321	1615	2014, 2005	Food waste & animal processing by-products & Pig slurry
EN	Charnwood	Non-metropolitan District	1	50000	185,851	60251	18,275	1500	2004	Organic fraction of MSW & C&I waste

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	Cotswold	Non-metropolitan District	1	50000	89,862	39703	29,350	2,000	2010	Animal manures, food waste & organic fraction of MSW
EN	Kettering	Non-metropolitan District	1	49000	101,776	39791		1519	2010	Food waste
EN	Hertsmere	Non-metropolitan District	1	48500	104,919	37434	30,046	2800	2016	Food waste
EN	Runnymede	Non-metropolitan District	1	48500	89,424	26523	26,925	2119	2014	Food waste
EN	Mid Devon	Non-metropolitan District	1	47480	82,311	28146	20,811	250	2015	Poultry abbatoir waste, grass silage, sugar beet & maize

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	Bournemouth, Christchurch and Poole	Unitary Authority	1	45000	395,331	76376	21,652	500	2017	Maize & food waste
EN	North Hertfordshire	Non-metropolitan District	1	45000	133,570	46241	25,826	2600	2014	Food waste
EN	South Oxfordshire	Non-metropolitan District	1	45000	142,057	50226	29,669	2078	2012	Food waste & crop silage
EN	Harrogate	Non-metropolitan District	1	40000	160,831	52891	26,868	1100	2016	Organic fraction of MSW
EN	Middlesbrough	Unitary Authority	1	40000	140,980	61864	15,835	6250	2015	Green waste, animal slurry & food waste
EN	Merton	London Borough	1	36000	206,548	70258	33,251	488	2013	Food waste

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	Forest of Dean	Non-metropolitan District	1	35000	86,791	32524	19,572	485	2013	Food waste, animal processing waste & energy crops
EN	Salford	Metropolitan District	1	35000	258,834	79348	17,524	2800	2013	Organic fraction of MSW
EN	Bristol, City of	Unitary Authority	1	34000	463,377	165990	20,249	1750	2012	Food waste
EN	Tewkesbury	Non-metropolitan District	1	34000	95,019	33926	21,669	338	2015	Food waste
EN	Milton Keynes	Unitary Authority	1	32000	269,457	117272	22,116	1110	2016	Organic fraction of MSW & C&I waste
SC	Midlothian	Council Area	1	30000	92,460	40,610	21,094	1460	2015	Food waste

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
SC	Perth and Kinross	Council Area	2	30000	151,950	74,293	21,504	1400	2012, 2018	Food waste & animal processing wastes
EN	South Northamptonshire	Non-metropolitan District	1	30000	94,490	38992		500	2015	Green waste & maize silage
EN	Stafford	Non-metropolitan District	1	30000	137,280	53679	20,473	1300	2010	Food waste, manure & crops
SC	Stirling	Council Area	1	30000	94,210	42,504	21,345	499	2014	Cattle slurry & brewery waste
EN	Welwyn Hatfield	Non-metropolitan District	1	27000	123,043	38547	22,895	1500	2015	Food waste
EN	Bath and North East Somerset	Unitary Authority	1	25000	193,282	71738	23,515	2032	2016	Organic fraction of MSW & maize

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
SC	East Lothian	Council Area	1	25000	107,090	49,979	22,494	500	2016	Food production residues & brewery waste
EN	Liverpool	Metropolitan District	1	25000	498,042	170235	15,673	466	2014	Waste streams from UCO biodiesel production
EN	Stockport	Metropolitan District	1	25000	293,423	97920	21,606	2000	2015	Organic fraction of MSW
EN	North Somerset	Unitary Authority	1	24000	215,052	99231	22,878	464	2013	Food waste
EN	Cornwall	Unitary Authority	1	22000	569,578	263354	18,846	850	2012	Brewery waste
EN	Birmingham	Metropolitan District	1	20000	1,141,816	412130	15,368	808	2012	Paper mill effluent
EN	Kirklees	Metropolitan District	1	20000	439,787	158334	17,288	944.5	2011	Cattle slurry, maize &

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
										bakery waste
EN	Melton	Non-metropolitan District	1	20000	51,209	20198	21,473	244	2015	Grass silage, Maize & whey permeate
EN	North West Leicestershire	Non-metropolitan District	1	20000	103,611	41457	19,644	500	2016	Potato peelings
EN	South Hams	Non-metropolitan District	1	20000	87,004	33438	23,927	490	2011	Food waste & cattle manure
EN	Tonbridge and Malling	Non-metropolitan District	1	20000	132,153	50834	25,249	1226	2015	Paper mill effluent
EN	Rotherham	Metropolitan District	1	18000	265,411	110296	16,985	484	2015	Organic fraction of MSW

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	South Somerset	Non-metropolitan District	2	16825	168,345		20,810	3500	2005, 2013	Food waste, Unspecified waste
EN	Telford and Wrekin	Unitary Authority	1	15700	179,854	83884	17,250	487	2016	Paunch, animal slurries & abattoir wastes
EN	Carlisle	Non-metropolitan District	1	10000	108,678	42286	19,110	500	2016	Food waste
EN	Herefordshire, County of	Unitary Authority	1	10000	192,801	75857	20,631	500	2008	Brewery waste
SC	North Ayrshire	Council Area	2	10000	134,740	60,322	17,473	3180	2015	Factory waste
EN	South Cambridgeshire	Non-metropolitan District	1	10000	159,086		27,610	240	2014	Effluents from drinks production
SC	City of Edinburgh	Council Area	1	9855	524,930	192,070	23,580	479	2011	Brewery waste
SC	Na h-Eileanan Siar	Council Area	1	7000	26,720	13,710	19,318	305	2007	Food waste

Nation	Name of Local Authority	Type	Waste-fed AD plants in 2019	Tonnes of total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	GDHI per head of population at current basic prices - GBP (2019)	Total energy capacity (kW) produced by waste-fed AD plants of LAs	Completion year of waste-fed AD plants	Feedstock (Type)
EN	Newcastle upon Tyne	Metropolitan District	1	1200	302,820	108593	16,473	200	2013	Confectionary production waste
EN	Test Valley	Non-metropolitan District	1	183	126,160	41890	25,872	8	2012	Food waste & grass silage
EN	Lancaster	Non-metropolitan District	1	143	146,038	45761	17,433	8	2013	Brewery waste
EN	South Holland	Non-metropolitan District	1	100	95,019	31139	18,459	0	2000	Waste water from vegetable preparation
EN	Central Bedfordshire	Unitary Authority	1	10	288,648	118822	22,419	10	2014	Food waste

Appendix VI

Most similar comparative case study

A ‘most similar comparative case study’ (or MSDO) enabled the researcher to identify the factors essential for a successful usage of waste-fed AD by LAs in England and Scotland. The key measure of success in this research is the ‘tonnes of total feedstock (kt) used by waste-fed AD plants of LAs’. This outcome serves as the dependent variable in this comparison of cases which share three independent variables. In other words, the total feedstock of waste-fed AD plants is the dependent variable which can influence the successful operation of each waste-fed AD plant and indirectly influence their successful use by their LAs. The MSDO approach allows the researcher to investigate the influence of different independent variables on the dependent and their relationship. The intention was to choose six cases that reflect a variance on the outcome of the dependent variable (tonnes of total feedstock used by waste-fed AD plants of LAs): three of them are English LAs and three of them are Scottish LAs. Similarity depends on three independent or control variables. The cases of each nation share similar values on the independent variables, which are the following: estimated population of LAs (mid-2019); household waste generated (2019); and Gross Disposable Household Income (2019) (See Table 3 for a complete list of independent and dependent variables). Furthermore, investigation of factors which lead to a certain outcome needs to be considerate to a range of different outcomes on the dependent variable (Collier and Mahoney, 1996).

Table 3 Dependent and Independent variables for case selection	
Dependent variables	Tonnes of total feedstock (kt) used by waste-fed AD plants of LA
Independent variables	Estimated population of LAs (mid-2019)
	Household waste generated (tonnes) in 2019
	Gross Disposable Household Income (GDHI) per head of population at current basic prices - GBP (2019)

A ‘most similar comparative case study’ (or MSDO) also enables the comparison between the most and less successful LAs with waste-fed AD plants in their territory. The most successful LAs are characterised as the LAs which have the waste-fed AD plants with the highest total amounts of food waste consumption. However, focusing only on the successful LAs restricts the variance of the dependent variable and consequently, the investigation leads to factors which only successful LAs have in common. The contrast of findings and data between 'strong' and 'weak' performers is more preferrable as it enables the researcher to avoid any selection bias and be confident in any conclusions made. Less successful LAs are defined as the LAs with waste-fed AD plants whose outcomes of the dependent variables are below the average. With the use of descriptive statistics, I explored the mean, minimum, maximum, median, and standard deviation of independent and dependent variables to identify which LAs are below or above the average of the independent variable and to group these LAs accordingly. The mean is the average, defined by the sum of the data and divided by the number of data points (the total number of LAs is 96). The mean of 'total feedstock used by waste-fed AD plants of LAs' is an important indicator because it can be used to group LAs that are below and equal to or above the mean as less and more successful. Furthermore, the focus of the MSDO approach is on similarity and the 'a priori knowledge' of potentially important causal variables is essential for the case selection, based upon a variance in the outcomes of the independent variables and similarity on a selection of dependent variables (Lemprière, 2016).

South Ayrshire Council was selected because it used the highest total feedstock of waste-fed AD plants in the LAs during 2019. Then, the challenge was to find a most-similar comparison in England, while taking into consideration the similarity in the independent variables. This led to an approximate comparison with North West Leicestershire, which has similarities with the initial case in estimated size of population and amount of generated household waste and GDHI per head of population (Table 4). These two LAs differ on the amount of total feedstock used by waste-fed AD plants of LAs, despite the similarities they share in socio-economic characteristics. Using the above logic, a second pair of LAs was chosen. Moray had the second highest amount of total feedstock used by waste-fed AD plants of LAs. The most effective filtering device is estimated population, as it can also give us an indication about the size of the Local Authority and can also influence the amount of household waste generated to a certain extent. Then the GDHI per head of population was the second filter used to identify similarities within LAs. While following this approach, Tewkesbury is the council to be compared with Moray as it shares similarities in population and GDHI in 2019 but has a low amount of feedstock used by waste-fed AD plants of LAs. The last pair is comprised of Selby, which was chosen as a non-metropolitan, district council with a high amount of feedstock used by its waste-fed AD plants. Then, using population as my main filtering device, I also chose Stirling, which had also similarity in GDHI with Selby (Table 4).

Table 4 List of selected cases in England and Scotland

England / Scotland	Name of LA	Type	Total feedstock (kt) used by waste-fed AD plants of LAs	Estimated Population mid-2019	Household waste generated (tonnes) in 2019	Gross Disposable Household Income (GDHI)[41]
EN	Tewkesbury	Non-metropolitan District	34000	95,019	33926	21,669
EN	North West Leicestershire	Non-metropolitan District	20000	103,611	41457	19,644
EN	Selby	Non-metropolitan District	118125	90,620	36066	21,994
SC	South Ayrshire	Council Area	300000	112,610	52,639	19,428
SC	Stirling	Council Area	30000	94,210	42,504	21,345
SC	Moray	Council Area	157450	95,820	47,186	19,319

[41] Gross Disposable Household Income (GDHI) per head of population at current basic prices - GBP (2019)

In table 4 above, the six LAs were selected initially while considering that their investigation can provide around six to eight interviews with waste managers and AD plant operators. Furthermore, availability of resources, time, and willingness of potential interviewees to participate were also factors that needed to be taken into consideration at this stage of the research.

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