Imagining Biofuels - Building Agricultural Supply Chains in the UK:

A comparison of UK policy expectations with on-farm perspectives

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Thesis Abstract

This thesis aims to drawn on theoretical insights from science and technology studies and rural studies literatures to interrogate the potential agricultural system and on-farm changes required for developing lignocellulosic biofuel supply chains in the UK. Previous work has largely examined first generation, food based biofuels, with limited focus on the prospects for lignocellulosic technologies. Likewise policy identifies a number of challenges for lignocellulosic biofuels, commercial, technical, and sustainability, that require policy solutions. However, biofuels straddle the agricultural-energy sectors. The deployment of these technologies will demand the adoption of certain practices and crops by farmers, as well as broader changes to agricultural systems. These important components for delivering lignocellulosic biofuels require examination which has so far been limited.

Using semi-structured interviews alongside documentary analysis I identify the ways in which policy constructs and imagines the interface between lignocellulosic biofuels and agriculture, before interrogating these tacit assumptions through comparison with perspectives from farmers, agricultural intermediaries and industry representatives. A key finding is that through knowing farmers and agricultural systems with modelling alone, important avenues for producing and procuring biomass for use in lignocellulosic biofuel production are obscured, whereas significant barriers are presented as readily negotiable.

This thesis argues the following points. Firstly, there is an emerging disjuncture between biofuel imaginaries and agricultural imaginaries. This is particularly apparent as food security concerns re-emerge and Common Agricultural Policy moves towards embedding types of multifunctional arable production which both exclude dedicated non-food energy cropping. Secondly, policy understands farmers as rational economic decision makers influenced by price, ignoring entrenched on farm practices, technologies, values and farmer decision making which are difficult to untangle. These factors can create resistance to increasing straw baling, or the cultivation of dedicated energy crops. Fourthly, marginal

land and straw are material heterogeneous resources not the fungible commodities imagined in policy. This materiality shapes how land and biomass is and can be used. Foregrounding these considerations identifies oil seed rape straw as a potentially large, but challenging opportunity. Finally, agricultural intermediaries are a crucial link in biomass supply chains but have been entirely ignored in policy. Contractors and merchants undertake in-field operations, own large scale machinery and manage inter-relationships between farmers and end users. Agronomists are important land management advisors and involved in the soft sell of new technologies and practices. Neither groups are addressed in policy and require active enlistment in lignocellulosic developments.

These insights highlight the following: a need for policy makers to forge better linkages between biofuel, bioenergy and agricultural policy domains; the incorporation of qualitative insights into policy understandings of on-farm decision making, practices, biomass materials and farmer values; the engagement with a wider range of agricultural actors to better deliver desired agricultural change.

List of Publications

Helliwell, R. & Tomei, J., 2016. Practising Stewardship: EU biofuel policy and certification in the UK and Guatemala, *Agriculture and Human Values,* In Press

Mohr, A., Shortall, O., Helliwell, R. & Raman, S., 2016. How should land be used?: bioenergy and responsible innovation in agricultural systems. In: I. Gordon & H. Prins, eds. *Food Production and Nature Conservation: Conflicts and Solutions,* London: Earthscan (Routledge), In Press

Morris, C., Helliwell, R. & Raman, S., 2016. Framing the Agricultural use of Antibiotics and Antimicrobial Resistance in UK National Newspapers and the Farming Press. *Journal of Rural Studies,* Volume 45, pp. 43-54

Raman, S., Mohr, A., Helliwell, R., Ribeiro, B., Shortall, O., Smith, R. & Millar, K., 2015. Integrating social and value dimensions into sustainability assessment of lignocellulosic biofuels. *Biomass and Bioenergy.* Volume 82, pp. 49-62

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Abbreviations

AD	Anaerobic Digestion
ADAS	Agricultural Development and Advisory Service
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food & Rural Affairs
dLUC	Direct Land Use Change
DTI	Department for Trade & Industry
EC	European Commission
ELS	Entry Level Stewardship Scheme
EU	European Union
FERA	Food and Environment Research Agency
iLUC	Indirect Land Use Change
GM	Genetically modified
RELU	Rural Economy and Land Use Programme
RTFO	Renewable Transport Fuel Obligation
SRC	Short Rotation Coppice
SSSI	Site of Special Scientific Interest
STS	Science and Technology Studies
UK	United Kingdom of Great Britain and Northern Ireland
USA	United States of America

1 Introduction

1.1 **Introduction**

This thesis examines the way in which agricultural systems, actors, and practices are constructed in UK liquid biofuel policy. In particular, I will be analysing on farm practices, decision making, values and inter-relationships and comparing them against the modelling assumptions that underpin how the role of agriculture in realising lignocellulosic biofuels is imagined in UK policy, thus shaping government (in)action.

Since the turn of the 21st century, liquid biofuels have been proposed by the European Commission (EC) as a renewable and low carbon alternative to mineral fuel use in the transport sector (EC, 2000ii; EU, 2003).

Liquid biofuels are defined as fuels specifically for transport[1] produced from the processing of biomass feedstocks (DECC, et al., 2012). Biomass feedstocks encompass a wide range of biological material, plant or animal, which can be used as fuel, processed into fuel or used in industrial production (EU, 2003; DEFRA, et al., 2007; DECC, et al., 2012). The two most common liquid biofuels in mainstream use are bioethanol, produced from the fermentation of starch and sugar crops, and biodiesel, a methyl ester produced from vegetable and animal oils. Biofuels based on the aforementioned feedstocks are referred to as 'first generation' biofuels (Naik, et al., 2010). My interest is in lignocellulosic biofuels. Also referred to as 'advanced' or 'second generation' biofuels (Naik, et al., 2010), lignocellulosic biofuels include bioethanol produced through processing fibrous non-food material such as wood, dedicated energy crops, straw, or seed husks (Somerville, et al., 2010). As yet these novel technologies are commercially nascent but are identified in UK policy and research as a promising future prospect and as a supposed next step towards the coveted bioeconomy (DEFRA,

[1] Liquid fuel for other energy purposes, such as electricity or heating is defined as a bioliquid (DECC, et al., 2012). This differentiation is due to the differences in the incentive and mandate regime between these different energy sectors.

et al., 2007; DECC, et al., 2012). Equally, the influential Gallagher Review (RFA, 2008) identified lignocellulosic biofuels as a technology that could deliver the original promises attached to the now controversial first generation biofuel technologies in the aftermath of the food versus fuel and land use change controversies that emerged in 2007/08.

As argued by Jasanoff and Kim (2009; 2013; 2015) in their work on socio-technical imaginaries, investments by nation states in certain technological projects are linked to imagined desirable futures which said technologies are presumed to embody. Liquid biofuels are one such example, imagined by the EU and the UK government as enabling a future socio-technical order in which non-renewable, fossil fuel derived petro-chemicals are substituted with renewable, low carbon, biological alternatives, transforming the basis of our energy economy. The touted desirable outcomes for materialising a biofuel industry include increased energy security, climate change mitigation and rural development benefits. To realise this, in 2003 the EU Biofuel Directive (2003) was passed establishing indicative biofuel blending targets for member states, which were later made mandatory in the 2009 EU Renewable Energy Directive. As an EU member state, the UK enacted the Renewable Transport Fuel Obligation (RTFO) that mandates and subsidises biofuel blending to meet these obligations.

The current low level blending of liquid biofuels into the mainstream fuel mix, equating to 3% of total road and no-road machinery fuel (DfT, 2016), represents only a slight change to the material characteristics of liquid fuel. A change that does not significantly disrupt existing transport infrastructure and rolling stock. However, modest change to the UK fuel mix masks the wide range of biomass production infrastructures required to fulfil these relatively modest blending targets (Thornley & Cooper, 2008). The substitution of fossil fuel feedstocks with biomass alternatives situates biofuels within the agriculture-energy nexus. Imagining a future in which fossil fuel feedstocks are substituted with biological ones creates a crucial role for agriculture and forestry if an adequate supply of biomass is to be maintained for combustion, or processing. In the context of realising a UK-based biomass resource for the emerging lignocellulosic biofuel technologies, models predict farmers in the future to cultivate increasing

amounts of dedicated energy crops on marginal land, while making cereal and oilseed straw available in increased quantities for energy uses (see HM Government, 2009; DECC, et al., 2012).

In contrast, there is limited consideration of how existing practices, decision making, farmer values and actor inter-relationships may enable or hinder the development of current and future biofuel supply chains. As noted existing work on the agricultural dimension to biofuel futures, whether government commissioned research (see AEA, 2010; Turley, et al., 2010) or academic research (see Lovett, et al., 2009; Glithero, et al., 2013i; Glithero, et al., 2013ii), has heavily favoured modelling. These models broadly assume that future change is readily achievable with the correct level of fiscal remuneration and does not require more substantive changes to on farm practices, values and inter-relationships. In contrast social science research utilising qualitative methodologies to investigate the agricultural elements of biofuel production has been scant. Where it does exist, it presents a far less optimistic reading of the potential for agricultural change facilitative of biofuel futures (see Sherrington, et al., 2008 for one such example regarding energy crop adoption).

This thesis starts with the assumption that meeting the needs of emergent lignocellulosic biofuel technologies in the future requires more substantive changes to the existing management practices, values, supply chain inter-relationships than expected by current policy and academic modelling. Utilising the concept of socio-technical imaginaries, the work presented here examines how biofuels and their connections to agriculture are imagined over time. This provides a conceptual framework through which to draw out the key assumptions and expectations that underpin the delivery of this socio-technical future. The critical analysis of biofuel modelling assumptions and expectations will draw on empirical findings from semi-structured interviews with livestock, mixed and arable farmers, straw merchants, agronomists and biofuel and bioenergy industry representatives. The work presented in this thesis therefore contributes to a small body of qualitative research into the agricultural dimension of realising a lignocellulosic biofuel future.

This chapter is structured as follows. Section 1.2 briefly introduces the background context for the study. Section 1.3 identifies important research gaps addressed by this thesis. Section 1.4 outlines the research aim, specific research questions, and introduces the important components of the socio-technical imaginaries concept which informs the analysis conducted in this research. Section 1.5 gives an overview of the research methods before section 1.6 outlines the thesis structure.

1.2 Biofuels: Background

In 2003 the EU *Biofuels Directive* (EU, 2003) was adopted establishing an indicative target for biofuels of 5.75% on the basis of energy content to be reached by 31 December 2010 (p. L123/45); extended to 10% by 2020 with the adoption of the *Renewable Energy Directive* in 2009 (EU, 2009). Initially, NGOs such as Greenpeace and Friends of the Earth included biofuels positively in their campaigns (Raman & Mohr, 2014), technology assessments suggested easy integration into existing infrastructure and attractive low carbon emissions (Hart, et al., 2003), industry assessments suggested a strong role for bioenergy and biofuels in energy futures (Shell, 1995), positive media narratives expressed low carbon credentials and energy security benefits (Wright & Reid, 2011), and modelling of biomass potential pointed to seemingly abundant supplies of biomass in the EU bloc (Faaij, et al., 1998; Askew & Holmes, 2001; Pisarek, et al., 2004), and globally (Fischer & Schrattenholzer, 2001; Hoogwijk, et al., 2003; Smeets, et al., 2007), with prospects for rural development benefits from exploiting these supplies (Mathews, 2007).

Post 2007/08, and the food versus fuel and land use change controversies, the sense of optimism surrounding biofuels in the early 2000s had vanished. Rapid food price rises and volatility from 2007 to 2008, with disproportionate impact on the world's poor (Watts, 2007; Oxfam, 2008; van der Horst & Vermeylen, 2011), produced the conditions in which the food versus fuel controversy became a prominent public and political controversy. Biofuels were presented as contributing to these price rises to various degrees (see Mitchell, 2008; Zhang, et al., 2013; Zilberman, et al., 2012) and as presenting a moral and ethical controversy regarding the claims that "liquid transportation fuels derived from

plant-based feedstocks will take food out of the mouths of hungry people, [producing] …an ethically powerful argument against the entire package of [biofuel] technologies" (Thompson, 2012, p. 340). Further to this has been the predominant concentration of impacts on the spaces of the Global South, as biofuel production, trade and consumption networks have become spatially organised around north-south relationships, perceived to shift burdens unjustly towards the south (Mol, 2007; van der Horst & Vermeylen, 2011).

In parallel, a set of linked technical issues have arisen. EU level focus on carbon metrics as the means of ascertaining the sustainability of biofuels created a wicked problem in the form of accounting for land use change (Palmer, 2012; Palmer, 2014). Although land use change of any kind has the potential to alter the services provided for by parcels of land (Coleby, et al., 2012), the primarily focus has narrowed around the contestation of actual carbon savings from biofuels once all supply chain and production emissions have been quantified. Land use change is broken into two categories: direct land use change (dLUC) and indirect land use change (iLUC). Both types of land use change are considered to potentially increase carbon emissions due to destruction of carbon rich habitats as well as diminishing biodiverse areas (Fargione, et al., 2008; RFA, 2008; Searchinger, et al., 2008; Bringezu, et al., 2009; Börjesson & Tufvesson, 2011). However dLUC is seen as methodologically manageable whilst iLUC faces methodological uncertainty in terms of quantifying its impacts (RFA, 2008; Cherubini, et al., 2009; Börjesson & Tufvesson, 2011, Gawel & Ludwig, 2011). With carbon accounting being an important pillar of the EU sustainability certification schemes that were produced as a response to emergent biofuel controversies, how to quantify carbon, incorporating dLUC and iLUC into such calculations has been a site of heated contestation (Palmer, 2012).

These controversies have had enduring implications for the shape of EU and UK policy. First, the UK Renewable Fuels Agency's Gallagher Review (RFA, 2008), which was nationally and internationally influential, placed significant emphasis on lignocellulosic biofuels as the sustainable future of biofuel technologies. Additionally it favoured feedstocks that were perceived to sidestep issues of food versus fuel and land use change, most notably dedicated energy crops on

marginal land and agricultural residues and wastes. Second, recent legislation passed in 2015 by the EU Parliament, capped food based biofuels at 7% of the 2020 target, with individual member states able to choose a lower percentage if they so wish (EurActiv, 2015). Reaching the 10% target for 2020 with biofuels alone will therefore require deployment of lignocellulosic technologies. Finally, a consequence of the spatial component to the controversies has been an effort to refocus lignocellulosic biofuel supply chains around domestic spaces of feedstock production. DEFRA has been a keen purveyor of this vision, arguing that it offers the best means of delivering energy security and rural development opportunities (House of Commons, 2003; House of Lords, 2006). However, biofuels policy has consistently neglected the biomass production infrastructure required to realise this vision (Thornley & Cooper, 2008). These implications will be returned to and covered in more detail in Chapter Two.

This emphasis on increasing the cultivation of dedicated energy crops such as miscanthus and short rotation coppice (SRC) willow, and the availability of straw for energy in domestic markets has focused on the roles of farmers as energy crop adopters and as key supply chain actors. However, despite the importance of materialising these resource supply chains to facilitate the deployment of lignocellulosic technologies in the UK, UK policy and research has mainly engaged with agriculture through modelling.

1.3 **Biofuels: Research Gaps**

Current social science studies on the impact of farmer decision making, management practices and inter-relationships on realising these expectations are scarce. For energy crops the work that does exist paints an uncertain picture. These studies highlight policy ineffectiveness and failures (Piterou, et al., 2008; Adams & Lindegaard, 2016), the need for farmers to adopt new land and business management practices (Sherrington, et al., 2008; Sherrington & Moran, 2010), as well as challenging farmer values and identity – e.g. farmers not foresters (Convery, et al., 2012). However, this work is limited to examining farmer attitudes, and policy analysis. As the research synthesis conducted by Raman et al. (2015) emphasises, it is important to incorporate on farm decision making rooted in forms of practice, technologies, and cultural values when

assessing the future prospects for lignocellulosic technologies. Although Raman et al. (2015) do not examine these elements in depth, a task undertaken by this thesis. Furthermore it has not engaged with the wider range of actors involved in influencing on farm decision making such as agronomists and contractors who are required for much of the management work (Sherrington, et al., 2008).

With regards to straw, existing social science research has drawn on agricultural economics approaches. AEA, (2010), Copeland & Turley, (2008), Glithero et al. (2013i; 2013ii) all model farmers attitudes to straw sale into energy markets. Furthermore, only Glithero et al. (2013i) directly questioned farmers on straw using a survey methodology. However, all studies interrogate farmers on the basis of price considerations, in particular the level of renumeration needed to compensate for lost fertiliser and, in the case of Glithero et al. (2013i) contractual arrangements. Furthermore, research and policy has focused on the farmer as the crucial supply chain actor, neglecting the importance of broader inter-relationships in influencing farm decisions (see, for example, the work of Ingram (2008); Ingram & Morris (2008); Klerkx & Proctor, (2013); Sutherland, et al., (2013) on farm advisory services).

Although these on-ground interactions are essential, as Jasanoff (2015) argues about technological emergence more generally, there are "divergences in technological development that lack obvious grounding in natural, economic or social disparities" (p.3). Jasanoff & Kim (2009; 2013; 2015) propose the conceptual framework of socio-technical imaginaries as a means of analysing these disparities through scrutiny of future orientated visions of desirable socio-technical regimes articulated by nation states. Specifically those which are supportive of and shape the delivery of certain scientific and technological projects.

The socio-technical imaginaries concept interrogates the following conceptual areas which have particular relevance to the analysis conducted in this thesis and will be briefly covered in Section 1.4: origins, embedding, and resistance.

Scholars utilising this concept have engaged with energy as an important domain for state socio-technical imaginaries in the context of nuclear power (Jasanoff &

Kim, 2009; 2013) and energy security discourse (Tidwell & Smith, 2015). However, only the work of Levidow & Papaioannou (2013) and Eaton et al. (2014) have examined bioenergy/biofuel socio-technical imaginaries, the former in the context of UK bioenergy and biofuel policy and the latter regarding Michigan bioenergy policy and developments. Eaton et al's work does interrogate practices and values and their implication for materialising bioenergy technologies in Michigan but in the context of forestry not agriculture. Levidow & Papaioannou's work examines in detail policy imaginaries regarding specific renewable biomass technologies including anaerobic digestion (AD), combined heat and power (CHP), energy crops and liquid biofuels in the UK. However, the focus of the article is on teasing out how technologies are imagined as part of delivering public good, and reflecting on the policy and fiscal factors that have impacted on the relative success and failure in stimulating deployment of said technologies. The agricultural dimension to these success and failures is largely absent from their account. Where it is touched upon, in the context of energy crops, 'economic reasons' predominate in explaining why farmers were not attracted to energy crops (Levidow & Papaioannou, 2013, p. 44). Scrutinising agricultural pasts, presents and imagined futures, the trajectories of change these have established and continue to enact, and how these interface with biofuel energy imaginaries going forward has not been a focus of research. Indeed, there is a deeply held assumption that agricultural actors are willing and malleable participants in realising biofuel policy expectations as long as the price is right. A comparison between the future visions of agriculture encoded in biofuel and agricultural policy imaginaries is therefore an important component that is yet to be addressed in the literature.

More broadly in the literature, the agricultural dimension to the emergence of biofuels and biofuel controversies has been conspicuous in its absence. Whereas work has challenged the deeper legitimacy of EU biofuels policy and its implications for the Global South (see Journal of Peasant Studies special issue 2010 - Borras Jr, et al., 2010; Levidow, 2013; Tomei, 2015). The predominant focus has been on the disjuncture between optimistic EU biofuel policy expectations and how biofuel developments have played out in practice in Global

South contexts. Research examining the spatial dimension to biofuel controversies and the distribution of burdens and benefits (Mol, 2007; van der Horst & Vermeylen, 2011; Raman & Mohr, 2014) has likewise touched upon but otherwise skirted around an in-depth analysis of how the emergence of biofuels has been shaped by agricultural landholding and management practices, values and inter-relationships. Research on the policy process (Boucher, 2012; Palmer, 2012; Berti & Levidow, 2014; Palmer, 2014) and policy visions for biofuels (Boucher, 2013; Levidow & Papaioannou, 2013) further highlights how biofuels are situated within their own energy policy ecosystem, navigating biofuel specific controversies without a wider reflection on their embeddedness within particular types of agricultural practice.

Furthermore, assessments of sustainability challenges and constraints which routinely assess the availability and sustainability of various biofuel feedstock supplies, often do so while ignoring the influence of farmers, agricultural practices and other agricultural supply chain actors on feedstock availability (see Thornley, et al., 2009; Upham, et al., 2009). Although there are exceptions (see Raman, et al., 2015), sustainability assessment has not incorporated an in-depth analysis of agricultural perspectives on biofuel production and prospects. Equally, this work is largely pre-occupied with the present situation regarding first generation, food-based biofuels. Less attention has been given to the future regarding emerging lignocellulosic technologies, or the historical interaction between biofuel and agricultural systems (an exception being Mohr & Raman, 2013).

The work that has charted biofuel and particularly bioethanol histories situate the analysis within the context of liquid fuel developments. Work by Bernton et al. (1982), Carolan, (2009), Kovarik, (1998) charts the history of bioethanol as a energy technology. Although this does include some acknowledgement of agricultural developments and interactions, this is largely peripheral to the account. This highlights a need to examine historical agricultural developments and how they have shaped past and present emergences of biofuels.

It also implies that an in-depth examination of farmer decision making, values, practices, and broader inter-relationships is needed for two main reasons. First, this would provide a means of critically investigating the tacit policy assumptions embedded in modelling methodologies that underpin claims and expectations about the imagined future deployment of lignocellulosic biofuels in the UK. Second, it would provide an important contribution to the limited literature that aims to interrogate biofuel expectations from an agricultural perspective with a focus on the UK.

1.4 Research Aim and Questions

Biofuels straddle the agriculture-energy nexus and realising this energy future creates present and emerging demands on agricultural actors, particularly with an envisaged shift towards lignocellulosic technologies. As Raman & Mohr (2014) note, biofuels are a heterogenous category including numerous feedstocks and production systems, that raise different issues, and demand different agricultural practices and interactions. The transition to lignocellulosic biofuels strongly emphasises this point, requiring different crops and feedstocks and thus different supply chain configurations. Consequently, ways in which agricultural systems are imagined in regards to facilitating lignocellulosic biofuels, and how this interface is performed in policy and then in practice, will have a significant bearing on government action and intervention, and their success or failure.

The aim of this thesis is utilise the socio-technical imaginaries concept to examine the ways in which biofuel policy imaginaries envision agricultural systems in the UK, scrutinising the assumptions and expectations about agriculture embedded in policy through modelling exercises, examining how well they hold up through comparisons with on farm decision making, practices, values and inter-relationships. Furthermore the thesis will situate this on farm analysis in a historically rooted context of evolving biofuel and agricultural imaginaries and trajectories.

As Jasanoff (2015, p. 21) argues, “the past is prologue”. Tracing the origins of socio-technical imaginaries (see Bowman, 2015; Dennis, 2015; Jasanoff & Kim,

2009; Jasanoff & Kim, 2013; Storey, 2015; Tidwell & Smith, 2015) is important for examining the formative context within which new futures are imagined and the consequences of past efforts to realise desired futures. Such analysis illuminates the practical issues of how past infrastructure shapes where new infrastructure can be easily placed (problems with connecting renewable electricity generation from wind to the grid being an obvious example), and but also draws attention to how past events, mishaps and successes creating the mental landscape within which the future is visualised with hope and apprehension. In the context of biofuels this requires closer attention not just to socio-technical change in the present but also past agricultural change.

Furthermore, socio-technical imaginaries approaches are not just interested in examining overarching proclamations of good futures, entwined in technological development but also in examining the tacit assumptions and expectations that are embedded in policy and which underpin the delivery of this vision (see Burri, 2015). Embedding biomass production infrastructure has been performed in policy through modelling exercises. Models have been used to justify and legitimate regulatory decisions regarding biofuels in a number of ways. Forecasting energy futures suggesting increasing transport demand (DTI, 2003), estimates of carbon savings (or carbon debts accrued) from the production of biofuels (DTI & DEFRA, 2004; DEFRA, et al., 2007), to identify surplus or under-used biomass resources, and the prospects for farmer adoption of energy crops (AEA, 2010; DECC, et al., 2012). Indeed the UK Bioenergy Strategy (DECC, et al., 2012) is littered with numerous forecasts of the future and the role of bioenergy and biofuels in it. Therefore, there is a need to compare these modelling assumptions with empirical findings drawn from on farm investigations building on the work of Eaton et al. (2014) who begin to interrogate how imaginaries are enabled and hindered through on-ground interactions and contestations.

Embedding envisioned futures is not a seamless process. Resistance is part and parcel of the articulation and manifestation of imagined futures. The existing socio-technical imaginaries (and biofuels) literature has been drawn to the explicit forms of resistance, to varying degrees deliberate and organised, and coalessing around particular points of controversy. But such analysis fails to

capture how certain encounters, between materials, practices, and ideas create friction and resistance without intention. Like a pebble in the shoe they cause disruption but without explicitly meaning to (Tsing, 2005). In contrast to the prevailing literature, this study engages with the way in which agricultural values, decision making trajectories, and practices create everyday frictions, shaping efforts to embed supply chain infrastructure crucial to the development of lignocelulosic biofuels.

This suggests a socio-technical imaginaries approach provides a productive framework for guiding the analytical gaze of this project. Specifically, it draws attention to important aspects of imagined futures and the claims that underpin them providing a space to identify and analyse these assumptions and expectations. At the same time the concept highlights the roles of historical developments, state interventions, and events in shaping future imaginaries and trajectories.

The intention is not to simply address whether the performative claims and tacit assumptions of models are 'correct'. Rather the aim is through examining on farm practices, values, decision making and inter-relationships, to reflect upon how they produce opportunities and barriers to realising a domestically configured lignocellulosic biofuel supply chain that are obscured, ignored, or overlooked through a reliance on modelling exercises in policy. Equally, the analysis is not only concerned with the 'present', it also reflects on the past and the future. In particular, it aims to situate the contemporary emergence of liquid biofuels within a historical narrative that charts past agricultural change, events and trajectories, the role of government intervention within it, and how this has impacted on liquid biofuels over time. Finally, I aim to reflect on some of the pathways for the future that emerge from the interface between potentially competing visions for agriculture encoded within biofuel and agricultural policy imaginaries.

This research undertakes this aim, whilst making a contribution towards addressing the gaps identified previously in Section 1.2, through examining UK and EU policy, and analysing the attitudes and perceptions of UK agricultural and

biofuel industry actors to the prospects offered by lignocellulosic biofuel. The choice of the UK is justified as follows. The country has a well-developed agricultural sector that already supplies modest amounts of biomass and food crops to bioenergy and first generation biofuel plants in the UK. Current policy expectations foresee increased domestic supply chain opportunities and capacity arising from lignocellulosic technologies (House of Lords, 2006; DECC, et al., 2012), these claims have yet to be interrogated in detail. The UK government and research councils such as the BBSRC[2] have taken an active role in supporting research into lignocellulosic biofuel processing technologies, and feedstocks, particularly dedicated energy crops for deployment in the UK. As such the UK has already undertaken action and intervention, supportive of science and technology, as a means of attaining the desired lignocellulosic biofuel future.

1.4.1 Research Questions

To reiterate, the aim of this thesis is to examine the ways in which biofuel policy imaginaries envision agricultural systems, actors and practices in the UK, through scrutinising the assumptions and expectations about agriculture embedded in policy through modelling exercises, critiquing these assumptions through comparisons with on farm decision making, practices, values and inter-relationships.

This overarching aim has been operationalised into the following research questions:

- How do biofuel and agricultural policy imaginaries compare and contrast over time in the UK? How has policy attempted to materialise them into practice?

- What are the UK biofuel policy modelling expectations with regards to agricultural systems, decisions, and practices? How do they compare with on farm decision making, practices, values, and inter-relationships?

[2] Biotechnology and Biological Science Research Council

- What are the opportunities and challenges, highlighted through understanding the agri-energy nexus, for the future emergence of lignocellulosic biofuels?

1.5 Research Methods

Qualitative research methods are used to address the research questions and gaps identified in this chapter. Semi-structured interviews were conducted with farmers, agronomists, straw merchants, contractors, and biofuel/bioenergy industry representatives and consultants. Participants were sampled using purposive, and snowball sampling to access a wide range of views from relevant groups. Interviews were complimented by documentary analysis of UK and EU legislation, regulation and policy concerning agriculture and biofuels from 1945 to 2015.

Analysis was inductive and interpretative, identifying the most salient themes and topics that emerged from the data. Comparative analysis is an important component of the socio-technical approach and informed the analysis conducted in this thesis: firstly, with comparison utilised to draw out salient themes, and areas of cross-over and competition between the historically rooted trajectories of agriculture and expected trajectories for agriculture embedded in lignocellulosic biofuels imaginaries; secondly, between the tacit assumptions about agricultural decision making, practices, values and inter-relationships in modelling and accounts from qualitative interviews with agricultural actors.

1.6 Thesis Structure

Following on from this introduction the thesis is structured as follows.

Chapter Two provides an overview of the background context to the emergence of liquid biofuels as an area of UK policy concern, the response to the controversies, and the positioning of lignocellulosic technologies in reaction to these contestations as a means of situating this thesis in a broader landscape of developments. The chapter identifies the 'agricultural gap' in policy and

academic literature due to the framing and focus on biofuels as a low carbon energy technology, a gap this thesis contributes to.

Chapter Three examines the socio-technical imaginaries literature in detail. The chapter outlines how this concept has been used previously, examines its application, and identifies important conceptual areas, in particular origins, embedding, and resisting. Equally, the chapter will situate existing biofuels literature within the context of these areas, highlighting what has already been addressed (albeit not from the perspective of socio-technical imaginaries). In the process this chapter will highlight the thesis's contributions to the socio-technical imaginaries and biofuels literature that are realised through drawing on this approach, before examining its limitations and how these are addressed.

Chapter Four sets out the methods used and the research process of the PhD. The chapter then describes and justifies the qualitative research methods, outlining how the research evolved, and its implications for the scope of participants selected, and how the thematic and content analysis was conducted. The chapter also examines two points of reflection regarding the implications of using numerous interview modes (face to face, walk and talk and phone interviews) and my 'insider' status as a farmer's son.

Chapter Five begins the empirical analysis by focusing on origins and past. The chapter draws on documentary analysis of legislation, regulation and policy, published by the UK and EU, to examine agricultural change from World War II onwards and biofuel policy from 1990 onwards. Specifically, the chapter differentiates between a dominant agricultural imaginary which has evolved from end of World War II onwards, and a more recent bioeconomy imaginary within which lignocellulosic biofuels is situated as a desirable technology. I compare both the imagined futures, the breadth of legislative and regulatory efforts to embed said imaginaries and finally identify areas of disjuncture and cohesion between these different imagined futures, both of which have implications for agricultural systems. Finally, this chapter identifies the tacit assumptions that underpin the biofuel imaginaries expectations about future

agricultural systems that are critically investigated in the following three chapters.

Chapter Six continues the analysis by examining policy assumptions about what domestic supply chains will be embedded and who are the actors important in this process. Specifically, it draws on analysis of policy and modelling documents to identify key expectations and assumptions, contrasting this with the findings of interviews with supply chain intermediaries, such as merchants and contractors, farmers and biofuel and bioenergy industry representatives. The chapter begins by highlighting some shared themes between policy and industry expectations with regards to how lignocellulosic technologies will manifest, at what scale and in hybrid configurations with other biomass processing platforms. It then moves on to complicate the simplistic assumptions that suggest only farmers and industry drive supply chains by drawing attention to the role of intermediaries in maintaining and shaping biomass supply chains.

Chapter Seven considers how efforts to embed particular practices to facilitate the use of straw in energy meets resistance in the form of entrenched management practices, and the material heterogeneity of the feedstock. It begins by examining how straw is assumed in policy modelling to be a homogenous material item, and the assumption that a farmer will privilege the market uses of straw over non-market uses. The chapter draws on interviews with farmers, straw merchants and contractors and agronomic advisors as a means of highlighting the how factors influencing straw are in a constant state of flux, that the role of intermediaries is an important influence on this and that the weather is a major determining factor in how straw is used. The chapter then highlights how straw is a materially heterogeneous product in terms of type, quality and bale size which shapes straw markets and on farm use.

Chapter Eight explores how resistance to cultivating energy crops on marginal land manifests in on farm contexts. The chapter begins by illuminating the assumptions embedded in policy efforts to map marginal land in the UK, particularly the predominance of biophysical considerations. This chapter highlights how these biophysical qualities are, in the context of individual farms,

transacted by practices, use and farmer's pride in their farm holding, which has implications for how land is understood and valued. The chapter draws attention to how farmers perceive energy crops as for marginal land, a connection that becomes highly problematic when they do not consider their land marginal enough. In this context marginal land becomes a site of resistance rather than a facilitator for the cultivation of more sustainable feedstocks.

Chapter nine concludes the thesis, answers the research questions drawing out key opportunities and barriers to the emergence of lignocellulosic biofuels that have arisen from this qualitative study into agricultural practices, values, decision making and inter-relationships in the UK. The chapter outlines key recommendations, evaluates the limitations of the study, and sets out areas of future potential research.

2 Biofuels: Context, Controversy, Policy, and Research

2.1 Introduction

The purpose of this chapter is to provide context and background to this project, in particular highlighting the evolving landscape of controversy and policy that has been important in moulding lignocellulosic biofuels as a future technological aspiration, alongside the way in which agriculture has been backgrounded as a site of policy intervention and academic analysis.

The chapter is structured around a chronological narrative. Section 2.2 begins by recounting the early 2000s policy rationale for biofuels utilised by the EU to justify investment and support for biofuels. It highlights the lack of clear links between energy policy and agricultural policy within the biofuels agenda as well as noting that in this initial policy formulation lignocellulosic technologies were a more efficient 'next step' technology. Section 2.3 charts the various controversies first generation biofuels accumulated from 2007 onwards. It touches upon the food versus fuel controversy, the way in which spatial scale was an important lens influencing this debate, and iLUC controversy. Section 2.4 examines the responses to these technologies which includes new governance mechanisms, certification, and technological fixes, lignocellulosic biofuel technologies. With regards to the latter it highlights how lignocellulosic technologies were positioned as resolving various aspects of these controversies and what consequences this has had for policy. Finally, section 2.5 examines the lack of an agricultural connection within UK biofuels policy, unpacking the way in which framing biofuels as an energy technology serves to obscure the agricultural infrastructure crucial to their delivery. In this respect it firstly overviews the biofuels narrative, highlighting how in each case the framing shifted attention away from agriculture and towards biofuels as a technology, before examining the literature on building biomass production infrastructure that is crucial to fulfilling the emergence of lignocellulosic technologies.

2.2 First Generation Biofuels

Over a relatively short period of time beginning in the late 1990s, biofuels were brought out of relative obscurity and given political support (Boucher, 2012). In 2003 the passage of the European Union's *Biofuels Directive* (EU, 2003) marked a major step change in the scale and scope of biofuel developments, breaking with the past and leading to the emergence of a global biofuels network (Mol, 2007). The directive established the cornerstone of the EU's strategy for biofuel development, creating indicative targets for biofuel blending to reach 5.75% by 2010, later becoming a binding target to reach 10% by 2020 with the passage of the *Renewable Energy Directive* (EC, 2009). Rather than being driven by scientists, industrialists, or corporations, biofuels has become a state-led project with global implications.

Cresting a wave of optimism and enthusiasm, biofuel blending mandates were adopted by a range of nations, including EU member states, the USA and China, triggering unprecedented production and consumption of biofuels. In the EU, energy policy in the form of the 2003 *Biofuels Directive* (EU, 2003) and the 2009 *Renewable Energy Directive* (EU, 2009) has been essential in creating both the demand for biofuels and the institutional frameworks that have governed their use (Tomei & Helliwell, 2015). The EU *Biofuels Directive* (EU, 2003) establishing an indicative target for 2010 of 5.75% calculated on the basis of energy content of all petrol and diesel for transport by December 2010.

As a member state the UK has followed suit and through the Renewable Transport Obligation (RTFO) statutory instrument, adopted in 2007 and overseen by the Department for Transport[3], established its own targets and incentive regime to meet its EU obligations. The RTFO established an escalating set of targets rapidly upscaling the level of biofuel blending. The RTFO stipulated that by April 2008 biofuels blending would reach 2.56% by volume of all petrol

[3] Initially the RTFO was overseen by the Renewable Fuels Authority, however this agency was dissolved with the election of the coalition government in 2010 and powers were returned to the DfT.

and diesel fuel for transport, rising to 3.89% by April 2009, and finally to 5.26% for each subsequent obligation period (HM Government, 2007). In 2009 the RTFO was amended to extend the time frame within which to meet the 5.26% target to 2013 (HM Government, 2009ii) in response to the Gallagher Review. It has been amended a further three times (see HM Government 2011; 2013; 2015), most significantly in 2011 to incorporate the sustainability criteria outlined in the EU *Renewable Energy Directive* (EU, 2009). Energy policy has therefore been a key site of imagining and making biofuel futures a material reality. This has both framed the debate and academic analysis of biofuel issues as well has guided the analysis of this thesis towards energy policy as a key site of vision making.

The consequence of targets enforced by the EU, the US and other governments has been to trigger unprecedented expansion of biofuel production. Global production of bioethanol more than doubled from 30 billion litres in 2004 to 76 billion litres in 2009, whilst during the same period biodiesel production grew from 2.3 billion litres to 17 billion litres (Timilsina & Shrestha, 2011). How has the necessity of supporting such a massive up-scaling of production been justified by the EU and thus the UK?

2.2.1 Policy Rationale

At the turn of the 20th century, EU policy developments became broadly motivated by the convergence of a range of global contemporary issues, most notably, climate change and energy issues (Lovell, et al., 2009). This alignment is most visible in the 2000 Green Paper 'Towards a European strategy for the security of energy supply' (EC, 2000), arguing that dependence on external sources of energy had the potential to limit economic growth and hinder responses to the challenge of climate change and Kyoto Protocol Commitments (Skogstad, 2016). Meeting the short term carbon targets laid down in the Protocol meant that signatory governments needed to find immediately applicable solutions in all areas of energy production and consumption (Dincer, 2000).

The transport sector accounts for around 26% of the national carbon emissions in the UK (DTI, 2003; DECC, 2012). UK and EU policy expected transport demand to continue on an upwards climb (see DTI, 2003; EU, 1997). Efficiency measures had only managed to keep carbon emissions from car transport flat (DTI 2003) and behaviour change and demand management were expected to fail (RCEP, 2000). If carbon reductions were to be realised then policy would have to address the carbon intensity of fuels. Although hydrogen, and to a lesser extent electric, were and still are, envisioned as the long term solution, current infrastructure precluded them from consideration in the short term.

Fuel supply infrastructure and rolling stock are orientated almost entirely around the use of crude oil derived fuels, with 97% reliance of fossil fuels (DECC, 2011). In the short and medium term biofuels were posited as a low carbon substitute fuel (EC, 2000; DTI, 2003) that is able to interface relatively easily with entrenched petroleum infrastructure and user interface when blended at low levels (Foresight Vehicle, 2004; DEFRA, et al., 2007; Thornley & Glibert, 2013). Additionally it requires no changes to consumer behaviour diminishing barriers to adoption. In contrast electric vehicles are deemed to have technological, range, infrastructure and behaviour barriers limiting their rapid expansion (Garling & Thøgersen, 2001). The ease of integration with existing infrastructure, while delivering carbon savings was a key part of the policy justification. Therefore to curb emissions biofuels were promoted as a part of a range of immediate measures that will assist in achieving compliance with the Kyoto Protocol (EU, 2003; DEFRA, et al., 2007; Fischer, et al., 2010). Equally, there are some sectors in which liquid fuel demand will persist (aviation) and therefore biofuels are also a long term option (Thornley & Gilbert, 2013).

The carbon credentials of biofuels were established on two grounds. The first is perhaps best described as a 'common sense' understanding of carbon emissions which relates to the claim that growing biofuel crops sequesters carbon in new plant material which is then released upon combustion resulting in no net increase in carbon. The second relates to a range of life cycle assessments. Two reviews of the LCA's conducted between 1996 and 2003, and 1997 and 2005 by Quirin, et al., (2004) and Larson (2006), respectively, concluded that LCA studies

during these periods suggested favourable energy balances and GHG emissions when compared to fossil fuels. Although this was qualified by noting that these estimates were highly variable. This broader literature suggesting that biofuels would deliver carbon savings was mirrored by a range of UK government commissioned studies (see Eyre, et al., 2002; Reading, et al., 2002) which expressed similar claims about the potential for significant savings.

The prospect that biofuels offered genuine carbon savings over existing petroleum fuels was situated against the background of a changing energy landscape. In the late 1990s and early 2000s a steadily rising oil price, and the consequences of 9/11 (Suurs & Hekkert, 2009) placed new emphasis on the continued stability of crude oil markets. An almost total reliance on fossil fuels means that the transport sector is economically vulnerable to both the continued instability in oil extracting regions such as the Middle East and Nigeria, and high oil prices. Further impetus to shift transport energy use away from petroleum fuels comes from several commentators with the International Energy Agency acknowledging that 'peak oil' may already have passed in 2008 (Global Witness, 2009; IEA, 2010; Miller, 2011; Alekett, et al., 2012; Sorrell, et al., 2012). Subsequent large scale exploitation of shale gas and oil obviously changed this landscape through unlocking new reserves (see Energy Information Administration, 2013), however the undeniable fact remains that oil is a diminishing non-renewable resource (Campbell, 2006).

The substitution of mineral fuels in the transport sector with biofuels was deemed to offer energy security benefits over potentially volatile crude oil supplies from uncertain parts of the world (Demirbas, 2008). Although what exactly energy security entails is open to question, EU policy has nevertheless resulted (intentionally or not) in the diversification of fuel imports and some level of self-sufficiency through domestically produced fuels. Furthermore, these systemic changes are complemented by a technological replacement of a non-renewable fuel with a renewable one. Renewability is therefore an aspect of producing a secure energy future (Bang, 2010; Verbruggen, et al., 2010; Valentine, 2011)

Finally, the ambition of biofuel policy that it would provide a broad platform of climate change and energy security benefits was complemented by the expectation that it would also help deliver rural development opportunities (Boucher, et al., 2014). However, rural development played a limited role in the case for justifying biofuel production in the UK, and is perhaps more of an add-on beneficial consequence rather than a key purpose of promoting biofuels.

Nevertheless biofuels emerged at a time when the diversification of EU and UK agricultural markets was positioned as an economic necessity (Centre for Rural Economics Research, 2002) against a backdrop of diminishing direct CAP support and low commodity prices. In this context biofuels were positioned as supporting agricultural prices by providing additional outlets for crop commodities, whilst contributing to wider EU and UK socio-economic objectives (EC, 2000). Albeit neglected in UK biofuel policy, rural development implies the construction of biomass production infrastructure as necessary for producing biofuels. However, UK biofuel policy has consistently downplayed this component (Thornley & Cooper, 2008). In particular, biofuels policy has had limited cross over into EU or UK agricultural policy (Tomei & Helliwell, 2015). CAP for instance had only a short lived energy crop set aside incentive that ended in 2008.

Lignocellulosic technologies were not absent from this initial policy context. Second generation biofuels are produced from lignocellulosic materials such as straw, wood and energy crops like miscanthus and SRC willow (Ajanovic & Haas, 2010). The eventual transition to advanced biofuels has been a long held policy goal and is not directly attributable as a response to first generation controversies. In 2003 UK Department for Trade and Industry (DTI) Energy White Paper (DTI, 2003) outlined the future development of biofuels in which advanced biofuels were clearly anticipated:

> "Biofuels are currently made from food crops. We are also interested in supporting the development of bioethanol and biodiesel production from biomass such as farm wastes, forestry residues, coppice crops and possibly also domestic waste. These can potentially deliver bigger

carbon savings and wider environmental, farming and rural employment benefits." (Pg. 69)

Similarly, the prospects for lignocellulosic technologies to unlock greater domestic potential for biofuel production were signposted earlier in UK policy via the 2002 Energy Review conducted by the Performance and Innovation Unit (Cabinet Office, 2002). In this initial framing policy vision lignocellulosic technologies were positioned as being more efficient means of producing liquid fuels from agricultural and forestry resources, unlocking greater prospects for indigenous production and delivering greater benefits.

With biofuel policy shifting first generation biofuels from an imagined to an actual reality it became apparent that biofuel production had the potential for significant negative implications. Even the relatively modest biofuel targets demand considerable agricultural feedstocks due to the scale of fuel demand in the EU. Given the limited availability of suitable agricultural land in the UK and EU, crop yields and the demand for biomass for other uses (Cabinet Office, 2002), imports became crucial to meeting biofuel targets. A proportion of biofuel and biomass production therefore shifted beyond the spaces of the UK and EU. This has been perceived as shifting with it several negative environmental and societal consequences which were borne by people and environments in the Global South (Mol, 2007). How have these controversies emerged and how have lignocellulosic technologies been situated as responding to them?

2.3 Accumulating Controversy

With the rapidly escalating scale of biofuel production it quickly became apparent that there may be potentially significant negative implications to producing first generation biofuels. These negative impacts are primarily connected to the general issue of land use change. Food versus fuel controversies were catapulted onto the public stage in the wake of food price spikes in 2007/2008 (Koh & Ghazoul, 2008). Environmental impacts of expanding agricultural production into pristine or biodiverse habitats were linked to increased demand for commodities such as palm oil or sugarcane to produce biofuels (Spangenberg, 2009). While the issue of accounting for the actual carbon

emissions originating from biofuel production (and thus determining their eligibility for subsidies) was complicated by the issue of indirect land use change (Searchinger, et al., 2008). As this section will highlight consideration of agricultural practices within these controversies has been largely peripheral to these debates or marginalised.

2.3.1 Food versus Fuel

It has been the issue of food versus fuel and the potential impact on world food prices that has consistently attracted a large amount of media and public attention. The food versus fuel controversy peaked in 2007-2008 during a period of extended food price volatility. The rapid expansion of the biofuel sector from 2003 onwards, and the subsequent demand this placed on key food commodities positioned biofuels as the readymade culprit for causing these price hikes (Koh & Ghazoul, 2008; Tomei & Helliwell, 2015). The increase in staple food prices, in particular corn, led to major protests and disruption. Events such as the Tortilla Riots in Mexico (BBC, 2007) highlighted how the consequences of increasing staple food prices disproportionately impacted on the lives of the world's poor. It was this issue that led Jean Zeigler, UN rapporteur on the right to food, to refer to biofuels as a 'crime against humanity (UN News Centre, 2007). As a result food versus fuel has retained a poignant position within the public consciousness. It has resonated strongly with the public and impacted on the EU and thus UK biofuels policy process (see EU, 2009; EurActiv, 2015i; EurActiv, 2015ii).

Competition for food has long been acknowledged as a potential consequence of producing and consuming biofuels. For instance, in the 1920s and 30s General Motors framed its anti-knock[4] leaded fuel as preferable to anti-knock ethanol fuel additives because leaded fuel did not result in food competition and therefore price increases (Kovarik, 1998). Whereas in the 1980s and 90s food insecurity was signposted as a potential implication of using biomass for energy

[4] Knocking is when the combustion of the air/fuel mix does not occur correctly creating a shockwave and increasing engine pressure which can result in damage to, or in extreme circumstances destroy, the engine.

(see Lewis, 1981; Hall, 1991; Rosillo-Calle & Hall, 1992). However, the unparalleled scale of contemporary biofuel production meant this was relatively uncharted territory.

This issue has principlally been framed around quantifying the actual contribution of biofuels, and thus EU policy makers responsability to address it. Subsequently, a significant portion of the literature examining food versus fuel has been aimed at assessing the impact of biofuels on food prices (see Glauber, 2008; Mitchell, 2008; Baier, et al., 2009; Kretschmer, et al., 2012; Zilberman, et al., 2012; Zhang, et al., 2013; De Gorter, et al., 2015). At the height of the controversy on the possible impact of biofuels, the World Bank estimated that 70-75% of the food price rises were a result of increases biofuel production (Mitchell, 2008). The World Bank has since retreated from such high estimates (see World Bank, 2011) and in general biofuels contribution has been estimated around more conservative figures between 10%-30% (see IMF, 2008; Glauber, 2008; Baier, et al., 2009). This retreat was the result of various challenges to the simplistic claim that biofuels largely drove food price hikes. In the process a wider range of issues where brought into the fray highlighting the complixty of the issue. These have included the decline in public food reserves (McMichael, 2009), high oil prices and oil market speculation (Ajanovic, 2011), rising demand for food from a growing global population, climate change, and agricultural protectionist measures and subsidies (DEFRA, 2008; Rosset, 2009; Wetzstein & Wetzstein, 2011)

Further to this scholars have highlighted alternative means of understanding the food versus fuel controversies. For example by focusing on the ethical and moral arguments concerning biofuels and food versus fuel (see Gamborg, et al., 2012; Thompson, 2012i; Thompson, 2012ii), or through examining the spatial arrangements of biomass production and consumption that have influenced this debate (Mol, 2007; van der Horst & Vermeylen, 2011; Raman & Mohr, 2014).

Although food versus fuel has waned in terms of public profile it has nevertheless resulted in tangible, if delayed, policy change. The establishment of a requirement to report every two years on the price of key foodstuffs within the

2009 Renewable Energy Directive (EU, 2009) was followed in 2012 by more substantial recommended amendments. In 2012 the European Commission suggested that biofuels produced from food crops may be limited to 5% of the renewable transport target (EC, 2012). A final agreement between the European Parliament, Commission and Council emerged in April 2015 with an amendment to limit food based biofuels to 7% of targets (EurActiv, 2015). The solution to this has framed in terms of technological change. If biofuels are going to move beyond this capped target for 2020, then non-food biofuels will be required. Lignocellulosic biofuels, using non-food feedstocks, wastes and residues have been one of the key advanced future technologies, alongside even more prospective vision for algal biofuels, proposed as a means of navigating the food versus fuel controversy and sustaining the expansion of biofuels in face of this regulatory shift. The response to food versus fuel has therefore been important in placing policy emphasis on the future application of lignocellulosic biofuels framed as ensuring more sustainable future fuel production (RFA, 2008).

However, the food versus fuel controversy has also been about the people and places that have borne the brunt of the negative impacts (see Figure 1). Particularly, the controversy has contrasted the suffering of rural and urban poor in the Global South as resulting from the regulatory demands of a number of relatively affluent nations in the Global North to which the positive benefits of consuming the fuel have flowed. This is exacerbated by weak social and environmental governance that 'attracts' investments to the Global South (van der Horst & Vermeylen, 2011). What impact has this additional nuance had on the framing of lignocellulosic technologies?

Figure 1: Cartoon from World Vision, (2008).



2.3.2 Spatial Scale

Despite implicit and explicit assumptions within early modelling (see DEFRA, et al., 2007; Fischer, et al., 2010) that biofuel feedstocks would be sourced nationally or from within the EU, the lack of available feedstocks within these markets pushed producers to import a considerable proportion of feedstocks and fuel (EC, 2006). Equally, in contrast to Brazil which originally developed bioethanol as a nationally bounded socio-technical system (Hira & de Oliveira, 2009) other South American nations, such as Argentina, and Guatemala for instance, have developed biofuel sectors entirely organised towards exportation to the EU (Tomei & Upham, 2009; Tomei, 2015). The spatial scales across which biofuels are produced and consumed, in particular the development of an emerging global biofuels network (Mol, 2007), are an important means of understanding the emergence of controversies around production of biofuel feedstocks and fuels.

Work by Mol (2007), van der Horst and Vermeylen (2011) and Raman and Mohr (2014) have drawn attention to the role of scale and space within biofuel controversies. As Raman and Mohr (2014) note, the spatial scales across which biofuel industries have developed have impacted on whether biofuels have historically been more or less controversial. Of particular contemporary concern has been the concentration of these negative impacts upon more vulnerable populations within South America, South East Asia and parts of Africa to meet the climate change and energy objectives of countries in the global North. In

contrast localised or nationally contained biofuel production and consumption systems have faced significantly less controversy and exposure (Mol, 2007). A major aspect of the food versus fuel controversy as exhibited by figure 1 has been how the spatial scale of production is perceived to shift the benefits and burdens unjustly towards populations in the global south. In essence, biofuels are framed as reinforcing exploitative relationships in which the affluent states in the global north are able to effectively outsource the negative externalities of realising their domestic biofuel polices. This is exacerbated by weak social and environmental governance that 'attracts' investments to the global south (van der Horst & Vermeylen, 2011).

Weak governance and the demands for agricultural produce triggered by expanding biofuel production have also been linked to a wave of land grabs which have overwhelmingly impacted on marginalised and vulnerable populations in the global South (Cotula, 2009; Von Braun & Meinzen-Dick, 2009). Indigenous and local peoples have been cleared from lands upon which they have lived for generations and depend upon for their livelihoods (Nuffield Council on Bioethics, 2011). Often major investments in land in the global south are framed as making under-utilised, marginal or idle land productive (Borras and Franco, 2010). However, the reality can be quite different with 'idle' and 'wastelands' providing key common resources for the marginalised and poor. For instance Dauvergne & Neville (2010, p. 631) argue that the emergence of biofuel production has further reinforced historical processes that have sought to wrest the control of common lands and resources from people and communities with insecure land rights.

Food versus fuel and its spatial element has not been the only controversy that has had implications for lignocellulosic biofuels. Land use change, has been at the heart of a number of other controversies, albeit with different characteristics and emphasis. Most notably, indirect land use change.

2.3.3 Indirect Land Use Change

Contestation over accounting for land use change has been a high profile issue that emerged out of EU policy makers' efforts to narrow the terms of biofuel

sustainability debate to that of carbon savings (Palmer, 2012). This technical debate primarily focused on the contestation of actual carbon savings once direct (dLUC) and indirect land use change (iLUC) have been accounted for. Both types of land use change are considered problematic; potentially increasing carbon emissions due to destruction of carbon rich habitats as well as diminishing bio-diverse areas (Fargione et al, 2008; RFA, 2008; Searchinger et al, 2008; Bringezu et al, 2009; Börjesson & Tufvesson, 2011). However dLUC is seen as methodologically accountable whilst iLUC faces methodological uncertainty when quantifying its impacts (RFA, 2008; Cherubini et al, 2009; Börjesson & Tufvesson, 2011, Gawel & Ludwig, 2011). This uncertainty has persisted and continues to undermine claims that biofuels constitute a genuine alternative low carbon technology, with several commentators suggesting that certain biofuels are far worse than fossil fuels (see Pimentel, et al., 2009; Searchinger et al, 2008).

The academic and practitioner literature on iLUC deals principally with the methodological tensions that arise from iLUC within carbon accounting practices (see Fargione et al, 2008; RFA, 2008; Searchinger et al, 2008; Bringezu et al, 2009; Börjesson & Tufvesson, 2011; McManus, et al., 2015). The literature proposes various means of reconciling the tensions of providing an accurate appraisal of carbon emission for a particular biofuel with attempting to measure an ambiguous and intangible indirect outcome. Further to this, social science literature has focused on how iLUC came to be the field of battle which now dominates contestation of biofuel policies. Work by Palmer (2012) investigates the internal processes within the EU that led to these developments. Palmer details how the EU successfully narrowed the terms of sustainability discussions to carbon as a means of closing down avenues of controversy. Ironically this effort to close down contestation through a turn towards 'getting the carbon emissions right' (Palmer, 2012) amplified iLUC in the context of a debate that centres entirely on ensuring that measurement of emissions is accurate.

In 2012 the EC proposed the development of iLUC factors. Each crop group would be allocated a factor estimating the land use change emissions taking place globally due to biofuel production (EC, 2012). Contesting the accuracy of these factors has been a rich battle ground, acting as a proxy for wider conflicts

over the EU's continued support for biofuels (Levidow, 2013). However, to date iLUC factors have remained effectively toothless. Intense lobbying from biofuel industry interests successfully demoted them from a binding to reporting status (Kretschmer & Baldock, 2013) . However, lignocellulosic technologies, described a low-iLUC biofuels, have been incentivised by double counting energy content (e.g. a double subsidy) (EC, 2012) as a means of encouraging development and emergence of these technologies.

In summary the result of these controversies has been a call for the abandonment of biofuel targets and promoting policies. However, despite these strong criticisms the biofuels the agenda has largely remained intact although amended. Central to this achievement has been the narrowing of the issues within the public debate. With food prices subsiding since the highs of 2007-2008 the focus has become about carbon emissions (Palmer, 2012) the sustainability concern that is deemed to be addressable though technical or engineering solutions (Levidow, 2013). The issue of sustainability has been framed around issues of carbon emissions and steering land use change away from biodiverse and carbon rich habitats. Into this gap lignocellulosic technologies, so-called second generation biofuels, have been slotted as a desirable and achievable technical project that fulfils the original promises of biofuels without the negative shortcomings of first generation biofuels.

The *Renewable Energy Directive* (EU, 2009) began this shift. The directive sought to incorporate a now mandatory target of 10% share of biofuels in transport fuel for 2020, with a number of sustainability criteria. Only biofuels and bioliquids that complied with the following criteria, irrespective of whether the raw material was cultivated inside or outside the union, would receive government support:

- Greenhouse gas emission savings from the use of biofuels shall be at least 35%,
    - Rising to 50% by 1st January 2017 for existing installations
    - Rising to 60% for installations commissioned after 1st January 2017

- Raw material will not be sourced from the following land
    - Land with high biodiversity value – E.g. primary forest
    - Land with high carbon stock – E.g. peatland

These compulsory criteria were joined by a requirement to report every two years on the 'availability of foodstuffs at affordable prices' (EC 2009: L 140/38). One of the means of demonstrating compliance with these criteria has been through participation in voluntary certification schemes. A marketplace of 19 certification schemes (EC, 2015) has been created both extending the reach of EU governance measures into the plantations and processing facilities outside of the EU, whilst also creating a marketplace of schemes to allow 'consumer' choice. The successes and shortcomings of certification has therefore become another site of academic analysis.

2.4 **Responding to iLUC**

2.4.1 Certification

Governance and biofuel certification has become a rich topic for scholarly attention. Literature on certification and governance has interrogated a wide range of issues relating to how biofuel certification represents an emerging mode of global governance (Fortin & Richardson, 2013; Schleifer, 2013), extending EU governance reach along this specific resource supply chain (Di Lucia, 2010), and has stimulated discussion of future of standards and standardisation (Kaphengst, et al., 2009). Additionally the legitimacy of biofuel certification has been questioned (Partzsch, 2011; Upham, et al., 2011), whereas the interaction of EU certification with local contexts has highlighted the weak social component to such schemes (Hunsberger, et al., 2014; Tomei, 2015).

The majority of the certification literature is sceptical of the ability of such schemes to deliver sustainable biofuel production. Components of this are connected to the issue of iLUC as the measurement of carbon emissions is predicated on accounting methodologies that struggle to quantify this issue. However, much critique relates to the handling of social sustainability, its limited scope in some schemes, absence in others and poor coverage of critical issues

(German & Schoneveld, 2012). For instance, Tomei (2015), in the case of Guatemala, details the ways in which sustainability criteria effectively rubberstamp problematic practices due to the way in which generic certification schemata fail to engage with diverse contexts. The International Sustainability and Carbon Certification scheme used by biofuel producers in Guatemala, a country which has never undergone land reform, is a prime example. The majority of subsistence farmers are trapped in unstable rental agreements with the landowning elite. A major consequence of biofuel production in Guatemala was increased demand for land for sugarcane. Renting subsistence farmers had been displaced in favour of more lucrative agreements with sugar mills, damaging rural livelihoods and forcing many former farmers to become labours on the plantations that had displaced them (Tomei, 2015).

Further to this have been questions over whether certification is able to effectively grapple with the environmental impacts eschewing from biofuel production. The narrow framing of environmental sustainability in the RED, limited only to preventing expansion into biodiverse and carbon rich habitats and ensuring a certain level of carbon savings, has neglected the important contribution of agricultural practices to the outcomes associated with biofuel production. A major consequence of the boom in biofuel production is agricultural expansion and intensification (Naylor, et al., 2007; Banse, et al., 2008; FAO, 2008). Although some policy literature has acknowledged the contribution of intensive agricultural practices to biodiversity loss, soil erosion, eutrophication due to nutrient run off, and increased water stress (FAO, 2008; UNESCO, et al., 2009), it has been limited and largely unaddressed conponenet of the controversy

The reason for touching on this literature is twofold. Certification and its critique remain orientated in the unjust distribution of negative externalities to the global south. Meanwhile it pays significantly less attention to the global north as a space of production and the way in which biofuel production interacts with, is shaped by and shapes agricultural systems in these places. On the other hand, the literature points to the way in which biofuel production infrastructures interact with agricultural systems in different ways due to the heterogeneity of

local contexts. The consequence of this interaction influences how and in what ways a biofuel production system emerges and what implications this may have. A key point of critique of certification is how it has been unable to grapple with this heterogeneity effectively, therefore rubberstamping unequitable practices in certain instances. It is this interaction, in the context of the UK and lignocellulosic technologies that this thesis is concerned, although I make no claims about the potential for positive or negative implications of this emergence, focusing instead on the cohesion and disjunction between certain expectations and present realities. In addition with the social implications of biofuels gaining significant attention and being a major cause for concern, certification and its weak ability to address social concerns, has only gone so far towards closing biofuel controversies. Lignocellulosic biofuels have therefore remained an important future orientated aspect of fulfilling the promises of a biofuel future whilst certification grapples with the present.

2.4.2 Lignocellulosic Biofuels

A rapid fall from grace for first generation biofuels changed the baseline context within which lignocellulosic technologies were being imagined. Since 2007 these advanced technologies became enrolled in the engineering response to the problems of first generation biofuels (RFA, 2008). This has been a key factor in attempting to dissipate the controversy and shift the focus onto the promise of the next generation of fuels rather than the current reality (Boucher, 2012).

The use of non-food material is particularly attractive as it is claimed this allows second generation biofuels to overcome the damaging food security and food competition concerns (Larson, 2008) whilst allowing conversion of seemingly abundant material in to liquid fuel (Gomez et al, 2006). This is in addition to the claims that they offer considerable improvements with regards to sustainability and land use (DEFRA, 2007), carbon emissions and energy balance over first generation fuels (Larson, 2008) and are more ethically acceptable (Nuffield Council on Bioethics, 2011).

The Gallagher Review of the indirect effects of biofuels production (RFA, 2008) has been particularly influential in cementing this new framing of lignocellulosic

technologies as a means of responding to the concerns expressed about first generation technologies. It's consciousness of indirect land use change resulted in a proposal to hasten the adoption of advanced technologies using feedstocks such as dedicated energy crops grown on marginal land, non-food wastes and residues as a means of deriving sustainable future biofuels.

Marginal land is of particular importance here. Prior to this point marginal land was deemed potentially unsuitable to the objectives of biomass production due to the risk of low yield (RCEP, 2004) or not mentioned at all in policy. Now marginal land was framed as an untapped, unused and/or underused resource for dedicated lignocellulosic crops. In the process cultivation would create new opportunities and dodge more problematic forms of land use change associated with first generation feedstocks grown on prime agricultural land. Through using crops grown on marginal land, and residues and wastes, lignocellulosic technologies, have been framed in policy as representing a set of low-iLUC biofuels (EC, 2012). Although, it is important to note that the Gallagher Review is cautious in its assessment of lignocellulosic technologies offering a sustainable pathway. The cultivation of dedicated energy crops still requires land and therefore the prospect of land use change is ever present.

Marginal land was a particularly strong narrative in the 2009 Renewable Energy Strategy (HM Government, 2009i). Although it had diminished in importance by the 2012 Bioenergy Strategy (DECC, et al., 2012) it has persisted in the wider discussion about lignocellulosic biomass production as a key aspect of the supposed sustainability of the crops.

A consequence of the spatial component has been an effort to re-focus lignocellulosic biofuel supply chains around domestic spaces of feedstock production. Although imports will remain an important source of biomass feedstocks this is perceived as balanced by a UK industry supplied by domestic feedstock production. DEFRA has been a keen purveyor of this vision, arguing that it offered the best means of delivering energy security and rural development opportunities whilst competition delivers good value (House of Commons, 2003; House of Lords, 2006). Furthermore, imports of biomass are

expected to decline in volume due to increased competition as international demand for biomass increases (DECC, et al., 2012). Over the long term the national supply chain is therefore placed in an important position, providing a stable resource upon which these future industries can be sustained (DECC, et al., 2012). Such a domestic turn will require the manifestation of certain infrastructures of biomass production, which have so far been lacking and a contributory factor to the movement of biofuel production into alternative spaces outside the EU. The development of a domestic supply chain is currently linked to expectations around dedicated energy crop expansion, and exploiting surpluses in agricultural residues such as straw (see DECC, et al., 2012). This thesis examines the prospects for realising such a UK supply chain.

Implicit in this framing of certain crops grown on certain land and in certain places as more sustainable is acknowledgement that the production of biomass feedstocks has been at the core of controversies. Yet policy and academic literature has consistently not engaged with agricultural practice as a site of controversy, governance or policy making.

2.5 The Agricultural Connection

2.5.1 The Agricultural Absence

Agricultural practice has been consistently absent from the framing of biofuel as a technology, within controversies and the subsequent policy responses. An important aspect of this is that EU policy began by situating biofuels principally as a low carbon energy technology (EC, 2000ii; EU, 2003) and this has continued. Governance of biofuels started by addressing the need for the end product – the biofuel – without any provision specifying favoured feedstock, cultivation practices or place of production. In the UK the RTFO is the only mechanism governing biofuel production, overseen by the Department for Transport and with no agricultural equivalent. In response to emerging controversies, policy has aimed to govern biofuels as a low carbon and energy technology not as an agricultural technology.

When stepping back from biofuels as an end product to bring into view biofuels as the finished product of a potentially complex global supply chain the picture

changes. Agricultural supply chains are brought firmly into the field of vision highlighting how many of the controversies around biofuels are intimately linked to the agrarian political economy and practices of production within certain spaces. However, the way in which controversies have been framed has once more sought to mask this link.

For instance, food versus fuel became focused on quantifying the actual contribution of biofuels to the problem of food price rises, and an ethical debate about using food crops for fuel. In this context the solution has been to report on food price rises and their linkage to ongoing biofuel production (EU, 2009) and to limit food consuming first generation biofuels (EurActiv, 2015). The way in which food insecurity was also linked to a shift from subsistence small holding to large scale plantations was far less prominent (Tomei, 2015) and not addressed in policy responses. iLUC continued this trend, becoming a technical controversy about carbon accounting with considerably less attention given to resolving the actual instances of land use change, or the environmental and social consequences of shifting land use and intensification of agricultural practices due to adoption of plantation mono-cropping. Equally, this controversy seems to suggest that land use change is a problem inherent to biofuels, rather than being a consequence of changing patterns of agricultural production. Consequently, biofuels has been treated as separate from agricultural systems requiring its own mechanisms of governance.

Similarly, a failure to account for agricultural practice means that policy responses do nothing in instances where agricultural intensification on existing land use has been the root of environmental pollution and degradation. Indeed continued intensification in existing areas is situated as a solution to land use change (Hermann, et al., 2012; Witcover, et al., 2013). However, models of agriculture based on intensification of production have often carried repercussions for environmental health and quality of life (Chappel & LaValle, 2011; Fish, et al., 2014). Finally, the literature on spatial scale touched upon how different configurations of agricultural practice and biofuel production are controversial to varying degrees. In particular, intensive, large scale monoculture plantations have received more attention than small scale, localised systems

(Mol, 2007). This suggests that intensification is not a given route to resolving these issues.

The only arguable governance link to agriculture is through the certification criteria established in the RED which acknowledge that production in certain ways in certain places is more problematic that others. The RED included compulsory requirements with regards to carbon emissions savings and direct land use change – again linked to carbon emission concerns with a specific requirement prohibiting the cultivation of carbon rich lands – peatland and forests. Nevertheless it has no specific prescriptions for ensuring sustainable agricultural practices at the site of biomass production.

Similarly, sub-section 2.4.1 highlighted how the literature on certification has drawn attention to the ineffectiveness of this mechanism of governance when it comes into contact with diverse agrarian regimes that are at the core of the negative social and environmental problems. Nevertheless none of the literature directly engages with this component to the problem. Rather academic literature has favoured engaging with policy and critiquing the instruments of supporting and governing biofuels, rather than examining the nuances of agricultural systems, practices, and decision making that resulted in some configurations of biofuels over others becoming problematic.

Additionally, policy has been similarly circumspect in its engagement with agriculture as a site of development. Although rural development was an initial aspect of the policy rationale for biofuels, only limited and short lived connections were made to EU agricultural policy, in particular CAP. The primary example has been set-aside incentives that allowed the cultivation of set-aside for energy crops. In 2003 non-food energy crops for biofuels were allowed on set-aside land with a further special aid for energy crops (EC, 2005). Oilseed rape for biodiesel became the main feedstock grown. However, in 2009, the CAP Health Check abolished set aside (EU, 2009ii), ending this incentive. UK policy has taken a laissez faire attitude to embedding rural development. The Energy Crops Scheme promoting dedicated energy crops has been the only agricultural incentive policy linked to biofuels and bioenergy, which itself ended in 2013. In

short, policy has neglected rural development under the assumption that markets would deliver desired developments. Agricultural policy has therefore not engaged with the aims of biofuel policy in any substantive way.

Finally, as Thornley & Cooper (2008) note, the absence of agricultural considerations means that biofuels policy has acted to downplay the requirement of a considerable biomass production infrastructure. Similarly, this is a situation unchanged with a shift to second generation technologies. The following section will examine the literature that addresses questions around the prospects for developing the necessary biomass production infrastructure in the UK.

2.5.2 Agricultural Infrastructure

First generation biofuels benefitted to a certain degree from processing established agricultural commodities, wheat, maize, sugarcane, soy beans, oilseed rape, and palm oil. Conversely, second generation biofuels require farmers to adopt novel crops such as miscanthus and SRC willow (Sherrington, et al., 2008; Sherrington & Moran, 2010; DECC, et al., 2012), become commercial foresters of existing unmanaged woodland or new plantations (Forestry Commission, 2007) or be willing to make available straw and other residues for energy purposes (Copeland & Turley, 2008; Glithero, et al., 2013i; 2013ii). As noted in Chapter One, policy has engaged with this aspect of biofuel emergence through modelling farmer decision making. The requisite agricultural infrastructure is assumed to materialise off the back of upstream market incentives, creating impetus for rational market actors to respond. Given that examining these models, their embedded assumptions and expectations, is an important part of the analysis in Chapters Five through Eight, I will focus instead on the small body of existing literature that has engaged directly with UK farmers to assess the prospects for building a biomass production chain (Mattison & Norris, 2007; Sherrington, et al., 2008; Convery, et al., 2012; Tate, et al., 2012; Glithero, et al., 2013i; Glithero, et al., 2013ii). This literature covers the adoption of energy crops, in particular miscanthus and SRC willow, and residues such as straw.

All studies use questionnaires or focus groups as a means of assessing farmer's attitudes and intentions towards growing or supply biomass feedstocks. Only Mattison & Norris (2007) investigated farmer's intentions towards growing first generation crops (sugar beet and oilseed rape) in the UK. Their main findings were that farmers who did not already grow the crops were most unwilling to adopt them and sell for biofuels and, conversely, those already growing one or both these crops were most willing to sell for biofuels. Although not touched upon by Mattison & Norris (2007), this unwillingness to adopt unfamiliar crops, even ones that are well established in the UK crop mix, points to a potentially challenging picture for novel dedicated energy crops that are agronomically very different and have no proven market.

Convery et al. (2012), Sherrington et al. (2008), and Tate et al. (2012) document this challenge. These studies noted that financial returns were the major deciding factor in decisions to adopt these crops. Perceptions of risk and uncertainty around market security, market direction and level of returns against traditional uses were key determining factors in limiting the deployment of dedicated energy crops such as SRC willow and miscanthus (Sherrington, et al., 2008; Convery, et al., 2012). Equally given the recent high prices of wheat and oilseed rape traditional annual crops remained very attractive in comparison to an uncertain future for miscanthus (Sherrington et al, 2008). Similarly, in the context of straw, Glithero et al. (2013i; 2013ii) couch their investigation in terms of economic and contractual factors that would facilitate the sale of straw. All articles note that the success or failure of energy crops will be determined by their economic viability and the wider market.

However, Convey et al (2012) nuances this assertion noting that farmers are interested in profit sufficiency over profit maximisation. Therefore, where existing and entrenched practices are sufficient to sustain the farm and their lifestyles, there was no pressing need to adopt new enterprises. This suggests that farmer decision making does not start and end with the bottom line but is influenced by a broader range of considerations and values.

Likewise, the literature points to the importance of existing practices in shaping the perception of renewable technologies more broadly. For instance Tate et al. (2012), when comparing dedicated energy crops against other renewable technologies, for example wind, solar, and AD, noted that dedicated energy crops fared poorly, in part due to the perception that they did not find easy synergies with existing business. Furthermore, dairy farmers were particularly resistant to energy crops in comparison to arable farmers but Tate et al. (2012) did not explore why. This chimes with the findings of Adams et al. (2011) who highlighted the conflict between energy crops and other more flexible investments. Existing farm practices have inertia that shapes what is possible and how easy it is to integrate a new set of technologies and practices into an individual farm. In addition, the ease with which different technologies such as energy crops, can be incorporated into an individual business is influenced by the dominant enterprise. Despite this, none of the literature interrogates on farm practices as influencing the process of embedding new technologies.

None of this literature engages with farming culture or identity to any significant degree and how these factors influence farmer decision making with regards to new crops. This separates it from a larger body of scholarship that has examined farmer attitudes and responses to government regimes, in particular agri-environmental schemes. Academics such as Rob Burton and Geoff Wilson (Wilson, 1996; Wilson, 1997; Wilson & Hart, 2000; Wilson & Hart, 2001; Wilson, 2001; Burton, 2004; Burton & Wilson, 2006; Burton, et al., 2008; Burton, et al., 2011; Burton, 2012) for instance have highlighted the powerful cultural, symbolic, identity and behavioural factors woven through the dominant ways of 'doing' agriculture which can be, and are challenged by the pressure to adopt new systems of practices. How these influence the adoption of practices and technologies related to facilitating the domestic production of lignocellulosic technologies has not been explored and therefore an important gap addressed by this thesis.

The actors examined by this body of work are similarly narrow with farmers being the primary actors examined in these studies. Only the work of Adams & Lindegaard (2016) has engaged explicitly with the role of policy and industry in

the emergence of dedicated energy crops. In particular, they highlight the major policy shortcomings which they characterise as being ineffective in stimulating a stable energy crop sector, alongside repeated industrial failures, which have cast a long shadow over more recent efforts to stimulate the market by firms such as Terravesta (Adams & Lindegaard, 2016). Therefore the problem with energy crops is not sitauated in a single 'place' in the supply chain but a consequence of multiple failings with regards to realising large scale planting of the crops. Adams & Lindegaard (2016) highlight the need to examine industry expectations, confidence and stability when examining the prospects for future lignocellulosic biomass supply chains.

Finally, although agronomists (Mattison & Norris, 2009) and contractors (Convery, et al., 2012; Sherrington, et al., 2008) were mentioned as influencing farmer decision and interest in the crops, these actor groups were not part of the research. Only farmers are questioned. The broader literature however identifies agronomists as important and influential actors, liaising closely with farmers and providing a range of advice in an increasingly complex and fragmented field of agricultural advice (see Ingram, 2008; Ingram & Morris 2008; Klerkx & Proctor, 2013; Sutherland, et al., 2013 on farm advisory services). On the other hand contractors and merchants are acknowledged as important but they are barely documented as a group (Ball, 1987). As such this study broadens in its empirical analysis beyond farmers, and industry to include other important intermedairy actors that have been signposted as influential but not been the focus of any existing research.

The review of this literature identifies two important gaps that this thesis contributes to filling. Firstly, biofuels literature and policy has largely neglected the processes and prospects for embedding agricultural production and supply infrastructures that are crucial to delivering socio-technical change and feeding lignocellulosic biofuel processing infrastructure. Instead the focus has been on the supposed ease with which biofuels and petroleum infrastructure can be integrated. The study therefore addresses these gaps by directly examining the prospects for developing the necessary supply chain infrastructure if the UK is to develop a substantial domestic capacity to produce lignocellulosic biofuels.

Secondly, the research that does cover the embedding of dedicated energy crops within the crop mix and sale of straw for energy has neglected important actor groups that influence the development of these systems. Despite being signposted, agronomists and contractors have not been the focus of any of the existing research into energy crops or agricultural residues for energy. This study addresses this gap by examining the perspectives and perceptions of merchants, contractors and agronomists, situating the findings from farmers and producers within a broader network of important supply chain actors that maintain biomass supply chains and influence on farm decisions.

2.6 **Conclusion**

This chapter has detailed the development of biofuels from 2000 onwards, the various controversies and contestations, and their impact on lignocellulosic technologies. The chapter began by outlining the policy rationale of climate change mitigation, energy security and rural development that was used to justify state support for biofuels. In this original conception lignocellulosic technologies were positioned as a more efficient future technology which would expand the array of biomass material able to be processed into liquid fuel. However, this vision has shifted in response to food versus fuel and iLUC controversies and the problematic spatial scales of production and consumption that have come to define the dominant first generation regime.

The response has been to positioned lignocellulosic technologies as a direct solution to first generation problems. These technologies are now positioned as being able to consume greater domestic material therefore returning biofuels to national spaces of production and consumption, utilise non-food residues and wastes, alongside crops grown on marginal land minimising land use change, as well as being positioned as having better carbon credentials. Lignocellulosic technologies have similarly seen this position cemented in policy support. The RED for instance set minimum carbon saving threshold for new biofuels, creating space for the more carbon efficient lignocellulosic technologies. In addition, EU policy has capped the use of food-based biofuels to 7% by energy content, 3% short of the 10% 2020 target, meaning that lignocellulosic technologies are

required if biofuel blending is to move beyond this target ceiling and if they are to contribute to meeting 2020 targets for renewable energy.

Finally, this chapter has highlighted the absence of analysis of biofuels as an agricultural problem. The policy and academic literature has consistently treated biofuels as a low carbon energy technology not as an agricultural technology. Thus agricultural practices and systems have been backgrounded within the discussion and policy response. Similarly, limited attention has been given to the necessity of building agricultural infrastructure for lignocellulosic technologies. Policy has once more created overarching incentives and provided research funds, but not linked to agricultural prescriptions. A review of the literature on the prospect for building agricultural supply chains for lignocellulosic technologies highlights how currently farmers show limited interested in the crops from an economic perspective.

However, the review of this limited literature identified two key research gaps. Firstly, the need to examine the wider cultural, technological, practice, and decision making influences that impact on farmer adoption of biomass production. Secondly, farmers are not the only important actors. Intermediary actors such as agronomists and contractors, alongside industry actors were signposted as important in influencing farmer decisions but no work had interrogated their role closely in this context. Therefore this review of literature identified two gaps towards which this study contributes in the existing literature whilst, justifying the focus on lignocellulosic technologies in light of a changing landscape that has made them increasingly important in taking forward biofuel developments.

3 Imagining Futures: Creating Realities

3.1 Introduction

This chapter's purpose is to review the socio-technical imaginaries literature, detailing its main conceptual areas, and its relation to other work on the future and imagination, as well as work on biofuels. The chapter is structured as follows. Section 3.2 highlights the trend away from looking into the future to looking at the future, situating socio-technical imaginaries in this body of work. It will then move on to examine the literature on imagination more generally, highlighting the central importance of science and technology and its advancement and adoption as an important distinction between the broader literature on imaginaries and socio-technical imaginaries. Section 3.3 will then begin to unpack socio-technical imaginaries as a concept highlighting three areas of recurrent emphasis within the imaginaries literature identified and expanded upon by Jasanoff (2015ii): origins, embedding, and resistance, before examining the limitations of the concept. Each sub-section includes a review of the relevant literature, identifying any gaps that are addressed by this study, before moving to examine the biofuels literature correlating to each section. The purpose of this is to situate this study within the relevant bodies of biofuel and imaginaries literature, highlighting the relevant research contributions to each.

3.2 Imagination and the Future

3.2.1 Looking at the Future

Emerging STS scholarship has engaged with the future as an object of empirical scrutiny shifting the emphasis from looking into the future to looking *at* the future. No longer perceived as a neutral temporal space (Brown & Michael, 2003), the future is an important resource forming a crucial part in social and political life (Jasanoff & Kim, 2009), contested as an object of social and material action (Brown, et al., 2000). Future orientated imagination takes on new importance when certain types of imagination are distinguished from fantasy

and illusion and recognised as having performative power, projecting positive goals and mobilising efforts to attain them (van Lente, 2012). Key to this power is the belief by policy makers and the public that pursuit and operationalisation of science and technology creates societal benefits (Sarewitz, 1996). Through this belief the future is mobilised in numerous ways. Most relevant here are the ways in which visions of the future accompany new and emergent technologies.

The development of science and technology has long been associated with expectations that they would change the future of society. New technologies inspire "lyrical utopianism and melancholy catastrophism" (Tenner, 2001, p. 241). Emerging technologies are no different, with much interest from policy makers due to the perception that they offer opportunities to change the status quo (Cozzens, et al., 2010; Alexander, et al., 2012), in the process unlocking new markets, competitive advantages and also beneficial societal and environmental outcomes. However, these are technologies that are not as yet fully realised. Subsequently, their impact is at present promissory and uncertain (Martin, et al., 2008). With the language of emergence placing emphasis on the 'process' of coming into prominence or being (Rotolo, et al., 2015), emerging technologies require active management and anticipatory governance, with the assumption being that their formative status means management is still possible (Guston, 2008; Guston, 2010).

Technology is not the sole determining factor in changing the future. Looking *at* the future does not endorse a technologically determinist account of socio-technical change. Society adopts, rejects, uses and modifies technologies often beyond the expectations of the innovators (Selin, 2008). Supportive policy regimes and emerging technological artefacts encounter practices of use, evolving and emerging needs, and existing infrastructures. The intricacies of this social shaping of technology influences the way that emerging technological developments advance, possibly producing unpredicted opportunities and risks, failing to deliver on original expectations, and taking different directions of development that maybe slower or faster than imagined (Geels & Smit, 2000).

The importance of future imagination in this respect is twofold. Firstly, projecting positive future visions creates the impetus to realise said future, creating spaces in which to marshal resources, coordinate activities and manage uncertainty (Brown & Michael, 2003) or derail those efforts. Through these efforts, emergent technologies can intervene in present realities, subsequently shaping future realities (Selin, 2008). Secondly, the projection of positive technological visions produces certain expectations and promises that prescribe a future that ought to be attained (Jasanoff & Kim, 2009). In turn this creates demands regarding performance and the management of uncertainties which attempt to render technological developments into specific dynamics (van Lente, 2000; Guston, 2014). The future, its contestation and the policies built around realising certain visions of it, has the power to influence technological design (Jasanoff & Kim, 2009). Processes of innovation are not isolated from the dynamic process of understanding and imagining the future (Borup, et al., 2006). Articulating visions of the future is important in shaping specific novel technologies, and through this, the emergence of the future.

3.2.2 Imagining the Future

Imagining the future is no simple task, requiring the connection of new and emerging technologies to a long term vision of radically changed future socio-technical systems, and a technology fundamentally transformed from its current material form. A key difficulty is the tendency to imagine the future as a fancier version of the present (Marvin, 1990). Although Marvin is discussing imagination in general, the computer provides an apt example of this blinkering.

The first computers were large assemblages of unreliable components, costly to build, cumbersome in size, and requiring skilled mathematicians to write the code that enabled them to function. Despite incremental developments improving the speed at which the machines could compute individual calculations, computing power became limited by the availability of trained mathematicians to write the code (Ceruzzi, 1986). The dawn of computer development was embedded in meeting and responding to the emerging needs of military and scientific communities which were the initial consumers of these products. These early pioneers struggled to imagine the computer outside of

these narrow initial roles as unwieldy and expensive machines requiring numerous skilled operators and continued to shape the computer to respond to this narrow range of applications (Ceruzzi, 1986). In 1953 Thomas Watson Jr. launched the IBM 701, the company's first commercial scientific computer with the expectation that there were globally around 20 potential customers and around five would place orders (IBM, 2007)[5]. However, this inherently conservative vision is also a means of managing technologies into societally 'acceptable' forms of use. This enables actors to head off challenges to technologies that are potentially disruptive to social-cultural-economic boundaries and relations. As such the wider transformative capacity of the technology was often overlooked whilst it remained cumbersome, labour intensive and expensive (Ceruzzi, 1986) and expectations of its broader utility were slow to manifest.

This story of computers speaks not just to the literature on imagination but also on transitions. The multi-level perspective (MLP) (Geels, 2002) and the associated strategic niche management (SNM) approach (Schot & Geels, 2008), provide a framework for examining transition through distinguishing three levels. The micro-level niche is nested within and interacts with a patchwork of meso-level regimes and macro-level landscape of developments to form a socio-technical system (Geels, 2002).

Innovations are posited as beginning in a development niche. The niche works as an 'incubation room' (Geels & Schot, 2007) in which radical new technologies can be tested, developed, nurtured, and buffered from mainstream market competition (Hoogma, et al., 2002). However, to achieve success they need to emerge into the regime, characterised as a patchwork of various interdependent regimes (science, policy, culture, market). The patchwork of regimes is characterised by the dynamic co-ordination and stabilisation of different social

[5] This is widely believed to be the root of the (false) quote attributed to Thomas Watson Sr in 1943 and Thomas Watson Jr in the 1950s that there was a world market for around five computers. The IBM 701 initially placed 18 orders (IBM, 2007).

groups through lock-in and path dependency that accounts for the relative stability of existing socio-technical systems (Geels, 2005; Geels, 2010). In turn the regime is influenced by landscape factors such as fluctuations in economic growth, changes in dominant political narratives and environmental problems, as well as pre-existing material and spatial externalities such as transport, industrial and urban infrastructures (Geels, 2002). This wider landscape is largely, but not entirely, beyond the control of niche and regime actors.

However, the MLP presents a largely linear and functional framework of innovation success. Innovations are nurtured in the niche before their emergence into a regime that, perhaps with the help of landscape factors, begins to change socio-technical systems. More recent work has aimed to address the emphasis on determinism and structural forces (see Geels, 2014). Nevertheless it still points to the resistance of the regime to change in the face of innovations (Geels, 2014). Similarly, the focus on the niche as the hotbed for innovation and principal site from which change emerges is problematic in the context of this study which does not examine the research niche for lignocellulosic technologies. This work focuses on what is considered the regime in the MLP.

The concept of a patchwork of regimes creates considerable ambiguity about what aspect of the regime is the principal level of analysis for examining socio-technical change (Berkhout, et al., 2004). Using biofuels as an example, what may appear to be more fundamental change at the level of primary fuel production is relegated to incremental change that has no significant impact if viewed from the wider transportation regime. Finally, previous work has considered deeper historical timeframes, drawing on primary and secondary historical information with far less work examining present emergent change. As such a purely socio-technical transitions approach was unsuitable.

However, the story of the computer is not just one of socio-technical transition but also one of expectations making. In contrast to what were the fairly circumspect expectations surrounding the computer, the abundance of future expectations for contemporary emerging technologies has seen them become a site of analysis in and of themselves. Work in the sociology of expectations (for

example, Brown, et al., 2000; Brown & Michael, 2003; Borup, et al., 2006) is diverse in origin and intent. Despite this, an important aim of the sociology of expectations is to combine analytical insights from looking at the future with assessments and exercises that look into the future, e.g. foresight, roadmapping, backcasting (Borup, et al., 2006, p. 296). This literature focuses on a broad range of issues. This includes: how future expectations are utilised by scientists and research communities to attract "allies" (Borup, et al., 2006, p. 289), how expectations create relationships of "promise and requirement" (van Lente, 2000) and the consequences of this going sour, the historical uneveness of expectations in the face of changing landscape of societal, political and technological developments (Koch, 2006), the importance of space and place, how expectations are used as a means of creating a commercial space in the present for future technologies (Brown & Kraft, 2006) and how different expectations and visions around a certain technology compete (Eames, et al., 2006). The focus of this work is often on innovations at a highly embroyonic stage of development, focusing on the apperatus of research and innovation rather than wider socio-technical systems that may impact on this or actors involved in vision making. A major intent of this body of literature is to provide insights into how expectations can be evaluated on the basis of empirical analysis of past and emerging experiences. However, the sociology of expectations has a narrow scope and language that has limited applicability to a study that encompasses wider supply chain considerations.

In contrast, the body of literature associated with examining imaginaries has examined a large array of contexts. A consistent theme across this body of work is that of a shared imaginary tying together groups both large and small. On the larger end of the scale imaginaries are situated as being the glue that binds together diverse and disparate groups in the context of global environmental activism (Jasanoff, 2004) or the nation state (Anderson, 2006 [1983]). At the other end imaginaries also emerge from smaller groups of scientists (Fortun & Fortun, 2005), government institutions (Marris, 2015) or corporations (Smith, 2015) shaping how they respond to real and imagined threats and/or socio-technical change.

Before considering the literature on socio-technical imaginaries per se, I will begin with the work on social imaginaries that situates them as the mechanism at the heart of drawing together communities in imagining enrollment in a common endeavour, or collective. Empirically this work contains a broad historical and theoretical examination of why at certain times any one society (although with an emphasis on the west) exhibits a particular dominant moral and material order. This literature serves to question what underpins and ties together these collective societal forms and practices.

Work by Anderson's *Imagined Communities* (2006 [1983]), Castoriadis's (1998 [1975]) *Imaginary Institution of Society*, or Taylor's *Modern Social Imaginaries* (Taylor, 2002; 2004) explores the imaginaries at the centre of these collective forms and practices. For Anderson this collective is the nation state. His work frees the nation from its ties to a physical land and borders and instead conceptualises it as a collective imaginary of membership facilitated by technologies that give a sense of shared experience and identity. The newspaper is prominent in enabling this shared imaginary but also other practices such as the census and the museum.

Whereas Anderson's imaginaries are more explicitly tied to the nation state both Taylor and Castoriadis articulate imaginaries as something more abstract. For Castoriadis the imaginary describes the ways in which societies construct mythologies around dominant social orders and means of production, such as western capitalism. Emergent from a socio-historical nexus of forms, figures and images, imaginaries project a cultural ethos that produces, normalises and reinforces certain forms of social organisation, institutions and behaviour. They "are like the final articulations the society in question has imposed on the world, on itself, and on its needs" (Castoriadis, 1998 [1975], p. 91). Similarly, in his exploration of the institutions and structures of western modernity Taylor comes to a similar definition. Imaginaries are the 'common sense' and shared understandings that underpin the moral and material forms of western modernity and its institutions (Taylor, 2002). What societal ends are desirable and legitimate (e.g. free markets) to pursue are the products of the imaginary.

In these accounts of social imaginaries, the role of technology and technological change is largely neglected. However, this body of work has shaped the conception of socio-technical imaginaries outlined by Jasanoff & Kim (2009). Socio-technical imaginaries are similarly positioned as shared and collective undertakings that underpin understandings of what is a good and desirable outcome for any society to pursue through techno-scientific innovation. However, technology is situated at the heart of these undertakings. In contrast the changing technologies of printing are absent in Anderson's work, despite the importance of newsprint in sustaining and producing the imagined political community of the nation. Taylor gives even shorter shrift for science and technology, noting them in passing as one of several factors implicated in the changing practices and instutional forms that define modernity. Castoriadis does recognise the reciprocal relation between the social, cultural and technological, pointing to disparities in investment and support between different fields of science and technology, but detailed analysis of specific technologies is absent in his work.

In contrast imaginaries have been central to other work in science and technology studies exploring the way in which scientists and institutions imagine the significance of their work, its ideal forms and the way in which others relate to its technological artefacts. Empirically this work narrows its analytical gaze to examine imaginaries in the context of specific institutions, or groups of scientists engaged in the same field. The imaginary is no longer an abstract construct tying together society at large but rather represents an institutional and professional ethos. For instance, the work of Fortun & Fortun (2005) details an imaginary of 'good science' within the minds of individual scientists involved in the field of toxicology. This imaginary has emerged in the context of new technologies for identifying toxicity which has created conditions within which new "modes and products of sense making come together" (p. 44). This imaginary of good science incorporates how scientists pursue their work in relation to meeting the imagined and real needs of civic society, what ethical concerns and care are worthy of attention, and what technologies and practices are required to conduct 'good science' (Fortun & Fortun, 2005).

Marris (2015) examines the way in which UK research and governmental institutions involved in synthetic biology envisage the public response to the technologies, detailing an imaginary of 'synbiophobia-phobia'. This fear of public fear drives institutional engagements with the public shaping its conduct and outcomes in an effort to head off the so called 'public threat' to synthetic biology applications and products (Marris, 2015). Despite their prominence in institutional narratives, the public being referenced is almost entirely a figment of these imaginations. Publics, as actual persons or organisations, are for the most part, absent and excluded from the processes of engagement and dialogue. Phobia is being projected onto the public, even when there are no grounds for such a judgement (Rip, 2006), perhaps linked to the inability of the UK state to anticipate adverse public reactions to technology in the recent past (Macnaghten & Guivant, 2011). In the work of Marris (2015) and Fortun & Fortun (2005), imaginaries are formed within a closed context of a particular institutional and professional context, that of the UK research and government institutions and US toxicology. There is limited sense that these imaginaries are finding shared collective coherence or work to enlist others in sharing the imaginary. Indeed, these are largely insular forms of imagination.

Finally, the work of imagination and imaginaries at the intersection of science, technology and politics has been incipient in Jasanoff's own work for some time. Two book chapters by Jasanoff (Jasanoff, 2001; Jasanoff, 2004) engage most explicitly with imagination. They both undertake to trace the work of the 'pale blue dot' image of earth from the Apollo 17 mission to the moon in the formation of global environmental activism. Here emergent imaginations of the globe as a self-contained, finite, and fragile whole are given visual form through this reproducible and transportable image. This helped to crystallise themes in environmental movements surrounding the 'globe' as a necessary space for action and helped bring together diverse local and national activist movements from different parts of the world. A shared imagination of the earth is therefore positioned in Jasanoff's (2001) work as setting the groundwork for global responses to the ozone hole and climate change.

In a direction more closely aligned with the socio-technical imaginaries concept the book '*Designs on Nature'* (Jasanoff, 2005) examines different policy responses to biotechnology from three nations, the USA, the UK and Germany. Although discussing different framings of biotechnology, these framings are positioned as being shaped by cultural nuances that each create different imaginative spaces from which governments are able to respond to the supposed risks and rewards of pursuing biotechnologies. This work highlights the contingency and partiality of the imaginative space that is carved out for political action in any society. However, discussion of the role of imagination in making possible certain forms of action is a secondary theme within these works rather than as the central conceptual framework around which the narrative is woven.

The socio-technical imaginaries framework concept builds on these bodies of work by examining how science and technology become enmeshed in producing and delivering collective and shared visions of a desirable future, in the process shaping techno-scientific projects, their form, function and aims (Jasanoff, 2015). The next section will examine the emerging socio-technical imaginaries literature in more detail.

3.3 **Socio-technical Imaginaries**

STS scholarship has argued for deeper appreciation of the political, moral and social choices that are encoded within technological forms (Eaton et al, 2014). Proposed by Jasanoff & Kim (2009), the socio-technical imaginaries framework builds upon the increased recognition that future orientated imagination forms a crucial part in socal and political life (ibid, p. 122). Similarly to the work of Anderson, Castoriadis and Taylor, imaginaries are group acheivements, positioned as something that expresses collectively held values and desires (Jasanoff, 2015i). This is not only the work of a single group of scientists as in Fortun & Fortun's account or government research institutions (Marris, 2015). However, it partly rejects Castoriadis's work on imaginaries as an undetermined cultural ethos, instead identifying them as far more bounded and purposeful constructs emanating from the state and other powerful actors. Not only do they encompass an expression of the opportunities for future change encoded in the design of certain technologies, but a broader understanding of 'what is a

desirable future', and 'what ought to be attained' through investment in science and technology (Jasanoff & Kim, 2009; 2013; Jasanoff, 2015i).

Socio-technical imaginaries are not just constructs tying people together nor do they simply shape ways of doing. Instead they are a driving force behind action being taken to realise a future with technology key to driving change. In contrast to the sociology of expectations, this is not just a vision of technical possibilities. Rather socio-technical imaginaries articulate the entanglement of broader future visions with particular forms of technology and science (Storey, 2015). Furthermore, the comparative element, central to Jasanoff's (2005) work on biotechnology and different national responses, is once more a key element of the imaginary approach. Imaginaries are positioned as being illuminated through comparison of distinct national contexts. Equally, the presence of numerous imaginaries at play within any society is acknowledged, although as we will see no work has yet effectively engaged with this component of the concept.

Jasanoff & Kim (2009) originally defined socio-technical imaginaries as "collectively imagined forms of social life and social order reflected in the design and fulfillment of nation specific scientific and/or technological projects" (p. 120). In this original incarnation, the role of the state was key in articulating and supporting imaginaries. However, the recent publication of a collection of socio-technical imaginaries work has seen this definition updated to: "collectively held, institutionally stabilized, and publically performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of advances in science and technology." (Jasanoff, 2015i, p. 4).

Clearly, both definitions share various aspects. Both place an emphasis on what is imagined as 'desirable', whilst such a emphasis recognises that imaginaries implicitly or explicity function to also illuminate the undesirable consequences that we must be ready to mitigate or manage. Included within this understanding of risks are also the lost opportunities for economic and societal good if specific trajectories are not pursued (Jasanoff, 2015i). Likewise, imaginaries retain the

need to encode collectively held values of a good future, alongside being supportive of advances in science and technology.

However, the important shift is from the 'nation specific' terminology to the 'institutionally stabilised'. A major consequence of this move has been to open up the emprical scope of the literature to comprise a wider range organisations seen as promoting specific imaginaries. This has included the World Health Organisation (Lakoff, 2015), a transnational corporation (Smith, 2015) and professional groups (Hurlbut, 2015). Similarly this has served to highlight how imaginaries do not need to be tied to large state dominated interventions and proclamations around 'big' technology, such as nuclear power (Jasanoff & Kim, 2009) or biotechnology (Kim, 2015).

Despite this broadening out in the literature the state remains a key propagater of imagined futures. Individual nation states, or comparison between nation-specific experiences are important sites and means of analysis. The world is not a single place, and despite the reach and leveling forces of globalisation, the responses from different nations in accomodating existing and emerging technological innovations are highly heterogenous (Jasanoff, 2004). Therefore, although many nations undertake similar technological trajectories, or investment in the same fields of scientific advance, cultural heterogeneity shapes outcomes between nation states in very different ways (Levidow & Papaioannou, 2013). However, neither is the state a unifed institution. As the work of Levidow & Papaioannou, (2013) and Eaton et al. (2014) have shown, the promotion of imaginaries can take place at different levels within government. In the context of the USA for instance Eaton et al. (2014) examine the role of the state government of Michegan in promoting a specific state centric imaginary for bioenergy. Levidow & Papaioannou (2013) take this a step further to examine individual government departments and research councils in the context of bioenergy technologies in the UK. Therefore, the focus on 'institutionally stabilised' aspect serves to expand the empirical scope of the socio-technical imaginary concept to include different levels within government, as well as organisations beyond the nation state.

In Chapter One, I highlighted four conceptual areas of the socio-technical imaginaries framework of particular relievance to this thesis : origins, embedding, resistance, stablity and competition. Although I will deal with them in turn these four areas of recurrent emphasis within the literature are thoroughly interlinked. I will now move on to examine these areas more thourghly, drawing out the most salient aspects for informing the analysis.

3.3.1 Origins

Imagining new worlds, prospective futures entwined with the delivery of techno-scientific projects is no simple task. Tracing the origins of socio-technical imaginary has been core a component of the literature. Bowman (2015), Dennis (2015), Jasanoff & Kim (2009; 2013), Storey (2015), and Tidwell & Smith (2015), all trace imaginary origins and in the process aim to draw attention to the formative conditions within which newly imagined futures emerge over time, how they gain traction through repeated rehearsals, and enrolment of new individuals, institutions and groups as they develop collective semblance, and become embedded through rhetorical, legislative, judicial and material actions. Attention to origins is therefore a means of situating the emergence of imaginaries to particular individuals, groups, and events, within certain periods of time.

The original work of Jasanoff & Kim (2009) outlining the socio-technical imaginaries concept, traced the genealogy of the respective imaginaries of nuclear power to the highest levels of national governments. Presidents, dictators and officials are crucial to articulating a future orientated vision that gathers collective and material purchase.

It begins in the US with important pronouncements from President Eisenhower capturing an anxious mood about the threat posed from nuclear weapons whose proliferation needed to be contained. Over time an imaginary of containment gains wider collective traction expanding to encompass the threat posed from nuclear power and waste disposal (Jasanoff & Kim, 2009). For South Korea, the origins of the 'atoms for development' imaginary are rooted in a re-envisioning of the 1956 US-South Korea Atoms for Peace initiative by the Park Chung Hee

military regime in the 1960s. State orchestrated reconstruction of the South Korean nation through the development of civilian nuclear power remained a resilient and tenacious imaginary that, unlike its USA counterpart, was not effectively appropriated to popular causes which rejected nuclear power (Jasanoff & Kim, 2009).

Storey (2015) focuses in more closely on the life and efforts of a single individual, Cecil Rhodes in the Cape Colony. In Storey's account Cecil Rhodes was the prominent individual formulating and driving the imaginary and delivering the political and material infrastructure necessary to re-shape socio-technical systems. Rhodes was no simple businessman or politician. Although the origin of the imaginary is situated firmly at Rhodes door, he was nevertheless a consummate networker, building relationships and cooperating with a whole range of influential personages involved in the judicial, political and administrative functioning of the colony, as well as the diamond mining trade. This network building was crucial ensuring that Rhodes' personal vision for the future of South Africa gained wider traction. Furthermore, Rhodes was one of the founders of the De Beers Consolidated Mining Company which continues to dominate much of the diamond trade (Storey, 2015), as well as becoming Prime Minister of the Cape Colony between 1880 and 1886, giving him power over determining the political, economic and social form of the diamond industry South Africa.

Bowman (2015) and Dennis (2015) also analyse the role of influential individuals but foreground the importance of historical developments in shaping the way in which said individuals envision the future.

Bowman (2015) examines the role of the Paul Kagame government in post genocide Rwanda as it aims to reconstruct the country, economy and machinery of the state through expanding the use of ICT technologies and computer literacy within Rwanda as a means of accessing new economic opportunities and delivering national prosperity. Although President Kagame is positioned as a key individual, the origins of the ICT imaginary are rooted firmly against the backdrop of the civil war and the fraught ethnic tensions in the aftermath of the

1994 genocide. Of particular importance is the fusion of ICT technologies with authoritarian forms of governance. The ruling Rwandan Patriotic Front party has rejected participatory democracy and modelled its future in the image of Singapore. Singapore is envisioned as an authoritarian but stable, and prosperous state with a high-tech economy based on prolific adoption of ICT technologies. This is juxtaposed against the failings of participatory democracy in Kenya, Uganda, and Iraq. By attempting to mirror this Singapore 'model' the Rwandan government aims to deliver economic growth whilst developing a bulwark against a return to civil war. Without excusing Kagame's government Bowman points to how fear of a repeat of the past powerfully shapes the ICT imaginary, its formulation and delivery.

Dennis (2015) focuses on the work of Don K. Price, an influential advisor and political scientist. Although this is a narrative detailing Price's s vision for science policy, and post-war relations between scientists, politicians and government, the pressing need to secure the USA as it emerges from a hot war into a cold one is constantly in the background shaping Prices proposed structure of cold war relations between scientists and the state. This study draws attention to the wider context within which imaginaries are made. Arming and defending the Cold War American state, ensuring national survival and staying one step ahead of the enemy was a serious business. The legacy of the nuclear bomb created a clear impetus to hitch science to the aims of the federal government and military establishment to assure more new weapons and US victory. Scientific freedom, although the topic of much of Price's writing, was not what was principally at stake for many involved (Dennis, 2015).

Finally, Felt (2015) and Hurlbut (2015) examine the origins of imaginaries in the context of singular important events, the 1978 Austrian referendum on nuclear power, and the Asilomar conference respectively, that through constant rehearsals and selective memories of their outcome, would gain considerable traction in the process of imagining political and professional communities. In both cases, the referendum and conference are framed as being tentative and indecisive events at the time. The referendum for instance was won by the no camp, rejecting nuclear power by 50.5% of the vote (Felt, 2015). It took two

decades of further referendums, acts of parliament, constitutional change, numerous public debates and the Chernobyl nuclear disaster before imagining Austria as a non-nuclear space became a stabilised as part of the Austrian imaginary. Nevertheless these events are now remembered not as tentative steps but as firm lines in the sand. By remembering the imaginary is renewed and rooted firmly in the past, projecting forth as a continuation of that legacy.

By attending to the origins of socio-technical imaginaries the literature points to several sites of analysis. Prominent individuals are important proponents of particular visions, whether within the upper-echelons of national government, politicians or advisors, businessmen and industrialists, or scientists. In each case influential individuals are positioned as being crucial articulators of future visions. Into this mix are also key events - commissions, referenda, or conferences. The common strand is the way in which a coming together of people in the context of answering a particular question, or exploring an issue has the potential to be a catalyst for imagining the world in new ways. In attending to the influence of these points of convergence, the literature both seeks to question and unpack common narratives, as well as explore the importance of memory in rehearsing particular chronologies and meaning. Finally, an attention to origins highlights the importance of past experience, whether of war (hot or cold) or genocide. Casting a long shadow, the past is a powerful shaper of imaginaries.

This study contributes to the imaginaries literature by contributing a novel empirical case in the context of biofuel imaginary origins, in particular drawing attention to their linkages with agricultural change over time and its consequences. Attention to origins necessarily draws attention to historical developments that have so far been largely overlooked within the existing biofuels literature, particular in the context of examples addressing the linkage with agricultural change over time.

Scholars that do examine this early history of ethanol production and consumption are drawn to different aspects of its discovery, emergence, success and failure as a technology. Rasmussen (2014) for example provides a detailed

account of the early history of ethanol's discovery by alchemists through rudimentary distillation of wine in the 11th and 12th century. Not used as a fuel, ethanol was instead an important medicine and solvent used by apothecaries in the Middle Ages. The use of ethanol of as a fuel appears to begin much later.

Authors such as Bernton et al. (1982), Kovarick (1998), Dimitri & Effland (2007), Carolan, (2009i; 2009ii) detail the history of ethanol fuel within the liquid fuel market with a particular focus on the early 1900s, and automotive fuel developments. Kovarik (1998) provides something of an exception analysing the importance of the ethanol-turpentine-camphor blend Camphene, produced and consumed in significant quantities for the purposes of lighting during the 1830s-1860s in the USA. However, this body of literature primarily aims to challenge the claim that petroleum's emergence and establishment as the dominant liquid fuel of the 20th century was due to some sort of natural superiority.

Ethanol was the fuel used in the development of Nicholas Otto's internal combustion engine in 1876 (Bernton, et al., 1982). Likewise the famous Model-T Ford first produced in 1908 was able to run on ethanol and ethanol-petroleum blends (Kovarik, 1998). In this early period of techno-scientific tinkering with the internal combustion engine and enquiry into the best means of fuelling it, there appears to have been a general consensus that the addition of ethanol to petrol fuels was highly favourable and improved a working engine otherwise powered solely on petrol fuel (Carolan, 2009i). Another common factor is an examination (to varying degrees) of the economic, political, innovations and social factors that resulted in leaded petroleum being established as the dominant automotive fuel over the technically favoured petroleum/alcohol blends in the 1930s and 40s. Although Carolan (2009i; 2009ii) provides something of an exception, agriculture developments are largely peripheral to these accounts.

Another body of literature examines the Chemurgy movement. The Chemurgy movement aimed to apply advances in chemistry to the development of new products from biological materials. The roots of the Chemurgy movement are found within an alliance of agricultural interests, leading chemists and

industrialists that emerged in the 1920s and 30s (Beeman, 1994; Finley, 2003). Unsurprisingly, due to these origins, the literature on the Chemurgy movement (see Giebelhaus, 1980; Wright, 1993; Beeman, 1994; Effland, 1995; Wright, 1995; Finley, 2003) deals more fully with agricultural changes and developments and their impact.

A key catalyst for the Chemurgy movement was a period of persistent agricultural crisis beginning in the 1920s and continuing into the 30s. Improved seed varieties (Carolan, 2009ii), tractors, and fertilisers (Finley, 2003), alongside agricultural expansion to meet the demand from Europe during World War I (Finley, 2003; Carolan, 2009i) had combined to produce a glut of agricultural commodities. Continued increases in agricultural efficiency, particularly mechanisation, were expected to exacerbate this issue (Wright, 1993; 1995). The Chemurgy vision re-defined this problem in the context of an imagined agriculture-chemical-industrial alliance that would produce new products and markets (Effland, 1995) consuming agricultural surplus.

Chemurgy leaders positioned the movement as an alternative, market and research led strategy to the New Deal. Indeed, in stark contrast to the New Deal, with its system of domestic allotments, and strategy of paying farmers to leave land idle, Chemurgy leaders projected a vision of continued expansion and diversification of agricultural activity to produce food, fibre and the raw materials for an expanding bio-based industry (Giebelhaus, 1980; Beeman, 1994; Wright, 1995).

Power alcohol was situated at the core of this vision as the first step technology providing a platform for other bio-based goods (Wright, 1993), in particular synthetic rubber[6] (Finley, 2003). Chemurgy articulated a synergistic socio-technical vision that imagined the interweaving of agricultural and industrial sectors. Agricultural developments and continued change were enmeshed in making practical the Chemurgy movement's biochemical aspirations.

[6] Ethanol is also used in the process of synthetic rubber production (Finley, 2003).

The review of this literature identifies two important gaps that this thesis contributes to filling. Firstly, the current historical literature suggests that past pursuits of biofuels and biochemical production also entails imagining particular forms of agricultural systems to support those endeavours. As yet the biofuels literature has not engaged deeply with how agricultural change has shaped biofuel emergence post-2000, or how imagining biofuel futures are entangled with a process of imagining agricultural futures. As noted in Chapter Two, liquid biofuels have been imagined and framed as an energy technology. This has resulted in the neglect of its entanglement with agriculture. This thesis proposes to contribute to filling this gap by tracing the origins of the dominant agricultural socio-technical imaginary that emerged in the post-war period in the UK, and its evolution over time, before examining how these developments have shaped the biofuels imaginary and developments that emerged in the early 2000s.

Secondly, the Chemurgy literature highlights the competition between the vision for agriculture that is encoded within industrial biochemistry imaginaries, and the visions for agricultural futures projected by the New Deal. It is therefore important to recognise that biofuels potentially construct a competing imaginary for agricultural futures. Particularly when we consider that lignocellulosic technologies process different biomass, require farmers to grow new crops, grown on marginal lands. Implicit in the delivery of these technologies is a different socio-technical configuration for agriculture. This thesis will therefore examine whether agri-biofuel imaginaries and agricultural imaginaries are converging or competing as we move forward in time.

However, imagined futures are not merely illusions or rhetorical devices. What gives them there power is the linkage between imagination and the expressions of power that allow imagined worlds to be made real through becoming embedded within material and social realities (Jasanoff, 2015ii).

3.3.2 Embedding

Embedding is an overarching term used to tie together the many means through which imaginaries make the move from rhetorical devices to achieving tangible change to socio-technical regimes. Often this is linked to the production and

adoption of concrete artefacts, whether they are large, nuclear power plants (Jasanoff & Kim, 2009), and mines (Storey, 2015), or minuscule, genetically modified organisms (Smith, 2015) and nanotechnologies (Burri, 2015). However, the development of physical artefacts is not the sole means of embedding imagined futures, it is also linked to the development of particular discourses and practices of governance (Jasanoff, 2015ii), as well as the development of legislation, regulation and legal instruments that create spaces within which new technologies can intervene in the world. Such acts allow imaginaries to transcend the difficult ground between the minds of individuals or small groups of dreamers, towards gaining collective assent, and being able to intervene in changing socio-technical realities. Examining the practices, processes and mechanisms of embedding the socio-technical imaginaries concept draws attention to the many partially overlapping pathways that allow imaginaries to latch onto tangible things (Jasanoff, 2015ii). Attention to embedding therefore highlights the actions and effort necessary to achieve tangible change to social life.

Not all the literature is concerned with the process of embedding. The work of Dennis (2015) and Tidwell & Smith (2015) pay such close attention to a singular text, the book *Government and Science* by Price and the US Congressional report *Resources for Freedom* respectively, that there is little room left over to explore the means through which the future visions are entrenched. These accounts are subsequently impoverished. Lacking this broader landscape they give no sense of how the vision encoded in each document is established and gains collective providence leaving the reader guessing. Therefore, exploring the processes of embedding and their consequences for structuring relations of power, facilitating certain technologies and practices, is a crucial aspect of providing a rich account utilising the socio-technical imaginaries concept.

Physical artefacts and infrastructures feature heavily in the process of embedding imaginaries. Moon (2015) for instance points to the crucial material dimension essential to realising different visions for Indonesia. Building cooperatives – houses, farms, craft industries outside of the traditional centres of colonial rule was a means of anti-Dutch, anti-colonial resistance in Indonesia.

Cooperatives were central to realising the vision of Muhammad Hatta of a civic and economic Indonesia outside of Dutch oppression and exploitation which was wrapped up in imported industries and mechanised technologies. In contrast the Indonesia of Suharto's New Order, which came to power following a coup d'état, embraced large scale, centralised industries. Massive factories providing a physical symbol of the regimes fast economic success, whilst large centralised developments allowed high ranking government officials to become passage points for those who wanted access to these new industrial activities.

Storey's (2015) account of Cecil Rhodes draws attention to the material infrastructures of mining in embedding the discriminatory and segregationist imaginary. A desire to control and secure the workforce of his mining ventures, whilst stamping out the apparently rampant illicit diamond trade, became envisioned within the context of discriminatory policies against black workers, and practices of segregation that took material form in the compound. Upon signing a six month contract workers were placed in enclosed, controlled compounds under surveillance. Black workers were compounded separately to white workers, in close quarters in which disease was rampant and conditions poor[7], and subject to harsher punishment (flogging) for engagement in illegal diamond smuggling. As mining came to dominate the economy of South Africa particular in the context of massive expansion of gold mining, segregated compounding became the normative form of housing for vast swaths of the populace. Materialising particular ways of doing mining were key to the crystallisation of the highly obstinate racist imaginary which would have hold over South Africa until the end of Apartheid and for which Rhodes was a key driver (Storey, 2015).

But materialisation is not the only means of attaching imaginaries to tangible things. Legislation, regulation (or lack of), contracts and judicial action all have a part to play through ordering relations, creating or closing down space for

[7] White workers were also compounded but their surroundings although controlled took the form of 'idyllic arts and crafts style suburbs' rented from De Beers (Storey, 2015).

certain types of socio-technical regime to exist. In Austria the rejection of nuclear power in 1978 following a closely contested referendum translated by 1999 into the Constitutional Act for Nuclear-Free Austria (Felt, 2015). Rejection of a technology once heralded as promising the delivery of energy too cheap to meter (Del Sesto, 1986) had off the back of a narrow referendum result, become a law, and then a constitutional provision. The imaginary enshrined in the document that lays out the fundamental principles to which the state is governed.

Embedding the imaginary within a national constitution appears not to be a common occurrence, the literature deals most readily with regulation and legislation. Regulation has been central to government's efforts to manage, avoid and control the perceived risks posed by nuclear power, biotechnologies and nanotechnologies (Jasanoff & Kim, 2009; Burri, 2015; Chen, 2015). In these ways embedding imaginaries through legislation and regulation makes possible certain technological, economic and social configurations and not others.

Chen's (2015) study of genetically modified (GM) rice in China points to the importance of changing relations between key actor groups. Rice production requires the construction of a material and social assemblage which includes "plants, physical geographies, systems of irrigation, land system, agricultural knowledge and practices, government roles, in modern society, and in addition to these, the relation of between farmers and R&D activities" (Shen, 2010, p. 1041).

Chen draws particular attention to the changing nature of this assemblage, in particular the relations between farmers and scientists that GM rice embodies and is reinforced through an emerging governance and testing regime. Farmers move from being skilled breeders of rice to field technicians following the prescriptions of, and under the gaze of scientists, now the custodians of the knowledge and technical equipment required to produce new breeds, as well as being at the forefront of enacting the GM testing regime, and securing the research funds to pursue GM research. Specialised institutions and the scientists that work within them have become important interlocutors of governance, testing and cultivation, enabling the imaginary to materialise in GM products and

in-field practices whilst eroding the traditional position of farmers in China rice breeding and production (Chen, 2015).

But, materialisation of certain socio-technical configurations requires the establishment of broader infrastructures. So far the literature has predominantly focused on a single technology (Jasanoff & Kim, 2009), important individual (Storey, 2015), or different emerging technologies in a single nation state context (Felt, 2015; Kim, 2015). For instance, in the accounts of nuclear power (Jasanoff & Kim, 2009; 2013; Felt, 2015) although much is made of where nuclear plants and waste disposal will be sited, and the ensuing contestation around such efforts, nothing is said of where the fissile material will come from and what work is undertaken to make that happen! This study contributes to the imaginaries literature by focusing on the feedstock production and supply infrastructure as crucial to the materialisation of lignocellulosic futures.

Chapter Two has already detailed how building biofuel and biomass production infrastructure has been conspicuous from policy and academic documents. Where infrastructure has prominently entered the equation it has been with regards to the interface between biofuels and existing liquid fuel infrastructure, whilst the regulatory environment has stimulated the blending of biofuels but has no firm prescriptions about where from. Policy has therefore created an overarching policy incentive and left the practicalities of embedding to the market. However, as powerful as the market is, and the importance of economic factors in decision making should not be overly downplayed, the cultural, practical, material, and technological factors that influence the embedding of imaginaries has not been examined in the biofuels, not the imaginaries literature at the level of supply chain infrastructure. The study therefore addresses these gaps by directly examining the prospects for developing the necessary supply chain infrastructure if the UK is to develop a substantial domestic capacity to produce lignocellulosic biofuels.

However, as was highlighted by the critique of the biofuels literature in Chapter Two embedding is not a smooth process. Jasanoff & Kim (2009) note resistance often accompanies the efforts to embed imaginaries. Actors such as the state

must also manage, suppress or accommodate varying forms of resistance if they are to successfully achieve the materialisation of the imaginary.

3.3.3 Resistance

The embedding of imaginaries rarely goes unchallenged. Resistance to state imaginaries is an important area of analysis, offering a lens into alternative visions for the future, alongside highlighting how the materialisation of socio-technical imaginaries is shaped through such resistance, and state efforts to manage it. Similar, resistance to the status quo is essential to imagining a better world. As Jasanoff (2015ii) argues "[i]maginaries move through the realm of resistance in double guise, sometimes raising impediments to the spread of new ideas and at other times crystallizing the dissatisfactions of the present into possibilities for other futures that people would sooner inhabit" (Jasanoff, 2015ii, p. 329). Therefore, resisting is crucial to the formation of imaginaries, and development of emerging socio-technical change, and has been an important area of focus within the socio-technical imaginaries literature.

Obviously resistance has been touched upon already. Felt's (2015) work examines the means through which resistance to nuclear power came to capture the Austrian imagination. Here resistance took the form of public protests, debates, and referenda. Over time, keeping technologies out became the dominant socio-technical imaginary at play, symbolised by the decaying remains of a nuclear power station that never operated. However, resisting imaginaries and their technological manifestations is not always so successful.

Jasanoff & Kim (2009) and Kim (2015) touch upon the failure of protest movements in South Korea to challenge the state's vision to utilise science and technology to drive economic and national development while tolerating health, safety and environmental risks to the country's citizens. Despite cyclical efforts catalysing around new controversies and dissatisfaction with the Korean state, particularly the military regime, the state's repertoire of nationhood, prosperity, and national autonomy/sufficiency entangled with rapid technological development has remained dominant. Activists have struggled to construct an alternative vision with coherency and resonance with South Korean society at

large (Kim, 2015). Indeed, the public seem willing to support the task of achieving rapid techno-economic development through backing potentially risk areas of techno-scientific development, and accepting the risks as the price paid for being late to the table (Kim, 2014).

The literature on biofuels has similarly gravitated to these explicit forms of protest and dissent as was outlined in Chapter Two, for example, the food versus fuel, and iLUC controversies. Nevertheless what of less visible forms of resistance? So far we have dealt with issues of resistance and dissent that are explicit forms of opposition, including legal battles, referenda, to more local disputes over specific planning permission for key infrastructure. These are to varying degrees deliberate and organised, coalessing around particular points of traction. This fails to capture how certain encounters, between materials, practices, and ideas create friction and resistance without intention, in particular how resistance, and disruption are generated but without meaning to (Tsing, 2005; Tsing, 2012).

What is being described as a 'friction perspective' (see 2010 special issue of *The Journal of Rural Studies* Biofuels) has already been adopted by an emerging body of work on biofuels. Two pieces of work, Franco, et al. (2010) and Hunsberger (2010), have particular relevance to this thesis as they both draw attention to the unintended forms of resistance that undermine, or reshape the delivery of imagined futures.

For Hunsberger (2010) creative frictions are evident when two visions for Jatropha development in Kenya encounter each other. Although Hunsberger (2010) does not use the language of imaginaries, her analysis shares much in common with the approach. It details a government led vision for Jatropha that involves industrial, large scale developments and exploiting international export opportunities to grow the national economy. In contrast, developmental NGO's and local community groups emphasise an alternative future that foregrounds local rural development and community objectives. Ironically, the most powerful resistance to realising either of these visions has come from the Jatropha crops.

Jatropha has failed to deliver on the optimistic agronomic and productive hopes and promises. Crops have failed and yields have been low (Hunsberger, 2010).

Franco et al. (2010) detail unintentional resistance from the perspective of regulatory and infrastructural encounters that curtail the prospects for biofuel emergence in Germany. For example:

> "… agro-intensification methods conflict with environmental protection measures and domestic land availability, thus limiting biofuel production; engine designs are not fully adapted to use biofuels, thus limiting biofuel mixtures." (p. 688)

Therefore, socio-technical change is shaped by a wider landscape of regulation and practicalities that impact on the ability to embed and materialise imagined socio-technical regimes. Indeed, the current socio-technical regime of biofuel production has been shaped by the limited land availability and potential for agricultural expansion in the global North, shifting biomass production infrastructure to the spaces of the global South, a move further eased by the weak social and environmental governance in the global south (van der Horst & Vermeylen, 2011).

As noted in the previous section, embedding biofuels has envisioned through the lens of numerous modelling practices that expect biofuel supply chains to manifest in response to price signals trickling down from upstream government incentives. It is assumed for example that farmers are already convinced or the means of convincing them is already well understood. Concepts such as marginal land and energy crop technologies are assumed to seamlessly interact with farmer's understandings of land and its use. All that is needed are adequate incentives under certain market conditions, conditions persistently modelled in policy to show potential for significant uptake (see DEFRA, et al., 2007; DECC, et al., 2012). Under these conditions conviction is ensured and material action ensues. These assumptions, about how support from key groups is enlisted, underpin claims around the attainability of the imaginary. Equally, they inform the strategies that are constructed as a means of translating the imagined future into material change to achieve it.

Yet the very limited literature on energy crop uptake has emphasised that farmer engagement with energy crops continues to fall well below even the most modest expectations. This calls attention to the need to examine on farm decision making, management practices and the interactions between farmers and other supply chain actors so as to explore the 'unintentional' forms of resistance that shape socio-technical change and have stunted uptake of energy crops.

Resistance also arises in the form of material differences. The technical literature has acknowledged that the heterogeneity of lignocellulosic material impacts on the outcome of pre-treatment, fermentation and the prospects for developing different final products (see Mosier, et al., 2005; Sassner, et al., 2008; Sánchez & Cardona, 2008; Cherubini, 2010; FitzPatrick, et al., 2010; García, et al., 2014), some material resists the thermochemical or biological action of treatment more than others. However, this starts and ends at the type of biomass, e.g. woody biomass is different to straw, and different varieties of straw have different properties. As yet these categories have not been further unpacked. Furthermore, there is no acknowledgement that material heterogeneity does not just shape the technical processing of the feedstocks into fuel but also has the potential to shape agricultural practices, decision making, and markets.

The socio-technical imagary literature has begun to touch upon this issue. Eaton et al. (2014) examine how an imaginary of 'wood for energy' is contested in Michigan. Emphasis is placed on what types of wood are for energy and what socio-technical systems of bioenergy supply and production this embeds. "Waste wood" is highlighted as a particular site at which material heterogeneity is made visible. The supposed availability of this waste wood, its underutilisation and production through existing practices, mean it is positioned by advocates to justify the claims that bioenergy presents no threat to Michigan forests and their sustainability. Foresters and loggers contest this framing of waste wood through drawing on their knowledge of its production through wood harvesting. The 'waste', branches, tree tops and other 'slash' is used by loggers in everyday practices to provide bases and pathways of traction for heavy vehicles. These uses mean very little actual 'waste' is generated, whilst the term 'waste' directly

challenges the forester's pride in finding numerous uses for this wood. Additionally, collecting this wood was deemed a potential logistical nightmare. Equally, dissenting voices argue that 'waste wood' deliberately obfuscates what types of wood are demanded by and how wood is consumed within bioenergy facilities. Existing facilities in the area operate through combustion of low cost wood chips the majority of which are produced from processing whole trees as a means of competing with coal (Eaton, et al., 2014). Therefore using different types of wood entails different harvesting practices, produces different logistical barriers, and shapes the competitiveness of the bioenergy facility in the energy market.

Therefore this study contributes to the socio-technical imaginaries and biofuels literature on resistance along three different lines of analysis. Firstly, the forms of resistance that arise due to the inertia of existing practices, values, technologies, and knowledges that become challenged by the socio-technical changes demanded by cultivating energy crops on marginal land, or making straw for energy. Secondly, by examining how material heterogeneity of feedstocks impacts on agricultural practices, decision making and markets that has been neglected in the social science literature in favour of how heterogeneity impacts on the ability to process lignocellulosic material into bioethanol. Thirdly, it highlights how policy modelling has been a means of imagining farmer support for biofuels, and constructs particular understandings of how farmers react to certain incentives and market conditions. These models are therefore an important site of analysis as they underpin how the state imagines that biofuel supply chains will be embedded. The thesis will therefore compare these modelling assumptions and expectations with empirical evidence gathered from interviews with agricultural and biofuel actors.

3.3.4 Limitations

The high level approach to examining imaginaries is however not all encompassing. The socio-technical imaginaries concept does not significantly engage with the broader socio-political changes taking place within any one society and crucially, outside of it. For example, the Cold War is an ever present element in both the US and South Korean imaginary for nuclear power (Jasanoff

& Kim, 2009), but there is only limited consideration of the impact of its end. Similarly, Felt (2015) touches upon Chernobyl and Three Mile Island as a catalyst for crystallising an anti-nuclear imaginary in Austria, but does not take this forward to examine whether climate has eroded the strength of this imagined future given that nuclear power is presented as a low carbon alternative. The answer may very well be no impact in both cases, however, it still stands that broader trends and events are given peripheral status within the analysis. In contrast the multi-level perspective touched upon in sub-section 3.2.2 examines more explicitly the 'landscape' which provides a backdrop impacting on socio-technical trajectories (Geels, 2002). Examining the landscape creates space to more explicitly engage with broader factors that influence imaginaries. Considering the wider landscape of trends (e.g. climate change, population growth) is particularly relevant given the propensity of government policy to identify the potential impacts of many of these macro-level trends when conceiving imagined futures.

As has been noted in this chapter, the empirical focus of this thesis takes the imaginaries concept into new ground, principally through conducting a more fine-grained analysis of a material supply chain in conjunction with an analysis of high level imaginaries. Currently the socio-technical imaginaries literature has not engaged significantly with these on ground interactions. Such a shift requires bringing into consideration a wider range of relevant literature as a means of generating productive insights through bringing additional bodies of academic work into view.

Obviously the socio-technical imaginaries concept is not specific to discussing agricultural systems and change. Therefore of particular importance is the work of rural sociologists. Rural sociology is a rich body of literature with previous work engaging with the broad range of topics with this thesis also engages. This includes farmer decision making, values, identity and culture (Wilson, 1996; Wilson, 1997; Wilson & Hart, 2000; Burton, 2004; Edward-Jones, 2006; Burton, et al., 2008), agricultural intermediaries (Ingram, 2008; Ingram & Morris, 2008; Tsouvalis, et al., 2000) and agricultural transitions (Lowe, et al., 1993; Ilbery & Bowler, 1998; Wilson, 2001; Evans, et al., 2002).

Although this body of work has yet to examine energy developments and their implications to on-farm and broader agricultural trends in detail, it nevertheless contributes important insights to the farm level analysis undertaken in this thesis that are not provided solely by the socio-technical imaginaries concept. Bringing these literatures together enables a move between a policy level landscape important for understanding and informing the fine-grained specifics of on farm perspectives. This literature has already been discussed in greater depth earlier in this chapter and also Chapter Two.

As previously noted in sub-section 3.3.3, resistance can be conceived differently when examined at the farm level than has been the case in previous socio-technical imaginaries work (Eaton, et al., 2014 is something of an exception). Rather than arising from public protest movements, judicial action, or referenda aiming to prevent, or re-shape dominant imaginaries, it is emergent from the everyday practices of supply chain actors and the raw materials imagined as being available for processing.

Despite an expanding body of literature on materiality and matter (Bennett & Joyce, 2010; Latour, 2005; Iovino & Oppermann, 2014; Bennett, 2010; Cohen, 2015), materiality has been an issue that has largely flown under the radar of the socio-technical imaginaries literature. Given the high level policy level focus of the concept this is perhaps understandable. However, enacting socio-technical change is central to the imaginaries concept. Such change requires consideration of materiality. Attention to materiality is particularly relevant to this study given its empirical focus on supply chains producing and processing agricultural materials.

Without delving too deeply into this rich body of literature it is important to note that the work of the 'new materialisms' aims to move the material from being exterior to the social, as well as beyond the notion that material things become effective in shaping social relations and conduct only through the mediating agency of human consciousness. Although this is undoubtedly the case in many instances it obscures "the distinctive kinds of effectivity that material objects and processes exert as a consequence of the positions they occupy within specifically

configured networks of relations" (Bennett & Joyce, 2010, p. 5). Matter (inorganic and organic) is not viewed as an inanimate substance but as having its own generative power emergent from complex heterogeneous assemblages, (Oppermann, 2013) which act to shape trajectories (Iovino & Oppermann, 2014). It is this latter aspect, the ability of non-human materials to effect trajectories that has most relevance to the thesis as it links closely with the concept of resistance taken forward in this thesis. By attending to the numerous non-human machines, technologies, land, and resources, and their capacity to interact with humans, consideration of materiality adds further nuance to the repertoire of explanations presented in this thesis.

3.4 **Conclusion**

This chapter has reviewed the literature on future and imagination, positioning socio-technical imaginaries as a concept set apart by its focus on science and technology as foundational to building new forms of social life. Through reviewing the literature I drew attention to three conceptual areas that will be developed empirically in this thesis: origins, embedding and resistance.

An attention to origins highlights the formative conditions within which imagining new future forms takes shape. It draws attention to the actors involved, the intentions and pressures of the time and sets the scene for a historical analysis of evolution over time. The existing biofuels literature has covered some of this historical context already and highlights how biofuel imaginaries also encode a vision for agriculture. However, this literature is USA centric and includes agricultural as a part of the landscape, rather than as the site of analysis.

Embedding examines how the imaginary move from being a rhetorical device to changing socio-technical systems. The literature explores the process and pathways, drawing particular attention to legislation, regulation, and construction and use of physical artefacts as enabling change. The respective biofuels literature was covered in Chapter Two and here it highlighted the limited analysis of farmer decision making, limited largely to economic factors, as well as the absence of a wider range of actors involved in the process of

influencing on farm change to socio-technical configuration. The cultural, practical, material and technological factors that influence the embedding of imaginaries have not been examined in the biofuels literature. Equally, the imaginaries literature has not engaged with supply chain infrastructure as a site of important socio-technical embedding which is the intent of this study.

Resistance was also highlighted as a key point of analysis. However, in contrast to the explicit forms of resistance that have been the bread and butter of the socio-technical imaginaries literature, protests, referenda, judicial challenges, this study is interested in the everyday frictions that limit and shape the emergence of new socio-technical systems. In this respect some of the biofuels literature has begun to engage with these forms of resistance, highlighting how poor crop yields, and conflicting regulation have limited the prospects for biofuel production in Kenya and Germany respectively. It is these everyday forms of resistance that emerge through conflicting regulation, development trajectories and attempts to disrupt entrenched practices, identities, knowledge cultures and technologies, with which this study is interested. This therefore contributes to expanding the socio-technical imaginaries understanding of resistance, as well as expanding a limited biofuels literature that has begun to tackle these forms of friction.

Finally, consideration of the limitations of the concept highlights a number of a literatures that will be drawn upon as a means of fleshing out the analysis in key areas. The multi-level perspective which includes more explicit examination of a wider landscape of trends, shifts and events that operate outside of nation specific context but nevertheless shape imagined futures. Rural sociology which as a field has already undertaken a large amount of on farm qualitative research, although not in the context of agri-energy developments. As such it provides an important pillar of literature informing the analysis in conjunction with the socio-technical imaginaries concept. Finally, the emerging literature on materiality which emphasises the importance of material and matter in influencing the form of socio-technical assemblages. Bringing this literature into play is particularly important as the analysis moves from exploring high level

policy imaginaries with regards to biofuels and agriculture to an interrogation of more specific expectations through comparison with on farm perspectives.

The next chapter will highlight the methodology that was undertaken to produce the empirical data for analysis using the socio-technical imaginaries concept as outlined in this chapter.

4 Methods

4.1 Introduction

The previous chapters have outlined the research questions and gaps within the literature that this thesis aims to investigate. This chapter therefore outlines the programme of empirical work undertaken to meet these aims and that forms the basis for the following chapters. In doing so I will reflect upon the theoretical assumptions and limitations of the research, the research design process, justify the choices made, and address the practicalities of data collection and analysis. Research reflexivity is an important aspect of qualitative research, and this chapter includes reflection on the consequences of utilising different interview modes, and my shifting insider/outsider status during fieldwork.

The chapter is structured as follows. Section 4.2 examines the theoretical assumptions, and limitations of the research. Section 4.3 outlines the evolution of the research design and justifies the choice of interview methods and documentary analysis as the principle means of data collection. I also reflect on the consequences for combining interview and documentary data. Section 4.4 outlines the research procedure building up to and in the field covering sampling and participant contact strategy, the interview guides, and the practicalities of conducting interviews, before reflecting on both the consequences of utilising different interview modes, and my shifting insider/outsider status during interviews with participants. Section 4.5 outlines the post interview deskwork procedures, including the process of post-interview note taking, transcription, analysis and ethical issues. Section 4.6 concludes the chapter.

4.2 Theoretical Assumptions and Limitations

4.2.1 STS

Science and technology studies (STS) and its origins within sociology mean it is rooted within social constructivist approaches. Constructivism concerns itself with constructions of meaning and knowledge, accepting the possibility of different constructions from the diverse actors engaged in social interaction

(Berger & Luckmann, 1966). By not taking knowledge and reality claims for granted, constructivism draws attention to the nuanced and heterogeneous processes through which human societies form their perspectives of reality (Jasanoff, 1999). STS approaches pay close attention to the inner workings of science and technology to examine what is actually taking place, emphasising the contingencies and choices rather than the forces of necessity (Winner, 1993).

Therefore, STS begins from the assumption that science and technology are thoroughly social activities investigating how scientific knowledge and technological artefacts are constructed (Sismondo, 2010). Science is a cultural space (Gieryn, 1999) and not neutral or separate from social influence (MacKenzie & Wajcman, 1999). In particular the field is interested in how meanings and values shape science and technology, and vice versa (Hess, 1997; Jasanoff, 1999; Sismondo, 2004). Jasanoff & Kim (2009) identify socio-technical imaginaries as adopting a co-production approach to understanding the co-construction of science and society. In short co-production interrogates the processes of knowledge making starting with the proposition that "knowledge and its material embodiments are at once products of social work and constitutive of forms of social life" (Jasanoff, 2004, p. 2).

Although foregrounding issues of knowledge Jasanoff argues that co-production is more about ontology (Jasanoff, 2014) and as Woolgar & Lezaun (2013) wryly note in a discussion of the so called ontological turn, co-production's "interrogations of knowledge-making can hardly be described as a study of conceptual or cognitive 'perspectives'." (p. 322), thereby demarcating them as solely about epistemology. Yet as Lynch (2013) argues the distinctions between epistemology and ontology are no longer clearly distinguishable from each other, instead he emphasises their inseparability.

Similarly, this work blurs this line. It is primarily concerned with issues of epistemology - dealing with practices, identities, cultures, and technologies, and considers how different social assemblages produce different situated knowledges in relation to resources such as straw, land and the farmer. However, the research unavoidably considers issues of ontology, such as what

are entities such as land, or straw? Therefore, although I principally undertake a comparison between the knowledge produced through the assemblages of modelling, and that produced by agricultural actors within farm contexts, a consideration of ontology enables space to appreciate that the seemingly stable material entities are fluid and cannot be taken at face value (Woolgar & Lezaun, 2013).

4.2.2 Relativism

A long standing tension within STS has been the question of "whether STS accounts should stick to descriptive (or explanatory) analysis… or whether they should also engage in normative criticisms, assessments or recommendations." (Radder, 1998, p. 325). A core part of this tension is about addressing the question of the value of a relativist study. In particular, with an empirical focus on deconstructing policy modelling, what significance do my own findings have in this context and can they be said to prove these models 'wrong'?

I raise two points with regards to the value of a relativist study. Firstly, relativism does not impose realist boundaries between "the domains of nature, facts, objectivity, reason and policy from those of culture, values, subjectivity, emotion and politics" (Jasanoff, 2004, p. 4), nor between the scientific, the social and the technological (Jasanoff, 1999). These assumptions often result in the narrow framing of problems and solutions, often in terms of technocratic or technological fixes. In contrast, a relativist approach-based study presents a more nuanced account of the numerous and dynamic interconnections between human and techno-scientific systems, adding to the repertoire of explanations, rather than falling into reductionist story telling (Jasanoff, 1996).

Secondly, it is important not to make the error that Jasanoff (1999) ascribes to the many critics of constructivism that equates it with "a mindless relativism that places all factual claims on the same footing, treating none as more robust than any other" (p. 65). Not all knowledge claims are 'equal' and so it is possible to make judgements about claims and thereby make prescriptive claims. The claims in this study therefore aim to add to the repertoire of policy understanding of the

process and interconnections that influence future trajectories of change in the context of lignocellulosic biofuels, bioenergy and agriculture.

4.3 Research Design and Methods

Firstly, I begin by describing how the research design evolved from the initial research proposal and justify the choice of semi-structured interviews and documentary analysis as the principle means of data collection (sub-section 4.3.1). Secondly, I discuss the implications of combining documentary and interview data (sub-section 4.4.2).

4.3.1 Evolving Design

Despite an early interest in pursuing ethnographic forms of enquiry across a small number of farms, the time commitment required for detailed and immersive participant-observation ethnography (Bryman, 2012) was deemed beyond the time and resource constraints of the project. The undertaking of what Wolcott (1990) calls a micro-ethnography was briefly considered as a means of accommodating the intention to conduct a multisite study whilst reducing the time commitment. However, discussions with my supervisors resulted in the eventual rejection of this method on the grounds that ethnography on a modern industrial farm would likely not produce a sufficient breadth of data for the purposes of meeting the needs of the research questions. Arable farms have natural ebb and flow to the work being conducted influenced by changing weather and the time of year. A risk was therefore identified with regards to spending time on farms during periods of down time in which land management practices were not taking place[8]. Similarly, during more intensive periods of management, such as harvest, negotiating access to farmers and farms was likely to be significantly more difficult given their high work load. With regards to livestock farming, the constant work of managing animals meant that the likely practices 'on display' were those of animal husbandry, whereas my interest is more broadly associated with land management and decision making.

[8] Interviews were scheduled by arable farmers to slot into these periods of down time.

It was felt that ethnography would not yield data that could not be obtained more effectively through the use of semi-structured qualitative interviews.

Semi-structured interviews have been drawn upon in a number of research studies that have a particular interest in how emerging policy initiatives (e.g. agri-environmental schemes) interact with on farm practices and processes (see Morris & Potter, 1995; Wilson & Hart, 2001; Burton, 2004; Burton, et al., 2008). Semi-structured interviews utilise a number of open ended but topic specific questions allowing the researcher to formulate sufficient themes to address their research interests and requirements whilst providing a level of flexibility that allows formulation of questions during the interview process (Wilson & Maclean, 2011; Bryman, 2012). Equally, semi-structured interviews allow respondents to shape the interview in ways that are meaningful to them not just the researcher (Murphy & Dingwall, 2003; Stephens, 2007). Therefore semi-structured interviews were adopted as the most appropriate means of providing a window into the perspectives, norms, values, decision making and management practices of a diverse array of agricultural actors.

In addition I was keen to include farm walk style interviews. These 'walking interviews' (Evans & Jones, 2011) are a key component of what Sheller and Urry (2006) identify as an emerging paradigm of mobility, which places emphasis on motion and situation within specific geographies as producing different kinds of engagement with the world. Movement and place are argued to be important to producing different kinds of contextually sited knowledge (Ricketts-Hein, et al., 2008). My interest in undertaking walking interviews was prompted by my numerous personal experiences as a child and teenager of farm walks. Usually organised through the group Young Farmers, farm walks were the means through which farmers presented their farm and discussed their farm practices and decisions making. They were useful for prompting questions from the group, structuring the discussion, allowing observation and experience of the farm.

One method that was not considered a viable alternative but is worth discussing briefly is focus groups. Focus groups have been used elsewhere with regards to farmers' perspectives and attitudes towards dedicated energy crops (for

instance Sherrington et al, 2008). Morgan (1988) argues that focus groups provide a lens into what participants think and why, drawing out through group interaction data that would not be accessed in a one on one interaction. In addition they can enable data to be gathered more quickly than from individual interviewing (Garforth, et al., 2004). Focus groups were not, however, seriously considered due to the following three issues: the logistics and practicalities of scheduling a focus group for each geographical area in which farmers were interviewed; bringing together participants in a place and at a time that was suitable for each; and the desire to observe and interrogate on farm practices and decision making. For these reasons focus groups were not considered suitable for the needs of the research questions and aims.

4.3.2 Combining: Documentary and Interview Data

In addition to the production of qualitative data from interviews, documents were also drawn upon as an important source of primary data, particularly those produced by and commissioned by the UK government and its agencies. The use of documentary as well as interview data raises the question of how these data sources will be combined.

Chronologically, the documentary analysis began before interviews were undertaken and consequently informed the construction of the interview guides. Documentary analysis in particular identified key areas of expectation making and the assumptions that underpinned imagined futures. These were then explored in interviews.

Methodologically, the documentary and interview data sources were treated as constructed textual artefacts. As Flick (2009) suggests, documentary data is not just a container of contents. Similar to interview data, documents encode the outcome of a specific set of interactions and processes, as well as accounts of the individual participant's (or organisation's) histories and future expectations (Spencer, et al., 2014). Both types of data were considered as articulating individual and/or organisations' expectations and assumptions regarding lignocellulosic biofuels. Documentary data was therefore given the same primary status as interview data.

Documents and interviews were analysed and compared as a means of highlighting the similarities and differences between the documented policy assumptions and expectations regarding lignocellulosic futures, agricultural practices, and decision making, and the accounts produced through interviews with agricultural and bioenergy industry actors.

4.4 Research Procedure: In the Field

This section firstly outlines the sampling strategy for interviews (sub-section 4.4.1) and documents (sub-section 4.4.2) before discussing the process for initially contacting potential research participants (sub-section 4.4.3). I then outline in brief the main themes explored in the interview guides for different participant groups (sub-section 4.4.4), before describing the way in which interviews were conducted (sub-section 4.4.5). Finally, I provide two points of reflection on the fieldwork. Firstly, the consequences of utilising phone, sitting and walk and talk interview modes are considered (4.4.6). Secondly, the implications of my shifting insider/outsider status whilst conducting interviews are reviewed (sub-section 4.4.7).

4.4.1 Sampling Strategy: Interviews

The prescriptive sampling strategy of quantitative research is often deemed unsuitable and impractical for qualitative research (Marshal, 1996; Coyne, 1997). In this respect sampling for qualitative research usually entails one or a combination of the following: purposive sampling – selecting participants on the basis of relevance to research questions; convenience sampling – selecting participants on the basis of ease of access; snowball or chain referral sampling – asking initial participants to recommend additional participants (Bryman, 2012). This thesis utilised all three of these means of sampling.

Due to the lack of access to a database of potential participants, such as the Farm Business Survey (Glithero, et al., 2013i; Glithero, et al., 2013ii) the Yellow Pages were used to compile lists of potential participants. The Yellow Pages has been used previously in farm surveys as a means of sampling participants (see Morris & Potter, 1995; Holloway & Ilbery, 1996; Morris, et al., 2000; Tsouvalis, et al., 2000) and accessing farmer contact information (see Burton, 2006; Warren, et

al., 2016). Nonetheless it is not without criticism. Burton and Wilson (1999) argue that it favours the identification of commercially driven farms as well as more established farming families, excluding less-commercial or 'life-style' farmers. In the context of producing a representative sample of the farming community this was deemed potentially problematic (Burton and Wilson, 1999).

However, this qualitative study is not interested in producing a 'representative' sample as a means of generalising results to the wider farming community. Furthermore, alternative databases were not readily accessible. Government (DEFRA, Natural England, Farm Business Survey) databases or NFU membership information was not readily available and would have required negotiating access to confidential data not otherwise in the public realm. In this context the Yellow Pages, was justified due to its accessibility, the ability to use postcode searches and no financial barrier to entry.

That said the main criticism of the Yellow Pages drawn from my experiences during this project relates to the website search and results interface. Although searching was straightforward, turning the resulting material of the Yellow Pages listings into a workable list of contact information for the purposes of this research was time consuming and required considerable tinkering.

Furthermore, given the large potential participant pool arising from the UK farming community in the UK the sampling strategy was narrowed to three geographical areas the selection of which is justified below. The use of geographical boundaries as a means of bounding the study and ensuring a more manageable quantity of potential participants has been widely used within studies examining agricultural studies literature. Specific research into certain areas has been justified on a number of grounds: they are convenient to the researchers (Tate, et al., 2012), the area is assumed to be suitable to the adoption of a new technology or practice (Morris, et al., 2000; Mattison & Norris, 2007; Warren, et al., 2016), that comparison between areas is an explicit aim of this research (Lobley & Potter, 1998), or because an area is being specifically targeted by policy e.g. Severely Disadvantaged Areas are mainly located in upland areas (Hanley, et al., 2007). The areas chosen below were selected on the

basis of their proximity to existing or expected biofuel and biomass production infrastructure, the convenience of accessing farmers in these areas, and that these areas were assumed to be suitable for the adoption of the new technologies and practices under study.

The research topic, the initial documentary analysis and practical considerations guided the choice of the following three areas from which to sample farmers:

- Humberside
- Cambridgeshire
- Lancashire

Humberside and Cambridgeshire were chosen due to the placement of a first generation biofuel and a bioenergy facility, respectively within these counties. Lancashire was chosen due to the geographic concentration of grade 3b-5 land which, as highlighted in Chapter Two, is considered to be marginal in UK bioenergy policy. The choice of these areas was therefore deemed suitable for exploring current configurations of first generation supply chains, a potential future lignocellulosic bioethanol supply chain, and farmers managing land considered marginal in policy terms and thus part of expectations about areas suitable for the future adoption of energy crops.

The choice of these three geographic areas was combined with the participant search strategy through the use of post code searches within the Yellow Pages database of farms in the selected areas. Initial searches identified over 1500 potential addresses. In total the contact information of 150 farmers was compiled, 50 for each geographical area. The 150 farmers were selected from each of the three master lists of farm addresses identified in a postcode search by using a random number generator on a calculator.

The sampling of participants from the straw merchant and agronomist group drew upon the publically available membership information from two professional associations, the British Hay and Straw Merchants Association (2015) and the Independent Association of Crop Consultants (2015). A list of 27 contact addresses was compiled for straw merchants. This represented every

member located within the geographical areas under study whose contact information was publically available at the time of the search. Similarly, 23 contact addresses were obtained for agronomists, again this represented every member located within the study areas for which there was publically available information available through the association website.

Information on biofuel and bioenergy industry representatives was compiled following discussion with supervisors, my own knowledge of the industry and the Department for Transport biofuel and bioenergy monitoring information (see DfT, 2015ii; DfT, 2015ii). Contact details were then obtained from business directories and internet webpages for the selected companies.

In total I conducted 48 interviews which involved the following participants:

32 Farmers (16 of these interviews included a farm walk)

7 Industry Representatives

7 Straw Merchants

9 Agronomists

Of the farmer's interviewed, 14 operated an entirely livestock enterprise, 14 arable and four mixed. Of the industry representatives, four interviews were conducted with bioenergy or biofuel producers while the remaining three interviews were with energy consultants.

All participants were contacted as outlined below in sub-section 4.4.4.

4.4.2 Sampling Strategy: Documents

The documents included in the data corpus included government legislation, regulation, and policy documents, academic articles, NGO reports, government commissioned research, and grey literature. Although documents were compiled and analysed throughout the research, two periods stand out. Between September 2011 and December 2012 a list of policy documents, reports and government commissioned research, key legislation and regulation was accumulated. All documents were produced from 2000-2012. This was later

extended to 2015. Despite this extension it is important to note that the 2012 Bioenergy Strategy (DECC, et al., 2012) marks an important 'end point' for UK biofuel and bioenergy policy. Subsequently, the Coalition (2010-2015) and now Conservative (2015-2020) governments have had significantly reduced engagement with biofuels and bioenergy as a point of policy focus (see DECC, 2014; DECC, 2015; DECC & DCLG, 2015) although the current EU and UK subsidy regime remains in place until 2020 (EC, 2009). Analysis of these documents fleshed out the background to the research, and began the process of identifying themes of interest and key policy assumptions and expectations about lignocellulosic biofuel futures. This analysis was undertaken prior to interviewing.

The second period from October 2014 to March 2015 included the selection and analysis of historical documents. This involved the collection of a number of policy, legislation and regulation documents: firstly, UK agricultural legislation from 1945 to 1993 (from the first and last Agricultural Act passed in the UK); secondly, EU regulation and policy documents relating to the Common Agricultural Policy from 1980 to 2015. The choice of EU documents represents the shift in power towards the EU regarding agricultural policy making and agenda setting. Analysis related to the important themes and topics within individual documents, but also aimed to unpack the story told by these documentary chronologies when taken as a whole.

4.4.3 Participant Contact

Industry representatives were initially contacted via email. Each email introduced myself, outlined the core interests of the topic and my purpose in contacting them. If this initial email resulted in no response, then a second email was sent as a reminder outlining the same information once more. If there was still no response, then no further communications were sent. In instances where a response was forthcoming, participants were given the option of a face-to-face or phone interview at a date and time of their convenience.

Farmers, agronomists and straw merchants were initially contacted with a priming letter. The letter introduced myself and outlined the core interests of the

topic and my purpose in contacting them. Each letter set a date when I would contact the prospective participant with a follow up phone call to request their participation in an interview.

Upon this date, each potential participant contacted via letter was called in turn. If the phone was answered I once more introduced myself and the topic of the project and requested their participation in the study. In instances of a negative response, I thanked the individual for their time and pursued no further contact. If the phone went unanswered during the first call a second call was made. If this was left unanswered I left a short message on the answerphone asking the participant to get in touch using the contact information outlined in the original letter. No further contact was pursued with non-responders. If the participant was willing to be interviewed then one of the following procedures was followed.

Although initially I intended to allow farmers to set the time and date, experience with the first few farmers made it clear that they preferred me to provide a set of dates for them to choose from. This practice continued for all following access negotiations with farmers. I identified a two week period during which I would travel to the respective area. The farmer was then free to choose a date and time convenient to them.

During the initial contact phone call with agronomists and straw merchants all participants willing to be interviewed were given the option of me calling back at a more convenient time. However, the majority of participants preferred to be interviewed there and then.

See sub-section 4.5.5 for details of the procedure for discussing the consent form and information about the project in relation to phone and face-to-face interviews.

4.4.4 Interview Guides

The interview guide covered a set of general themes across all actor groups alongside specific themes applicable to different actor groups. Furthermore, the guide and approach to questioning was intended to allow sufficient space for participant led discussions. Interviews with industry representatives sometimes

included further questions that were specific to the company they represented and its position in the biofuels industry. The checklist was structured so that themes were in a logical order. During the farm walks several questions asked during the sit down element of the interview were returned to within the farm specific contexts; however this portion of the interview was far more open in structure with no formal guide.

General themes were as follows:

1. Background: history of enterprise, type of enterprise, size of enterprise etc.
2. Attitude towards use of food and non-food crops, straw and land for energy
3. Existing engagement with biofuel or bioenergy supply chains
4. Attitude towards or experience of energy crops
5. Attitude towards or experience of other renewable energy
6. Future trajectories for business development/diversification

Specific themes were as follows:

Farmer specific

1. Enrolment in agri-environmental schemes
2. Management of straw
3. Differences between management of crops for energy vs. food/feed (if relevant)

Agronomist specific

1. Means of accessing knowledge on new crops
2. Differences between advice/management on crops for energy vs. food/feed
3. Current 'pressing issues' e.g., resistance blackgrass control, management of maize
4. Their experience of farmers' adopting energy crops

Straw merchant specific

1. What types of straw do they supply?
2. Do different users have different preferences for different straw types?
3. Do different users have different preferences for different bale sizes?
4. How do they influence farmers to bale straw?
5. What influences the availability of straw in the market?

Industry specific

1. Experiences of handling biomass for large scale energy or liquid biofuel production
2. Suitability of UK for lignocellulosic biofuel industry emergence
3. Company engagement with lignocellulosic biofuel technologies

An initial interview guide was produced and comments were made by all supervisors suggesting changes to framing and potential additional questions and themes for exploration. No formal pilot study was conducted, however due to my connections to the farming community I was able to trial the questions with a small number of family and friends which provided invaluable. None of the answers given by these informal participants were recorded, nor did they later take part in the formal recorded interviews.

Full details of the interview guide can be found in Appendix 1.

4.4.5 Interview Process

Before starting an interview I discussed the consent form with the participant. In the phone interviews the content of the consent forms was described to each participant, all of whom were made aware that the interview would be recorded and all verbally consented to the interview continuing. In the phone interviews all participants were given the option of receiving a copy of the information sheet and the consent form through the mail. No participants requested this. In face-to-face interviews a written version of the consent form was signed and I retained a copy. In face-to-face interviews all participants were given a copy of the information sheet, and the consent form.

I made all participants aware that recording was starting and then began the interview. The process of recording was to be undertaken with a digital dictaphone on the table and the use of a clip on microphone already attached to my lapel. The clip on microphone was initially intended to only be used in interviews where the farmers had consented to give a farm walk. However, during the first sit-down interview the participant exhibited visual and verbal cues suggesting the act of being explicitly recorded was unnerving. The participant sat side on to me, away from the table, repeatedly glanced at the recorder and otherwise looked out the window, providing only short answers to the questions. I then took the step of removing the recording device from the table, placing it in my pocket leaving only the microphone visible on my lapel. Within a short time the participant relaxed, turned to face me, made eye contact and began to give much longer answers. This process was then repeated in every single interview regardless of whether a farm walk was to be undertaken. This step made the development of rapport more straightforward and contributed to a more relaxed interview atmosphere. In addition it allowed a high level of fluidity in the instances where the interview moved between a sit down element and a farm walk allowing all the farm walk elements to be recorded without a pause caused by having to then attach a microphone to ensure adequate audio quality.

At the end of interviews I asked all participants if they would like a copy of the final transcript to review and make any redactions. Only two participants requested this and no redactions were subsequently made.

Average interview length was approximately 50 minutes and the total recorded interview time was 2395.3 minutes. The longest interview lasted 121 minutes and the shortest lasted 11 minutes. In general, phone interviews with straw merchants and agronomists were the shortest, averaging 26 minutes. The longest interviews were with farmers, averaging 54 minutes. I reflect on this difference and its consequences on the data below.

4.4.6 Phoning, Sitting, Walking and Talking

The practicalities of conducting interviews with a diverse group of agricultural actors, with differing time availability and accessibility meant that recourse to different modes of interviewing was a necessity.

The literature on qualitative interviewing holds different interview modes in different standing. In particular the face-to-face, semi-structured, implicitly seated interview is positioned as the 'gold standard' interview mode against which other forms of qualitative interviewing are compared (McCoyd & Kerson, 2006). Often such comparisons foreground real and presumed shortcomings of alternative modes against face-to-face interviewing (Stephens, 2007; Novick, 2008). Phone interviews are critiqued as inhibiting establishment of rapport, an important component of in depth interviewing (Stephens, 2007), whilst preventing the researcher from drawing upon potentially important visual cues (Millar, 1995). These shortcomings are deemed to impact on data depth and quality in comparison to that achieved through a face-to-face interaction (Sturges & Hanrahan, 2004; Stephens, 2007). In contrast the advantages of phone interviews are framed as purely practical, decreasing cost, travel, and potentially facilitating access, particularly when potential participants are geographically dispersed (Aday, 1996; Bernard, 2006). An unwritten aspect of this discussion is the pegging out of methodological territory. The differences between seated face-to-face interviews and phone interviews experienced in this project have two main aspects, firstly, my interview conduct, and second, data quality.

In all phone interviews I was often silent during the respondents turn to talk and reduced the amount of conversational filler. This was particularly important if the respondent paused, I quickly learned that it was important to wait and judge whether the pause was a moment of reflection or an end to their answer. This was more difficult during the initial stages of the interview when I was unfamiliar with the participant's talking rhythms. If I misjudged a pause and began to speak, the conversation would be disrupted. This could lead to confusion over whose turn it was to speak, derailing the conversation and line of

questioning. An aspect of this was both the lack of visual cues and the reduced ability to control the place of the interview, background noise, and interruptions.

Therefore, a lack of visual cues did impact on interview conduct, but aside from two instances where questioning became totally derailed due to background noise, and my mistimed posing of a question during a pause, it is difficult to identify a reduced depth or 'quality' with regards to the relevant data collected from phone interviews. Even though phone interviews were generally shorter than the seated interviews, they were also more succinct with less small talk.

It would be easy to interpret this as a difficulty in developing rapport with participants but given the nature of the topic and questions I did not feel this was the case. Personal and professional phone conversations are everyday occurrences due to the ubiquity of mobile phones. Therefore the question that remains is whether visual cues and observations are judged to be an important component to the data. Although this was the case for interviews with farmers where it was agreed to undertake a farm walk, I would argue it was not important to the data produced with other agricultural actors.

In summary my experiences of the differences between seated face-to-face and phone interviews mirrors that of other researchers who have compared these modes. There is no significant difference in the depth and quality of relevant data produced just in the form and process of producing it (Sturges & Hanrahan, 2004; Stephens, 2007).

The additional mode was farm walks or the walking interview (Evans & Jones, 2011). What Sheller and Urry (2006) identify as an emerging paradigm of mobility places emphasis on motion and situation within specific geographies as producing different kinds of engagement with the world, prompting different kinds of knowledge to that created while being stationary (Ricketts-Hein, et al., 2008). Although it is important to recognise that taking the researcher and participant outside of fixed environments is nothing new, anthropological techniques often require a move into the everyday context which necessitates movement (Jones, et al., 2008).

The use of a farm walk style interview stemmed from a desire to pay attention to more than just what people said they were doing and to consider practices (Law, 2012), and to draw on my personal experiences of numerous farms walks as a child. During my childhood and teenage years I was a member of Young Farmers. Although we were exposed to numerous seated talks from agricultural professionals and practitioners, the principal means through which farmers discussed their farm, on farm practices and decisions, was through a farm walk. The farm walk was a useful means of structuring the talk via the route taken around the farm, as well as allowing the farmer and the audience to make observations, perhaps touch and ask questions whilst situated within the context under discussion. Similarly, farm walks are often a means through which farmers share knowledge with other working farmers (British Grassland Society, 2016). All farm walks were conducted in addition to a seated interview with farmers.

When undertaken, farm walks enhanced the richness and nuanced the data produced from the initial sit-down aspect of the interview. The literature on walking interviews has highlighted how participants often find it easier to verbalise answers to questions about situated practices when 'in place', producing richer data (Hitchins & Jones, 2004). Farm walks provided space to further explore participant narratives of their lives and practices situated within the lived space of the farm. This allowed for participants to answer questions provoked by and situated within the spaces of interest to the researcher (Clark & Emmel, 2010). Similarly, walking through the farm was useful for illuminating habitual or hidden relations and practices that would not otherwise be readily exposed through seated interviewing (Kesuenbach, 2003).

In addition the farm walk was both more enjoyable (weather throughout the research was excellent) and more relaxed than the sit down portion of said interviews, allowing the farmer to talk about and show their farm on their terms. In a number of instances the experiences produced from the farm walk produced an additional, sometimes significant layer of knowledge that would have been absent if a sit down interview had been the only form of engagement. This raises questions beyond the scope of this thesis about the implications of where an interview is conducted on how we make farmers, their perspectives, values and

norms, knowable. Equally it suggests that a seated face-to-face interview should not be taken as the default form of face-to-face interviewing.

4.4.7 Insider/Outsider Status

An important part of my identity, one that repeatedly came up during interviews, is that I am a farmer's son. Indeed my father continues to work as a herdsman on a dairy farm. I therefore loosely remain a part of the farming community at large, and farming has played an important part in my formative years. My past and present involvement in farming, now significantly more peripheral, has been an important aspect shaping my interest in the research topic. Likewise, my past experiences of farm visits as a member of Young Farmers influenced the research design and were a catalyst for my aim to conduct farm walks with participants. This raises reflections about my insider/outsider status and its impact on the data produced.

In particular I wish to reflect upon two areas in which it had some discernible impact on the interview process and the data produced. The first relates to the impact participants' knowledge of my involvement in farming and identity as a farmer's son had on the interview. During initial contact with all participants I did not identify or allude to being a farmer's son, or having previously had some involvement in farming. Despite this, the subject arose across the majority of interviews. Usually this was due to questions from participants about my interest in the subject and how I had come to be involved in it.

The 'exposure' of my insider status during or before the interview was in most instances useful for farm walks, building rapport, trust and easing fear of me being an 'outsider critic' (Viseu, A, 2015). This did change the nature of the interview interaction. In some cases this meant that farmers took me to parts of the farm and talked about issues with a level of openness that might not have been readily broached with a complete outsider. Additionally, my knowledge of wider farming issues (I have been a reader of *Farmers Weekly* for a long time) was useful in engaging in broader conversations about farming issues.

The downside was that I was required to probe participants on certain topics which they simply assumed I would be well aware of. Conversely I did not ask

questions or ask for further explanations of certain situations, perspectives or practices due to my own familiarity and previous experiences. On the odd occasion these 'lapses' and absent questions were obvious when later listening to the interview recording for transcription, much to my own frustration. This was less of an issue when discussing arable practices for which at the time of undertaking the interviews, I had (and still have) limited knowledge and no practical experience.

Secondly, it is obvious that I am not a complete insider, I am younger than all of the interviewees, I am not a practicing farmer, and my professional status being that of a 'PhD student' was sometimes problematic, particularly given the common emphasis that participants put on the 'student' over the 'PhD' element. However, the most telling divergence was with regards to my own and what I hazard to describe as the farmers' 'shared values' on certain issues, particularly climate change. The majority of farmers considered themselves sceptical of climate change and its severity. Due to the nature of the research topic and the policy justifications for bioenergy and biofuels, the topic of climate change was raised in the majority of interviews. In these instances during the interview I often marked myself as an outsider when asked of my own views on the subject.

For the most part this had limited impact on the course of the interview, although on one occasion it became *the* topic of discussion. Additionally, most farmers were open to a discussion on the subject and it did not result in closing down the interview. This is largely unsurprising given that initially all farmers agreed to interviews, and often began them without any knowledge to suggest that I was not an 'outsider'.

In brief my insider/outsider status was in flux and evolved throughout the interviews to differing extents on the basis of the interaction. Equally "what an insider 'sees' and 'understands' will be different from, but as valid as what an outsider understands" (Merriam, et al., 2001). Therefore the empirical data underpinning this project and the accounts drawn upon within the empirical chapters are a social construct, created by my self-presentation, that of the

respondent and the interactions between the individuals participating in the interview (Dingwall, 1997).

4.5 Research Procedure: Deskwork

Continuing from the last section I outline the procedure for post interview note taking (sub-section 4.5.1), the process of transcription (sub-section 4.5.2) and the thematic analysis process (sub-section 4.5.3), before discussing some ethical issues that arose during the conduct of the research (sub-section 4.5.4).

4.5.1 Post-interview Notes

Despite taking some notes during the interviews, I found it both distracting for myself and the participant during seated face-to-face interviews and entirely impractical to make notes during farm walks. Walking interviews rely upon audio recording, and if deemed appropriate and not distracting, visual records (photos, or video) (Clark & Emmel, 2010; Evans & Jones, 2011). 'Notes' during the interviews take the form of 'prompts' inserted into the audio recording by the interviewer, for the purposes of noting particular landmarks or locations (Carpiano, 2009) or other features which are deemed important to understanding the participants narrative (Jones, et al., 2008).

As such I only made brief notes during interviews and instead endeavoured to make a more comprehensive set of notes and reflections on the whole interview immediately afterwards. Notes were nevertheless brief including my reflections on the key themes to emerge from the interview and any important quotes remembered. In some instances the immediate recording of notes was not possible due to having to travel to another interview. In such cases notes were produced later in the day, either during a gap between other interviews or after the last interview of the day. This inevitably resulted in a loss of albeit minor detail in comparison to recording notes immediately afterwards.

My notes were important in developing a list of initial themes which informed the analysis and coding process. See sub-section 4.6.3 for more details.

4.5.2 Transcription

Transcription was carried out using Microsoft Word and Sony Sound Organiser 2012. This software was used to control the speed of the audio. All transcription was done at 0.4-0.5 speed of original which allowed me to transcribe without having to go back and forth excessively. Due to the strong accents of certain participants and background noise, particularly associated with the farm walk element of interviews (wind, working machinery, and animals), certain parts of the transcripts were inaudible or difficult to fully understand. A note of these gaps was made in the relevant transcript; fortunately these issues did not result in any significant loss of information. All transcripts were anonymised removing names, business names and place names.

Due to the large amount of audio information produced from the interviews the decision was made to strategically invest transcription time. Due to their shorter average length and being conducted at different times to the farmer interviews, interviews with producers, straw merchants and agronomists were all transcribed in full. In comparison due to the length of certain interviews with farmers, particularly farm walk interviews, a more strategic approach was undertaken. Post interview notes were used to identify which interviews to fully transcribe. In total 18 farmers interviews were fully transcribed, with the remaining 14 interviews being partially transcribed. Only four farm walk transcripts were transcribed in full. The increased time spent with participants resulted in an increased amount of general talk not relevant to the study, which was therefore excluded from the transcripts. However, even partially transcribed the farm walk interviews were often longer than the sit-down interviews transcribed fully. Additionally, my analysis focuses on the themes and content of the interviews rather than the minutiae (pauses, sighs, laughs, emphasis on particular words or sounds, etc.) as such these details were only included if the nuanced interpretation gave further understanding to the interview tone.

I would justify this approach with the following three points. Firstly, all data is reduced: during the research event through selection of recording apparatus and note taking, the process of transcription inevitably results in decisions of what not to include, and during the analysis and writing because there is not room for

everything (Richards, 2015). With regards to transcription the talk that was not transcribed was talk that is important to the process of conducting an interview, (small talk, and tangential discussions) but not guaranteed to be important for the purposes of analysis. This was more prevalent, and in greater quantities in the farm walk interview due to the nature of the mode, and the increased time spent with participants expanding the range of topics discussed.

Secondly, partial transcription is not set in stone (Richards, 2015). Partial transcripts were expanded in some instances. This was not simply a process of expanding the transcription to include more of the interview, but also to note the tone, the presence of sighs, or a particular emphasis that was deemed important in understanding the nuances of a part of text and missed from the initial transcript. Regardless of the presence of small talk all interviews were listened to in their entirety, with certain interviews or parts of interviews being listened to more than once over the duration of the research.

Thirdly, analysis does not begin when transcription ends and once a full transcript is available. Transcription and analysis are interwoven endeavours (Gibbs, 2007) that encapsulate, interview and post-interview note writing and review, alongside the practice of carefully listening and typing during transcription. This interwoven process of analysis was important in identifying what was important to transcribe.

4.5.3 Thematic Analysis

Thematic analysis of the documentary texts, interview notes and transcribed interviews provides a flexible means of analysis, enabling a qualitatively rich and detailed account of the data (Braun & Clarke, 2006). Themes, a specific set of patterns within the data, can refer to something that is directly observable, repetition of a topic, or something implicit and requires interpretative analysis into the meanings and values within the data (Joffe & Yardley, 2004). However, thematic analysis has no agreed upon protocols (Braun & Clarke, 2006; Bryman, 2012; Vaismoradi, et al., 2013). The following section therefore documents how thematic analysis was applied in the context of this thesis.

Documents were read with the purpose of identifying key future expectations relating to the production of lignocellulosic biofuels and bioenergy, and constructions of agricultural systems, practices, decision making and values. This required a close reading of numerous policy documents as a means of identifying areas of shared assumption and expectation making. As noted these initial findings informed the interview guide and topics of discussion.

After this initial reading of the primary documents I sought to identify the modelling exercises that underpinned these policy expectations. The models were closely examined identifying important assumptions about agricultural systems and actors that were to be interrogated and compared with accounts from interviews.

As noted in the previous section, analysis of interviews was a continuous process, interwoven with the process of transcription and through reviewing the post-interview notes. Before transcription was completed the post-interview notes provided the first data resource to be analysed in depth. Although notes only provided a fragmented account of the interview and did not provide the same level of coverage for all interviews (see sub-section 4.5.1) they were a useful starting point from which to develop a loose overview of the data. The sketches they provided of the interviews, as well as their role in prompting my own memories, allowed identification of a number of key themes which were initially assembled. Familiarisation with the data through interview notes thus provided a means of crystallising some emergent thoughts into a tentative initial list of themes.

Once transcripts were available coding was undertaken using Microsoft Word rather than reliance on a programme such as nVivo. The advantages ascribed to nVivo over manual coding include that it is quicker (once familiarity with the program has increased sufficiently), more flexible, allows key word searches across the data set (Basit, 2003), reduces human error, and creates a shared and transparent resource especially useful for groups of researchers (Lee & Fielding, 1993). However, nVivo is not without its own short comings. The ability to code, re-code and create code sub-sets with ease has the potential to multiply codes

without adding meaning (Welsh, 2002), distance the researcher from the data, (St John & Johnson, 2000), whilst contributing to a loss of nuance, particularly where key word searches fail to capture similar instances that use different words to convey the same meaning (Welsh, 2002). Likewise the use of Word is still in effect computer assisted, this is not a comparison between the paper and scissors method and specifically written programs which have characterised this discussion in the past (see Lee & Fielding, 1993).

Putting aside the pros and cons of different coding techniques and technologies, Pope et al. (2000) argue that computer assisted or not, coding is rooted in the analytical skills of the researcher. In this respect the inclination and expertise of the researcher is important when choosing how to code (Basit, 2003). 'Manual' coding was chosen due to my familiarity with Word, and my desk set up (including two screens) that enabled easy movement between several documents. Similarly, past experience with nVivo had been frustrating and time consuming and the decision was made not to invest further time in the program.

Each transcript was given an initial pass which identified key themes in each interview, colour coding text and copying quotes into a separate Word document under a code heading. This list of codes and quotes was consolidated through amalgamation of thematically similar codes and removal of repetition. The transcripts were then given a second pass to ensure that the new coding captured the content and emphasis of the selected quotes. Each code document consisted of a number of quotes linked to each code and short analysis notes. I then compiled codes together into groups on the basis of topics being covered and their linkages to the expectations identified in the documentary analysis. Further decisions were made to determine which themes to focus on most prominently on the basis of their prevalence within the data and their contribution to the analytical narrative.

The results of this thesis are my interpretations of patterns in the data identified from interviews and observations, informed by the socio-technical imaginaries conceptual framework, insights from other bodies of literature highlighted in Chapter Three, my own analytical interests and through discussions with my

supervisors. The interviews were mutually constructed through participant–researcher interaction and further influenced by the interview situation (see sub-section 4.4.7 for reflections on the use of different interview modes). Nevertheless, the results are grounded in rigorous thematic and content analysis of the data and backed by evidence in the form of transcribed extracts from interviews.

4.5.4 Comparison

Comparative analysis is highlighted as being an important aspect of illuminating the work of imaginaries in society as well as discerning their specifics (Jasanoff & Kim, 2009; Jasanoff, 2015ii). Usually this is a comparison between different national contexts. Given that this thesis is empirically focused solely on the United Kingdom, this is not possible. Therefore comparison is incorporated into the analysis in the following ways. The first is comparison between agricultural and biofuel imaginaries that are both in play within the UK policy context. The second is comparison of policy expectations and assumptions about the nature of a future lignocellulosic agri-biofuel system and how this will be realised, with on farm decision making, values, and practices.

4.5.5 Ethical Issues

Ethical approval of the research was given by the Ethics Committee of my School before the participants were contacted and the field research began. The practice of social research requires the researcher to act ethically before, during and after the research is undertaken (British Sociological Association, 2002). This requires researchers to anticipate and respond to instances during the research practice to ensure that participants are not harmed or wronged, that informed consent is given, that the data is anonymised and secure, and that participants are not deceived or given false hope as to the researcher's role, the intent of the research and its likely outcomes (British Sociological Association, 2002; Bryman, 2012; Seale, 2012).

Although anticipation is an important component to conducting ethical research, researchers often encounter the unexpected. This is usually discussed in terms of risks and threats to the researcher as part of understanding and encountering

the world of the participants (Lee-Treweek & Linkogle, 2000). However, there were a number of occasions in which I was caught off guard by an unforeseen turn of events relating to consent.

The first was an elderly participant who was unable to read or write. My immediate thought was to not proceed with the interview on the basis that they would be unable to give written consent. However, the farmer was insistent and therefore I read the consent form at their request. Despite this the participant was uncomfortable about being unable to read the consent form, and furthermore it was impossible for me to gauge whether he was actually listening to what I was saying or simply going through the motions. As O'Connell Davidson (2008) argues, 'does yes mean yes?' Although O'Connell Davidson's critique is in the context of prolonged ethnographic research its sentiment applies. In this circumstance I would argue that informed consent was reflected in the participant's willingness to take part in the interview, be audio recorded and endure being read the consent form despite them being unhappy with the event. Consequently they gave verbal consent to continue and marked the form with an X.

This case draws attention to two areas of reflection. The first is with regards to anticipation. Farmers as a participant group have a median age of 59, with 34% of farmers being 65 or over, and a further 28% being between 55 and 65 (DEFRA, 2014i). Admittedly dated research by Gasson (1998), noted that 33.2% of farmers had no formal qualifications, much higher than other small business managers in the UK. Given the median age of farmers, and that farming communities often prioritise farming over education, it could have been anticipated that literacy levels may have been low for some participants with implications for consent.

Secondly, it calls attention to some of the possible grey areas within the notion of ethical research. To have left the interview would have been a disappointment for me and the participant, also going against the participant's own requests. Subsequently, I was required to muddle through an awkward situation. However, despite trying to handle the issue with sensitivity I would argue the

participant was 'wronged' by the research process (British Sociological Association, 2002) as it unexpectedly drew attention to their illiteracy, which was a cause for discomfort. Consequently at the start of the interview the participant was ill-humoured, although fortunately the discussion became more relaxed as the initial events were forgotten in the context of the interview and the farm walk.

The second was a former resident of Poland during communist rule who refused to sign the consent form on the grounds that he had a deep distrust of signing forms and would not be audio recorded, but nevertheless wanted to talk. This encounter did raise reflections about the boundaries between what is considered 'research data' and 'talk'. Due to the wishes of the participant no data was formally collected from the interview, it was not recorded and an immediate decision was made not to make notes during or afterwards. I do, however, still have a memory of the conversation and it did contribute to my thinking with regards to certain themes emerging in the data. I treated the interview in a similar manner to the many conversations I have had with peers, friends, and family over the course of the research, as a means of reflecting on the formative themes I had in mind whilst undertaking the research and before coding. In that sense the interview was placed outside the formal data but nevertheless within the wider landscape of contributory conversations and discussions that have shaped my reflections on the analysis.

4.6 **Conclusion**

This chapter has outlined the theoretical assumptions and defended the relativist roots of the study when making normative criticisms and assessments of government policy and modelling knowledge. It has outlined the qualitative methods, justifying their suitability to meeting the needs of the research questions and detailing the pre-field, in-field, and post-field procedures and experiences. In particular it has reflected on the use of different semi-structured interview modes between and within interviews with different actor groups and on some ethical issues that emerged during the data collection period.

The farm walks were identified as a particular useful approach for the needs of the project. They created space for farmers to discuss their farms and on farm practices in-situ producing differences in nuance between the seated and mobile portion of the interview that would otherwise remained hidden. Similarly the use of phone interviews was effective in allowing me to respond to emergent findings which pointed to the need to expand the scope of the project to include additional agricultural actors. Not only did they produce relevant and quality data, they were considerably easier to organise, and the mode was useful for exploring a narrower range of questions posed to the intermediary groups. With regards to analysing the data, the choice to manually code the interviews using Word, while initially time consuming, proved useful in the long term. Code documents included interview quotes and additional notes made through the process of coding. Subsequently, these documents lent themselves conversion into chapter sections.

A major difficulty however was the sampling of farmers from the Yellow Pages which proved to be time consuming and cumbersome due to the limitations of the website. Nevertheless, the Yellow Pages proved a readily accessible resource through which to contact farmers.

The project does not aim to analyse a representative sample of farmers, industry, agronomists or merchants, rather it seeks access to a diverse range of perspectives from which to interrogate policy understandings of decision making and biomass resources. These have been analysed through examination of the prominent themes and topics that emerged from across the interview and documentary data.

5 Socio-technical Past and Futures: Agriculture and Biofuel

5.1 Introduction

This chapter presents a comparative analysis of socio-technical imaginaries of agriculture and biofuels and therefore contributes to answering research question one: *How do biofuel and agricultural policy imaginaries compare and contrast over time in the UK? How has policy attempted to embed them into practice?* Furthermore, through unpacking these imaginaries, in particular the biofuels imaginary, it illuminates key sites of assumption-making with regards to changing agricultural futures. As such it contributes to answering the first part of research question two: *What assumptions do UK biofuel policy models make about agricultural systems, decisions, and practices? How do they compare with on farm decision making, practices, values, and inter-relationships?* To answer these questions the chapter draws upon documentary analysis of relevant legislation, regulation, and policy documents published by the UK and EU from the end of World War II to 2015.

The chapter is structured chronologically into four main sections as follows. Section 5.2 begins the narrative by examining the political and public experiences in the UK during and after World War II that provided the formative landscape in which an agricultural imaginary of sufficient production emerged in the UK. The desire to achieve a future in which sufficient agricultural production would protect against the food security vulnerabilities exposed during wartime, and to meet the needs of the poor and hungry, resulted in the UK state transforming on farm activities and reshaping agricultural markets. Arable, livestock and horticultural practices were comprehensively reworked through the application of science and technologies. This section will explore how risks to the nation were framed and how the role of government was imagined to justify these interventions. By charting the initial outcomes of this imaginary I then discern some implications of these developments for imaginaries of biofuels.

Section 5.3 explores how the post-war changes became a double-edged sword. Consistent increases to productivity eventually translated into a costly food surplus, whereas intensive practices damaged and degraded environments, produced risks to food safety and changed the rural economy. This was complicated by ascension into the EU which meant CAP became a key site in which agricultural futures were imagined and contested. In this context a future of sufficient production to meet social and security needs became increasingly threadbare as a means of justifying institutional structures that supported increasingly contested markets and practices. Agricultural policy was reconfigured to embed multifunctional objectives as EU and UK governments attempted to navigate these controversies and re-imagine agriculture in a changed context. The section ends with reflections on how the move to multifunctionality has opened up space for biofuels. Biofuels have been positioned as allowing agriculture to fulfil its multifunctional purpose by contributing solutions to numerous objectives, such as rural development, climate change and energy security.

Section 5.4 highlights how biofuels have primarily become imagined as energy and chemical technologies of substitution. Specifically, they are imagined as delivering a transition from a high carbon, non-renewable petrochemical present to a low carbon, renewable biofuel future. Due to this shift the connections to agriculture have been obscured to varying degrees, and biofuels are no longer positioned as a technology principally responding to agricultural needs. This section will explore how risks were framed and how the role of government was imagined to justify these interventions, whilst charting the outcomes of these developments over time. Additionally, I will highlight the position of lignocellulosic technologies within the biofuel imaginary, drawing attention to the different demands these technologies place on agricultural supply chains, signposting key sites of assumption making and modelling that will be explored in subsequent chapters. Finally, this section will compare the past efforts to embed evolving agricultural imaginaries with biofuel imaginaries, highlighting the absence of direct incentives targeting agricultural actors and systems.

The section 5.5 aims to provide a more tentative reflection on the direction of these imaginaries and whether agricultural and biofuel imaginaries encode cohesive or divergent futures for agriculture, particularly in a climate of changing narratives around the role of agriculture and the re-emergence of food security concerns following the food price spikes in 2007/8 and a new post 2008 regime with historically higher average food prices (FAO, 2015) being a matter of policy concern. Section 5.6 will then conclude the chapter.

5.2 **Imagining Sufficient Production**

This section will undertake a comparison between agricultural imaginaries from an agricultural and an energy perspective. The section will firstly examine the imaginary constructed after World War II that effected and shaped government interventions predicated on transforming agricultural socio-technical systems to deliver public good through increasing productivity (sub-section 5.2.1). I will then focus specifically on the legislative and regulatory interventions of UK government and their consequences for agricultural systems (sub-section 5.2.2). The section will then move to focus on how the trajectory for socio-technical change established in this period has influenced the emergence of biofuels post-2000 (sub-section 5.3.3).

5.2.1 Forging Consensus

The story told in this chapter begins during the Second World War, with the proceedings of the 1943 Hot Springs Conference. This conference, an important event in the formation of the UN Food and Agriculture Organisation (FAO, 1981), established a clear problem: "There has never been enough food for the health of all people (United Nations Conference on Food and Agriculture, 1943, p. 163). In tackling this issue it imagined an aspirational future and outlined a means of getting there. With 44 signatory nation states in attendance, the US and its wartime allies would undertake necessary action to ensure that in the future agriculture produced *sufficient*, affordable food, to meet the needs of the poor and hungry, through the promotion of "research in the natural sciences and their application to problems of food and agriculture" (UN Conference on Food and Agriculture, 1943, pg. 177). Furthermore, the resolutions signalled an intention

to prevent the mistakes of agricultural policy neglect after WW1. The consequence of this previous inattention was considered to be low input-low output-low return agricultural regimes that had brought significant hardship to rural communities (Jachertz, 2014).

Boosting food production was not the only concern. Agriculture was situated within a central move to expand economic activity to provide people with sufficient purchasing power to maintain an adequate diet.

> "The first cause of hunger and malnutrition is poverty. … There must be an expansion of the whole world economy to provide the purchasing power **sufficient** to maintain an adequate diet for all.... the food which is produced can be made available to all people." (emphasis added, United Nations Conference on Food and Agriculture, 1943, pg. 163)

Therefore imagining a sufficient future was a means of projecting positive goals that placed agriculture within a wider collective vision of a future society where people were freed from the fears of poverty and hunger.

Hot Springs was crucial in the establishment of a future vision for agriculture in the UK. In summation of the outcome of the Conference in 1944, Mr Thomas Williams the Parliamentary Secretary to the Ministry of Agriculture and Fisheries (and future Minister of MAFF) made the following declaration:

> "The Government have announced their acceptance of these Resolutions and indicated that they intend fully to subscribe to them. Therefore, the Government have given a general indication of the road along which they think we ought to travel in moving towards a lasting and, I hope, prosperous long-term agricultural policy in this country." (Hansard, 1944, p. 2085)

For the UK government an additional dimension arose. The war had revealed the vulnerability of the UK's significant reliance on food imports (Lloyd & Wibberley, 1977). Shaped by the wartime memories of food shortages and the enduring legacy of post-war rationing, ensuring sufficient production of key agricultural produce became a collective value adding further impetus for government and

farmers to modernise agricultural practices (Lowe, et al., 1993). In this regard, the risk of not fulfilling the imaginary was continued national insecurity. This was to be achieved through adoption of emerging technoscientific innovations, such as herbicides (Cobbe & Reade, 2010), bagged nutrients, mechanised farm equipment and advanced crop and livestock management practices. Therefore what emerged from these international deliberations in a UK specific context is succinctly expressed in preamble of the *1947 Agriculture Act*:

> "…this Act shall have the effect for the purpose of promoting and maintaining… a stable and efficient agricultural industry capable of producing such part of the nation's food and other **agricultural produce as in the national interest it is desirable to produce** in the United Kingdom, and of producing it at **minimum prices** consistently with **proper remuneration and living conditions for farmers and workers** in agriculture…" (emphasis added, (Agriculture Act, 1947, p. 1)

The phrase "in the national interest it is desirable to produce" highlights the interpretive space afforded by the socio-technical imaginary. At what level sufficient food is produced to satisfy the needs of the national interest is made flexible, allowing potentially diverse interests to contest the goalposts without contesting the core of the imagined future. The Agriculture Act 1947 was followed by similar acts in 1957 and 1967 which re-affirmed the government's commitment to realising this future. The Acts utilised the power of the state as a means of driving significant agricultural expansion, land improvements and productivity gains (Hodgson, et al., 2005). Scant attention was given to environmental conservation, with policy makers assuming a 'natural affinity' between farming and conservation (Marren, 2002).

In this respect the UK interpreted the best means of achieving the food policy goals of the Hot Springs Conference as the adoption of a suite of agricultural policy measures. From the post war period until the mid-1980s, the political and industrial orientation of agriculture was dedicated solely to food production, whilst ensuring the protection of farming livelihoods (Ward & Lowe, 1994; Battershill & Gilg, 1997; Ilbery & Bowler, 1998; Wilson, 2001; Walford, 2003) as

a means of securing nutritious, affordable food for all people. Likewise these developments were not restricted to the UK. The Treaty of Rome (1957)(article 39) signed by the original signatory governments founding the European Economic Community (EEC), the precursor to the modern European Union, aimed to achieve similar goals in the context of its Common Agricultural Policy (CAP). Therefore the UK ascension to the EEC in 1973 had limited initial impact on the direction of its agricultural policy due to a shared socio-technical imaginary which determined a need for states to realise continued increases in agricultural productivity, protection of national markets from global price volatility and securing fair standard of living for agricultural communities as a means of ensuring sufficiently affordable and readily available supplies of food for consumers.

5.2.2 Materialising Futures:

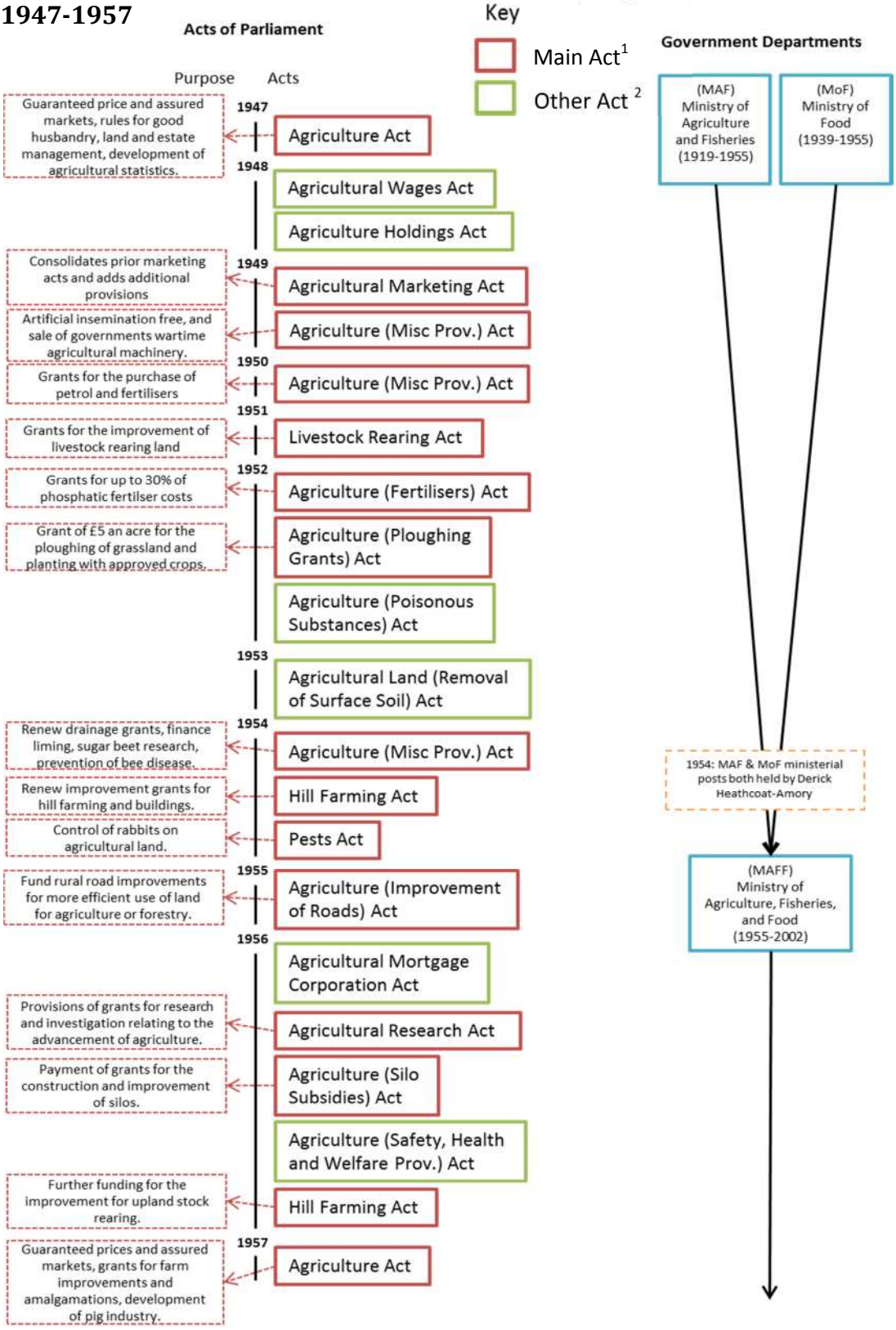
Returning to the Hot Springs Conference, it was the explicit responsibility of individual signatory governments to take action, as they deemed necessary to meet these objectives (Lyon, 1944). As noted by Jasanoff and Kim (2013) different national imaginaries and policy efforts to realise them, diverge in their treatment of risk, an analysis of which enables insight into past developments and prospects for future developments. The following section will explore the way in which governments imagines its role in managing risk and reflect on how this shaped the efforts to materialise the desirable future.

In this regard, the UK government framed market volatility as a risk to the achievement of its imaginary. In devising the *1947 Agriculture Act* the UK government aimed to secure agricultural markets through legislation and state institutions, to protect farmers from global volatility, most notably through guaranteed prices and privileged access to domestic markets to provide sufficient income to farmers. Furthermore, the government prioritised support for farm level investment as a way of curtailing risk for the farmer. Financial incentives, subsidies and grants, were provided to directly underwrite the cost of adopting the new infrastructure and technologies required to achieve the desired productivity and efficiency gains. Yet, it was not all 'carrot'. Failing to achieve these objectives was deemed sufficient to merit the disenfranchisement

of landowners and farmers that did not fulfil the requirements to modernise. Put frankly by the Earl of Radnor during a House of Lords discussion of the 1947 Agriculture Act, "The industry is to have economic security… We are given assured markets and assured prices, and in exchange we submit, as an industry, to control." (Hansard, 1947, p. 875). Thus began a flurry of legislative acts establishing this new regulatory landscape.

The section will now briefly explore a snapshot of legislation from 1947-1957 (Figure 1), starting with the 1947 *Agriculture Act* and ending with the 1957 *Agriculture Act*. It outlines the Acts of Parliament passed within this period relating to agriculture. It covers the departmental amalgamation between the Ministry of Food and the Ministry for Agriculture and Forestry. This resulted in the creation of the Ministry of Agriculture, Fisheries and Food (MAFF) which created a cohesive ministry responsible for the entire agri-food supply chain. MAFF remained the ministry responsible for agriculture until its dissolution in 2002 in the aftermath of crises around the handling of BSE and foot-and-mouth disease (House of Commons, 2002). This snapshot highlights the way in which state power was wielded through legislative and regulatory activity as the UK government made efforts to materialise its imagined desirable future.

Figure 5.1: Acts of parliament explicitly relating to UK agriculture, responsible departments, and the acts intended purpose, passed from 1947-1957



Source: *Figure produced by the author*

As shown in figure 1, the legislative acts had the purpose of using state power to insulate farmers from market and investment risks. The 1947 and the 1957 Agriculture Acts established and re-committed government to institutional structures that determined prices, privileged market access and provided a buyer of last resort. These interventions had the express desire of realising productivity gains to ensure sufficient food for the national and public interest, whilst securing sufficient income for agricultural workers and farmers. Additional regulatory and legislative efforts aimed to change specific on farm agricultural practices through the adoption of the latest science and technologies. Although commonplace now, this included mechanised farm machinery and inorganic fertilisers. Simultaneously the UK government set research priorities many of which were in response to specific war time vulnerabilities. For example, the 1954 *Agriculture (Miscellaneous Provisions) Act*, aimed to improve sugar beet varieties and processing methods for the benefit of providing sufficient domestic sugar production. Reliant on imports of sugar from the empire, sugar was one of the first products to be rationed starting in January 1940 (Zweiniger-Bargielowska, 2000).

Although the diagram highlights shared departmental responsibility between MAF and MoF, MoF, created in 1939 with the outbreak of war, was primarily concerned with overseeing the rationing system. When the rationing system was finally wound down with an end to restrictions on the purchase of bacon and pork in July 1954 (BBC, 2005) MoF and MAF were quickly merged to create MAFF. MAFF would remain the sole ministerial department with responsibility for overseeing agricultural, food, and fisheries policy for the rest of the century. Responsibility being held by a single government institution undoubtedly benefitted the construction and maintenance of a cohesive policy focus, aiding in the fulfilment of the sufficient socio-technical imaginary through encouraging productive practices.

Furthermore, the mechanisms for attaining the imaginary became realised only through negotiation between those supposedly working to secure the imagined public interest (MAFF) and the NFU, which represented the sectoral interests of agricultural actors (Grant, 2000). These negotiations were crucial in delivering

on the ground changes. MAFF therefore represented the 'citizen' within the decision making process. However, as Lang (1999) argues, the desired goal of increased production elevated the interests of farmers in policy deliberations, whilst a MAFF ethos emerged that positioned the ministry as 'the guardian of the industry' (Brassley, 2005, p. 247). The commitment to a proactive agricultural policy as a means of achieving societal goals enabled the 'new' farming interests that emerged and made links with MAF in the inter-war period greater access to and influence within the policy making process (Brassley, 2005).

MAFF was not the sole actor responsible for realising the sufficient future imaginary. Not included figure 1 is the means through which research priorities and fiscal support was channelled through the Agricultural Research Council which was complemented by the National Agricultural Advisory Service (NAAS later the Agricultural Development and Advisory Service, ADAS) created in 1946 (de Silva, 2012). NAAS was tasked with disseminating the latest scientific, biological and managerial information on 'good' agricultural management practices, and perhaps more importantly, ensuring that the farmers accepted and used it (Winnthrifth, 1974; Ilbery & Bowler, 1998). Government provided fiscal and knowledge transfer apparatus to ensure its imagined future was made material. The NAAS was responsible for ensuring that the fruits of techno-scientific innovations were adopted on the farm. Over time these efforts had considerable success in driving quantitative increases in production.

Crucial to this realisation was the discovery and adoption of new technologies that reconfigured long-standing agricultural practices. Ward (1995) highlights chemical herbicides as one such technology, although its transformative potential is amplified in conjunction with additional changes such as mechanisation and proliferation of bagged nutrient. The first herbicides were discovered during the Second World War as a result of military research into potential biological weapons, and upon the war's conclusion these newly discovered chemical compounds were commercialised for use in agriculture (Cobbe & Reade, 2010). Their success in increasing yields and reducing farm labour attracted further public and private R&D investment, sparking a search for additional chemical compounds (Cobbe & Reade, 2010). This search was

itself linked to the need of companies such as ICI, Du Pont and IG Farben, to shift chemical production from military to civil uses and the development of the post-war economy (Pettigrew, 1985).

The proliferation of herbicide use, bagged nutrient and mechanisation of input application is associated with profound changes to long established agricultural practices. Prior to the 1940s, sophisticated crop rotation and mixed farming regimes were required to control weed populations and manage soil nutrients. These new technologies enabled continuous monocropping, with herbicides being employed to kill weed populations on emergence (Ward, 1995) and bagged nutrients replacing the role of animal manures and imported guano. Consequently, the adoption of agrochemicals and mechanisation resulted in a major simplification of farm systems and practices, enabling specialisation and reducing the importance of mixed farming regimes. Ultimately, these technologies enabled transformations in farm and land management regimes. This change was not benign, over time generating increased concern over the health of the environment, eventually eroding the assumption that the countryside was generally a good habitat (Marren, 2002).

This section has aimed to highlight the sustained policy action and government intervention that was crucial to the development of so called productivist modes of agriculture. Productivism did not emerge organically but was rather the result of decades of government actions, scientific and technological innovation and on farm adoption of new practices and technology. Crucial to this was a certain affinity between farmer's core identity as food producers and the aims of the imaginary in achieving increased food production. Nevertheless, provisions were in place to supervise and even dispossess farmers on the grounds of inefficient farming, bad estate management or husbandry. Around 5,000 farmers were placed under supervision orders in the ten years following the 1947 Agriculture Act (Mackie, 1958), although only 377 farmers were disposed during this time (Hansard, 1958). These relatively low figures suggest that farmers were relatively willing (or sufficiently coerced) into adopting new technologies and practices for efficient management and husbandry.

The consequences were an agricultural sector that was entirely transformed from its post-war state, absolute increases in productivity and major efficiency improvements. Likewise, the analysis in this and the previous section highlights how the productivist "commitment to an intensive, industrially driven and expansionist agriculture with state support based primarily on output and increased productivity" (Lowe, et al., p. 221) was not pursued for its own sake but because it was situated within an initial vision of future public good. Imagining a better future, the risks to attaining it, and pursuing it consistently over time were all key to instigating lasting change.

5.2.3 Productivist Regime: Implications for Biofuels

The materialisation of the so called productivist agricultural regime has had a powerful effect on UK agriculture, with implications for the contemporary emergence of a biofuels industry.

Firstly, productivist policies and practices shaped agricultural markets into prioritising a narrow range of products. Products such as wheat, barley and sugar beet have been prioritised within productivist policies, and perhaps unsurprisingly are currently the three principle domestic agricultural feedstocks for bioethanol production in the UK (DfT, 2015ii). First generation technologies are and have been able to tap into these well-developed production chains causing minimal disruption to on farm infrastructures and management practices in the UK. Research by Mattison & Norris (2007) for example highlighted how most farmers questioned expected it would be very easy to easy to grow biofuel sugar beet and oilseed rape, reflecting the farmer's ongoing or previous experience with the crops.

Secondly, these past changes helped farmers do 'more of what they always had done – produce food" (Convery, et al., 2012, p. 298). While this has potentially favoured first generation biofuels which use the same food crops, lignocellulosic technologies demand farmers to pursue alternative land management systems and adopt non-food dedicated energy crop technologies. This is a significant departure from traditional activities (Booth, et al., 2009). Therefore the changes wrought by productivism re-enforced existing practices and identities which

have combined to produce significant momentum along certain development trajectories towards specialisation and high-input/high output food production that may produce barriers to the adoption of alternative low input, high output, perennial crops.

However, these modes of production and the institutional and legislative structures that supported it were not without their negative consequences. The following section will examine the impact of various controversies on the trajectory of the sufficient production imaginary.

5.3 Imagining Multifunctional Agriculture

The concerted government action outlined in the previous section resulted in the materialisation of new socio-technical systems, fulfilling some aspects of the sufficient socio-technical imaginary. In this regard, the UK government was able to reshape rural life, agricultural practices and norms, eventually resulting in a highly productive, efficient agricultural sector fundamentally changed from its pre-war state. The UK produced sufficient food in certain commodities (eventually surplus), satisfying the needs of the national interest and security. The fulfilment of the original vision of a 'good' society, in which productive agriculture freed people from the fear of want and hunger, through production of sufficiently abundant and affordable food is highly debatable, though not within the scope of this thesis.

Despite the best of intentions, the productivist regime resulted in a range of detrimental environmental, societal and economic consequences which became increasingly publicised and contested (sub-section 5.3.1). Subsequently, agricultural policy aimed to encompass and address these issues, expanding the functions of agricultural policy and the broadening the expectations of outcomes from agricultural activity to include provision of environmental goods and services, and broader rural development opportunities (sub-section 5.3.2). This move to multifunctional agricultural spaces created space for biofuels to be considered as an upstream diversification contributing to multiple societal aims (sub-section 5.3.3). These will be explored now.

5.3.1 Changing (Contested) Realities

One of the main fruits of fulfilling the imaginary of sufficient food through quantitative increases in commodity production, turned sour in the form of persistent surplus (Walford, 2003; Fouilleux & Ansaloni, 2016). The EU was beset with the so called butter mountains and wine lakes (Grant, 1997). The former was a particular problem for the UK as a major milk producing country. The government institutions that sheltered domestic markets were in turn exposed to global market volatility. Domestic surplus, high guaranteed prices, coupled with low global prices caused considerable fiscal stress on UK and EU governments as they attempted to dispose of excess produce, creating impetus for reform (Marren, 2002; Fouilleux & Ansaloni, 2016). In addition, the negative effect of CAP measures on developing countries (Koester, 1993) saw mounting pressure from the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) to decouple agricultural support from production by ending guaranteed prices and an unfair system of protection (Koester, 1993; Weyerbrock, 1998). The UK ascension to the EU during the 1973 enlargement had brought it into the Common Agricultural Policy (CAP) for which it became an important financial contributor (Bache & George, 2006). Furthermore, surplus became an issue of major embarrassment as persistent overproduction in Europe was juxtaposed against a series of food crises and famine in Africa, which some blamed on EU protectionist policies creating unfair trade terms that undermined developing world agricultural capacity (Gibson, 2012). Finally, the short lived oil crisis in 1979 caused a persistent economic malaise characterised by high unemployment in the EU nations until around 1986 (Fitousi & Phelps, 1986).

Initially the European Commission (EC, 1980) attempted to defend the surplus, arguing that it represented the technical successes achieved by EU and member states in modernising agriculture and that CAP had broadly achieved its objectives and would thus only require marginal change (EC, 1981i; EC, 1981ii; Ackrill, 2000). But this unravelled as the technical methods themselves were being contested. Environmental damage as a result of intensive practices of land management was gaining increased political profile. Core agricultural

technologies deployed as part of fulfilling the sufficiency imaginary, such as pesticides and herbicides, became contested and lost legitimacy against a backdrop of detrimental environmental consequences. Farmers now became framed in a villainous light (Marsden, et al., 1993), intensive practices adopted by farmers to produce more food having resulted in the 'theft of the countryside' (Shoard, 1980). Equally a major expansion in the number of environmental NGOs in the 1980s, as well as increasing membership (Princen & Finger, 1994), resulted in a political movement opposed to intensive agricultural practices.

The CAP, the EU's central agricultural policy was framed as driving intensive methods of food and fibre production. As such it became a major field for contesting the causes and solutions of environmental damage resulting from intensive practices (Latacz-Lohmann & Hodge, 2003). Similarly, the 1986 Agriculture Act and 1993 Agriculture Act[9] mark the beginnings of drift away from agricultural legislation at the UK level and thus the Common Agricultural Policy will be the key point of focus for this section.

Furthermore, despite significant surplus in food, and generous support mechanisms, the role of agriculture in supporting rural communities had diminished. Rural prosperity was no longer synonymous with agricultural prosperity (EC, 1988). Labour-saving innovations had reduced the workforce by more than half in the twenty years since 1965 (EC, 1987). Yet the rural economy had struggled to diversify and create new opportunities, due to issues of isolation and infrastructure dilapidation (EC, 1988). Additionally, planning policy prioritised agricultural land use within rural areas, whilst adopting a 'key settlements' approach that acted to reduce urban sprawl (Cloke, 1988) but also concentrated economic opportunities and developments around urban centres.

Finally, human and animal health episodes in the 1980s and 1990s centred on the UK, such as the salmonella crisis and the BSE/vCJD crisis temporarily

[9] The 1993 Agricultural Act was the final such act, effectively dismantling the institutions and support mechanisms that had been the cornerstone of agricultural policy over the preceding decades.

threatened consumer confidence in certain agricultural sectors. The BSE crisis was particular significant with an emerging disjuncture between scientific and lay risk assessment (Lynch & Vogel, 2001; Wales, et al., 2006). Initial technical risk assessments by the government identified no risk to human health from BSE, but failed to engage with the drivers of public concern, such as animal welfare issues and uncertainty in the risk assessment process (Frewer & Salter, 2002), instead dismissing public fears as inappropriate (Grove-White, 1998). On 20th March 1996, UK ministers announced that BSE was the most probable cause of 10 cases of a new variant of CJD (van Zwanenberg & Millsone, 2005), triggering a major political crisis. The announcement would precipitate a collapse in trust in the mechanisms and institutions of agricultural governance (Frewer & Salter, 2002; Wales, et al., 2006). In 2001, in response to the BSE Enquiry, HM Government (2001, p. 3) stated that BSE is a "national tragedy". This would have longstanding implications for efforts to deploy genetically modified (GM) crops within Europe which will be explored in section 5.3.3.

Overall the numerous criticisms of the environmental and welfare performance of intensive forms of UK and EU agriculture continue. This has had consequences for the contemporary emergence of biofuels which will be examined in sub-section 5.3.3.

5.3.2 Towards Multifunctional Agriculture

A concerted effort to provide avenues of controversy closure began in 1985. In this year a new Commission under President Jacques Delors took office (EU, 2015), instigating a comprehensive debate on the future of CAP exhibited by the release of two Green Papers (EC, 1985i; EC, 1985ii). These papers challenged previous efforts to tackle the issue of surplus, such as the failure of relatively modest quotas (EC, 1984) to reduce production surpluses and the considerable difficulty of reducing guaranteed prices in line with global prices (EC, 1985i). Furthermore, they recognised that the mono-functional aims of CAP although having achieved productive increases had not been without its shortcomings, impacting negatively on the environment and rural development more broadly. The papers began to establish a trajectory within which agricultural policy was imagined as encompassing multiple future aims.

In addition to internal discussions, the interventionist policies that sustained the productivist regime were under attack from external organisations. The Uruguay Round of GATT negotiations, a global effort to liberalise agricultural markets saw concerted effort from the US to reduce EU agricultural protectionism (Ackrill, 2000). After a protracted period of negotiation between the US and the EU, signatory governments committed to a trend of unravelling the 'distorting' practices deemed to be undermining efficient free markets. The policies and actions of these international organisations have been influential in the erosion of the state interventions that had previously enabled direct support for farmers in the UK (Potter & Lobley, 2004). By 1991 the Commission concluded that existing price supports were contributing directly to a costly surplus, as well as providing the mechanisms for promoting intensive production that put the environment at risk (EC, 1991).

These political pressures translated into the beginning of a new CAP trajectory crystallised with the landmark 1992 MacSharry reform. MacSharry adopted a number of structural reforms to agricultural markets, ending supply side support, to control the spiralling cost of the CAP, and end sustained over-production (Walford, 2003). As Potter and Tilzey (2005) argued, these reforms involved, 'freeing the [agricultural] market from the shackles of the state' (ibid, 2005, pg. 586). This began a course of policy reform that re-defined the functions of the state around the language of the market (Lowe et al, 1993). This move de-politicised the issue of productive surplus with governments shifting their role and responsibilities in shaping agricultural markets and productive capacities to the 'market'. Other attempts at closure included support for technological innovation such as new bio-industries (bioethanol) to consume surplus crops and diversify rural economies (EC, 1985i, POSTNOTE, 1993). However, these options did not manifest in the context of these reforms. Rather it was through subsequent attachment to energy security and climate change objectives that they came to secure state support.

The sufficient production imaginary became increasingly threadbare in this context. Its formation took place in a very different political, economic and social climate. The promised future had morphed into a nightmare producing

numerous public and political controversies. Food-first policies and institutional structures that aimed to drive productive increases gave way to CAP policies aimed at embedding "an agriculture that produces safer food in a more environmentally friendly way that takes better care of animals" (Grant, 2000, p. 227). This suggests a move towards a more multifunctional agricultural policy aiming to meet a broader array of public needs and expectations.

However, not all aspects of the sufficient production imaginary vanished. Support for farmers was retained but it took the form of a new system of direct payments envisaged as providing greater stability (both to the farmers and the EU budget) (EC, 1991). This would eventually evolve into the Single Farm Payment in 2003 (EC, 2003), now the Basic Farm Payment as of 2015 (EC, 2013). Furthermore, the EU began to regulate productive land capacity through set-aside, as a means of curtailing productive excesses. Although primarily concerned with tackling surplus the knock-on effect has been potential environmental benefits with land removed from intensive production providing habitats for insects, farmland birds and mammals (MacDonald, et al., 2007).

In addition to the knock-on benefits from set-aside, environmental concerns were more directly addressed through the establishment of a suite of environmental policies. This was part of a move to ensure that agricultural practices provided for more than just increased food output and also included protection of the rural environment. Most notably this has been realised through agri-environmental schemes, formed out of a collective consensus over the causes and solutions to degradation of the rural environment (Potter, 1998). The shape of these schemes has largely been at the initiative of individual member states.

In this respect the UK was somewhat ahead of the game. The concerns that agricultural policy was neglecting larger environmental concerns and the rural economy, which begun to be addressed by MacSharry in 1992 had begun to emerge into UK legislation earlier. For example, the *1986 Agriculture Act* expanded legislative focus with regards to agriculture to include consideration of the wider services provided by the rural space:

"…provisions for the supply to any persons of any services or goods relating to-

- The production and marketing of agricultural produce and other food;
- The conservation and enhancement of the natural beauty and amenity of the countryside; or
- Any other agricultural activity or other enterprise of benefit to the rural economy." (pg. 2)

This is not to say that the 1986 Act was not still committed to core tenets of the productivist era as outlined previously. However, it was the first time that the position of productive goals within agricultural legislation was also placed alongside acknowledgement of environmental and wider rural development provisions.

The 1986 Act established provisions that enabled the designation of an agricultural area as an Environmentally Sensitive Area on the basis of its landscape, wildlife or heritage value. Interested farmers would be able to make agreements to manage the land in a way conducive to maintaining the area in return for payments. Such schemes were followed in 1991 by the Countryside Stewardship Scheme which attempted to conserve habitats and landscapes on a broader front (Lobley & Potter, 1998), tax concessions for the management of "Heritage Landscapes", alongside covenants and public purchase (Saunders, 1994). This was informed through a framing of sustainability which has largely been in terms of responding to environmental concerns (Tilzey, 2006).

These developments established the trajectory within which the 1992 Maastricht Treaty was formulated and signed as well as the Agenda 2000 reforms. For example, the Maastricht Treaty made the integration of environmental concerns into CAP a priority (EC, 1995), as well as acknowledging that CAP needs to continue to provide for a sufficiently prosperous rural (not just agricultural) economy.

The Agenda 2000 reforms took place in an atmosphere of continued criticism that agriculture consumed vast funds but only provided a narrow range of goods

and services (Pezaros, 1998). In attempting to navigate these contestations the CAP was extended further to include a more comprehensive rural development strategy. This illuminates the way in which financial contestations shifted from the problem of surplus to become entangled with delivering multiple environmental and rural development goals as a means of justifying continued CAP support. As a result "The Union should make a parallel effort to enhance the economic potential and environmental value of rural areas and their capacity to provide sustainable jobs" (EC, 1997, p. 26). Means of closing the continued fiscal contestation took the form of CAP objective expansion, intending to justify its high financial requirements through meeting a wider array of objectives.

These objectives were crystallised in the 2003 reforms to CAP which aimed to give "concrete form to a European model of agriculture … [which involved] market orientation and increased competitiveness, food safety and quality, stabilisation of agricultural incomes, integration of environmental concerns into agricultural policy, developing the vitality of rural areas" (EC, 2002, p. 5). Most notably, direct payments moved from being an arable and livestock based aid to an area based payment linked to farmers adhering to the requirements of cross-compliance, a set of basic rules for good agricultural and environmental management (EC, 2009).

In this regard, the EU imagined agriculture as integrated within a much broader rural strategy with CAP funds split between two so called 'pillars' the first of which would promote market orientated, sustainable agriculture and the second which would strengthen rural development (EC, 2002). The 2003 reform took what was established in the Agenda 2000 reform (a voluntary option to shift funds from pillar 1 to pillar 2) and made it compulsory (EC, 2004), demanding that member states undertook to achieve multiple outcomes from CAP funds. Finally, the emergence of biofuels onto the policy agenda saw the only formal cross-over between biofuels policy and CAP with the establishment of an energy crop aid in which farmers were eligible for a financial incentive for crops for energy grown on set-aside land.

However, increasing the diversity of agricultural contributions to a wider set of environmental and rural development goals was not restricted to on farm practices. It was here that biofuels became signposted as a means through which agriculture could contribute to climate change objectives, rural development (EC, 1999), and energy security goals through replacing petroleum fuels (EC, 2000i). Biomass production and value added products (biofuels) were beginning to be mooted as a potential technology through which to diversify the rural and agricultural economy. A position re-enforced in later iterations of EU rural development policy (EC, 2008). The 2003 reform included provision for energy crops, aiming to incentivise the use of set-aside land for energy crops, providing an incentive payment for any crops grown for biofuels or bioenergy purposes, excluding sugar beet (EC, 2004). However, this was brought to an end with the 2008 CAP Health Check which abolished set aside and the energy crop incentive with it (EC, 2008). I will return to continue this analysis of agricultural policy imaginaries encoded within the CAP in section 5.5.

The implications for biofuels of these earlier contestations, and the new trajectory which efforts to close these controversies sparked will be explored now.

5.3.3 Multifunctional Agriculture: Implications for Biofuels

The period of contestation and attempted policy closures has opened up the rural and agricultural space and eroded the food-first role of agriculture. Imagining agriculture as a provider of multifunctional goods and services that contributed to multiple EU objectives, therefore established a space within which biofuels came to be considered as a means of upstream market diversification of the rural economy, an opportunity for on farm crop diversification as well as contributing to energy security and climate change goals that were converging in the early 2000s.

However, the environmental impacts of intensive agricultural production systems have remained an ongoing area of contestation. Despite UK government assumptions to the contrary (see DEFRA, et al., 2007), UK agriculture is still contested as unsustainable and environmentally damaging, resulting in ongoing

biodiversity decline, particularly of farmland birds a key indicator species (Skinner, et al., 1997; Pretty, 2002; Pretty, 2003; Gregory, et al., 2004; Vickery, et al., 2004; Reif, et al., 2008).

As noted by Walford (2003) farmers have been able to engage with the fruits of environmental policy reform without creating conflict with their primary productivist objectives of intensifying, expanding and specialising their operations. However, explicit government objectives have been replaced with global market competition which has continued to favour a trajectory of intensification and efficiency savings. Equally efforts to close this controversy through the adoption of GM technologies that would deliver a supposedly environmentally benign agricultural production regime (Kearnes, et al., 2006) became heavily contested in the aftermath of the BSE crisis. As argued by Winter and Lobley (2009), biofuels have been embraced by agri-business as a new environmentalism that allows ever more productive, intensified agriculture and investment in technology as a means of tackling climate change. These historical failures to close environmental controversies related to intensive agricultural productions systems have meant that first generation biofuels have become another arena within which these environmental controversies have played out.

Therefore the environmental controversies facing biofuels are rooted in unclosed controversies that emerged due to the realisation of the initial sufficiency imaginary objectives. As will be examined in more detail in the next section EU policy has attempted to close this controversy through investment in 'advanced' lignocellulosic biofuel technologies. This implicitly situates the controversy as an inherent consequence of first generation technologies rather than being a consequence of the technology's dependence of agriculture. As this chapter has argued so far the sufficiency socio-technical imaginary and its realisation has been key to re-shaping agriculture, with often negative and controversial consequences that have yet to be closed. However, why regulatory and technological responses to first generation biofuels have not attempted to reform agricultural practices and regulatory frameworks is linked to how biofuels is situated within a different socio-technical imaginary of substitution with a different imagined future 'good'. This will now be explored.

5.4 Substitution: Energy Imaginaries – Agricultural Implications

5.4.1 Imagining Substitution

As Robert Bud notes in the book *The Uses of Life: A History of Biotechnology* (1993), the substitution of petro-chemical feedstocks with bio-based substitutes has long been of interest, with a number of corporations, research organisations and national governments attracted by the ability of biotechnologies to deliver potential bio-energy, bio-material and bio-chemical possibilities. This vision is situated within a broader ambition to replace high carbon, non-renewable fossil fuels with renewable, low carbon alternatives, to fundamentally reshape industrial societies and deliver a more sustainable, efficient and competitive future. Biofuels have long been positioned as a promising biotechnology, providing opportunities for upgrading agricultural produce to commodities of greater local and export value (la Riviere, 1982). Indeed, bioethanol was one of the first biotechnology products (Bud, 1993). Furthermore, the opportunities for substitution provided by biofuels do not just relate to transport fuels. Biofuels are situated as a breakthrough or 'first step' biotechnology (DTI, 2007) crucial to establishing a market for bio-based goods, and to fund further specific R&D investments (Birch, et al., 2010). This longer history points to how substitution of petro-chemical feedstocks with biological alternatives has been an enduring ambition prior to more recent linkages in the EU and UK to imagining a low carbon future (see DTI, 2003). Likewise, imagining a low carbon future is at its heart imagining the socio-technical systems that arise through the act of substituting petro-chemicals with alternatives.

Despite this long standing interest, policy support for biofuel has waxed and waned over time. During the oil crisis of the 1970s, several nations viewed the opportunities for deriving high value bio-chemical products from agricultural goods as highly attractive (Bud, 1993, Pahl, 2005). However, as oil prices fell the incentive and momentum for biofuel development diminished. Only in Brazil did a broader nexus of nationally important socio-economic and political objectives align to maintain biofuel developments. A high dependence on petroleum

imports caused a foreign exchange crisis, at a time when the domestic sugar industry was hit by a price collapse (Hira & de Oliveira, 2009). These events created sufficient political pressure for the Brazilian government to intervene, stabilising a strategic sector of the Brazilian economy, reducing dependence on imported fuel, all in the name of alleviating poverty and providing rural employment (ibid). In 1975 the National Alcohol Program (Proálcool) was established and persisted until 1991.[10] In Europe biofuels production returned to relative obscurity.

That said, throughout the 1980s biotechnology was repeatedly signposted in EU documents as on the horizon (see EC, 1983; EC, 1985i; EC, 1985ii), wherein it was expected to be a transformative technology in the context of EU agriculture and opportunities afforded the rural economy. During this time period the agricultural commodity and land narrative in the EU was about managing the problem of oversupply (Lobley & Winter, 2009; Potter & Thomson, 2010). Biofuels were an opportunity to provide outlets for these surplus agricultural commodities and substitute potentially insecure petro-chemical products (see POSTNOTE, 1993).

By 2000, EU objectives had evolved to incorporate the rise of the climate change agenda and renewed energy security fears. In the context of agriculture, biofuels were positioned as a value-added product that could allow agriculture to diversify value chains and land use thus contributing to environmental and climate change objectives.

> "The potential for certain types of agricultural activity to make a significant contribution to environmental objectives should not be underestimated, particularly within a favourable policy context. The production of biofuels can, for example, make an important contribution to combating climate change." (EC, 2000iii, p. 11)

[10] Despite the end of Proálcool the industry continues to receive support through generous tax breaks for ethanol fuel, and fuel flex vehicles (Martines-Filho, et al., 2006).

The perceived ability to mitigate climate change impacts has been important to biofuels receiving government largesse. Biofuels were prominently placed upon the table by the European Commission's Green Paper, *Towards a European strategy for the security of energy supply* (EC, 2000ii). The paper asked whether "an ambitious programme to promote biofuels and other *substitute* fuels, including hydrogen, geared to 20% of total fuel consumption by 2020" (emphasis added, EC, 2000ii, Part 1) could be part of the solution to the problems of climate change and energy security. As noted in the UK *Low Carbon Transport* strategy document (DfT, 2007), biofuels "have the potential to emit 338-371 million tonnes of global CO2 less each year than the fossil fuels they *replace."*(emphasis added, ibid, p. 57). The effort to materialise biofuels into a tangible industry of significant scale began with the EC *Biofuels Directive* (EU, 2003).

As a member state of the EU and as a signatory of the 1997 Kyoto Protocol, the UK government was required to meet legally binding targets for carbon reductions. These obligations resulted in biofuels becoming an aspect of the future low carbon economy (DTI, 2003). However, rather than as a transformational technology in the context of agriculture, biofuels were foregrounded as a non-disruptive substitution technology in the context of transport fuel. In particular, they were conceived as having advantages over other technologies (electric and gas) in that they are able to use existing fossil fuel infrastructures and fuel distribution networks, sidestepping potentially considerable infrastructure barriers to adoption (EC, 2001i; Foresight Vehicle, 2004). These presumed synergies have fed into claims in the 2007 UK Biomass Strategy and 2012 UK Bioenergy Strategy that biofuels are the only short term option for significant carbon reductions, with first generation biofuel production being a mature technology (DEFRA, et al., 2007; DECC, et al., 2012). Therefore biofuels was conceived as the most immediately applicable technology that could reduce the emissions of the transport sector (EC, 2001ii; DTI, 2003; Foresight Vehicle, 2004, DEFRA, et al., 2007) with a competitive advantage over technological options that require significant investment in infrastructure.

Achieving increased future sustainability was also a key value informing the imaginary, narrowly defined as renewable technologies when contrasted with

non-renewable fossil fuels. As a means of delivering this sustainable future, biofuels are one of a suite of technologies (including hydrogen, natural gas and electric powered vehicles) that will enable the more specific sector goal of 'zero carbon transport' (DTI, 2003, p. 69) through substituting petro-chemical feedstocks with low carbon alternatives.

Despite the energy emphasis much that is 'good' about this future is underpinned by agricultural resources and systems that are framed as renewable and reproducing, and therefore 'sustainable' (Birch, et al., 2010). The renewable production of agricultural products is positioned as sustainable when juxtaposed with a continued reliance on high carbon non-renewable fossil fuels. Likewise the development of biofuels as a techno-scientific project is framed as unlocking competitive advantage through creating a trajectory of technology development that achieves more efficient resource use and therefore sustainability (Levidow, et al., 2012i). However, the foregrounding of biofuels as a substitute transport fuel, backgrounds the links to agriculture that are effectively demoted to the position of ambiguous rural development opportunities and provider of raw materials (see DTI, 2003, DEFRA, et al., 2007; DTI, 2007; DECC, et al., 2012).

However, the delivery of the substitution imaginary through adopting first generation biofuels has become hotly contested. As noted in Chapter Two, these technologies, reliant on food commodities, have become embroiled in a set of controversies that has undermined confidence in the ability of biofuels to contribute to delivering the imagined 'good' future. This has led to a strategic shift in the narrative and the re-positioning around so called 'advanced', 'second generation' or 'lignocellulosic' biofuels. Biofuels controversies undermined claims that biofuel technologies and their expansion would enhance environmental and socio-economic sustainability (Berti & Levidow, 2013) and provide a low-carbon alternative to fossil fuels. The principal response from the EU to the mixed record of the first generation of biofuel technologies has been threefold. Firstly, the RED (EU, 2009) extended the timeline for increasing biofuel blending levels (Bennett, 2011). Secondly, sustainability standards were developed and made mandatory to improve environmental performance (EC,

2009). Thirdly, lignocellulosic biofuels were positioned as an urgent necessity and as the sustainable successor to food based biofuels.

Lignocellulosic fuels have shifted from a promising technology offering greater efficiency and flexibility in feedstock conversion (see EC, 2006) to providing a solution to the negative environmental and socio-economic problems resulting from the expansion of first generation biofuels (Ponte and Birch, 2013). Through realigning lignocellulosic technologies current targets are maintained under the auspices of creating a market for these future technologies, while first generation technologies are deemed a stepping stone to developing lignocellulosic successors (Berti & Levidow, 2013). Therefore the *ecological substitution* to petroleum fuels offered by first generation biofuels was replaced, by a supposed *technological substitution* offered by second generation biofuels (Ponte and Birch, 2013).

Despite this more recent shift, the transition to lignocellulosic biofuel production technologies utilising non-food biomass material rather than traditional food crops has been encoded within the substitution imaginary surrounding biofuels from very early on. The 2002 *Foresight Vehicle Technology Roadmap* predicted the shift to 'advanced biofuels' within roughly 20 years. Equally in the 2003 Energy White Paper, the UK government had highlighted its interest in investing in these advanced technologies:

> "We are also interested in supporting the development of bioethanol and biodiesel production from biomass such as farm wastes, forestry residues, coppice crops and possibly also domestic waste." (DTI, 2003, pg. 69)

However, this was not because they solve the problems of first generation biofuels (yet to materialise) but because they were expected to deliver improved benefits, a point also reflected in European policy (e.g., EC, 2006).

> "These can potentially deliver bigger carbon savings and wider environmental, farming and rural employment benefits." (DTI, 2003, pg. 69)

Therefore lignocellulosic technologies were envisioned to be more efficient and thus sustainable by drawing upon more productive low-input high-output dedicated crops. It was not until the Gallagher Review which identified second generation technologies as being a pathway to realise 'genuine environmental benefits' (RFA, 2008, pg. 44) that these technologies became more explicitly positioned as a means of navigating the credibility crisis facing first generation biofuels, delivering the now tarnished promises of first generation biofuels (Boucher, 2012ii).

Again the links to agricultural production are paramount to the success of lignocellulosic biofuels. This linkage is performed in policy through a number of models. These models aim to examine certain aspects of agricultural presents, and the potential for future change that is favourable to lignocellulosic biofuels. The *UK Biomass Strategy* (DEFRA, et al., 2007, p. 20), and then the *UK Bioenergy Strategy* (DECC, et al., 2012, p. 26) have aimed to quantify the UK domestic agricultural and biomass capacity to produce estimates of feedstocks currently available and likely to be available going forward. Agricultural residues such as straw and under and unmanaged woodland have been identified as important presently available resources. Dedicated energy crops such as miscanthus and SRC willow have the greatest prospects for future expansion. The *UK Biomass Strategy* outlined an ambition to establish 350,000ha of energy crops (DEFRA, et al., 2007, p. 22), a figure arrived at through the modelling conducted for the *Renewable Innovation Review* (DTI & Carbon Trust, 2004). The *UK Bioenergy Strategy* produced a significantly greater potential figure through modelling farmer decision making linked to price, with planting reaching between 3-15% of total UK agricultural land, if sufficient profit margins were reached (DECC, et al., 2012, p. 28).

Further to this the Gallagher Review highlighted the importance of so called marginal lands. This stemmed from a not entirely optimistic assessment of second generation biofuels, which noted that the use of already productive agricultural lands to grow dedicated feedstocks may have an even greater effect on land use change (RFA, 2008). This was navigated by inclusion of 'marginal' land as a site for dedicated energy crop production that is truly sustainable (RFA,

2008). Marginal land as a concept was most prominent in the *UK Renewable Energy* Strategy (HM Government, 2009). This strategy undertook a number of modelling efforts to identify adequate marginal land and its productive potential to assess the claims that it provides a practical resource for energy crops. These assumptions have been key to underpinning the delivery of a biofuel imaginary of substitution, now centred on the delivery of emergent lignocellulosic technologies and supply chains.

Returning to the definition of socio-technical imaginaries as "collectively held, institutionally stabilized, and publically performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of advances in science and technology." (Jasanoff, 2015i, p. 4), the above section has argued the following. Firstly, that the biofuels imaginary is institutionally stabilised by EU and UK level governmental organisations. In the UK context this has included a number of government departments (the DTI, DEFRA, DfT and DECC) which have been the main departments task with overseeing public policy formulation and the regulatory regime. Secondly, the biofuel imaginary is positioned as delivering numerous desirable and 'good' outcomes including a more sustainable, renewable and competitive economy as a result of substiting petrochemical fuels with biological alternatives. Likewise, such developments are positioned as crucial to combatting climate change. Thirdly, this imaginary does not end with the deployment of first generation technologies, but rather sets in motion a trend of further techno-scientific advance unlocking the potential of lignocellulosic technologies and even more speculative third generation biofuels. It is the prospects for delivering the supply chain conponent upon which the delivery of this imaginary rests which is the empirical focus of the rest of the thesis.

However, it is useful here to make a distinction between the biofuel imaginary and more specific policy expectations about how a lignocellulosic supply chains will be configured in practice outlined in this section. The existing literature on socio-technical imaginaries has been rather vague in examining the more specific expectations of the socio-technical system being embedded. Levidow & Papaioannou's (2013) are something of an exception to this. Their work

examined the bioenergy technologies promoted by different UK government departments and research councils. At this scale their work suggests that an overarching imaginary (for renewable bioenergy) can serve to mask more specific competing visions that exist at the UK government departmental level. In this work it is therefore important to take this finding forward by differentiating between the overarching biofuel imaginary of substitution detailed here, and the more specific expectations of what socio-technical system will be delivered in practice. When examined at this level there is potential for competition between policy expectations and assumptions and on-farm and agri-system perspectives. These are not competing imaginaries per se but rather a competing set of expectations around what types of change are desirable and practically feasible at this level with consequences for the delivery of a lignocellulosic supply chain.

5.4.2 Materialising Technologies: Policy Focus and Risk

To realise the potential of biofuels the UK government was keen to frame its role as a market facilitator. Indeed the 'market' was framed as being crucial to achieving a sustainable future. Specifically, market competition was situated as facilitating greater innovation, efficiency and securing the benefits of the market (DTI, 2003; 2007).

> "It will be for the market to develop and invest in this [renewable energy systems]. But we need to set clear goals and a strategy within which the market has the confidence, ability and sense of long-term commitment to do so." (DTI, 2003, pg. 16)

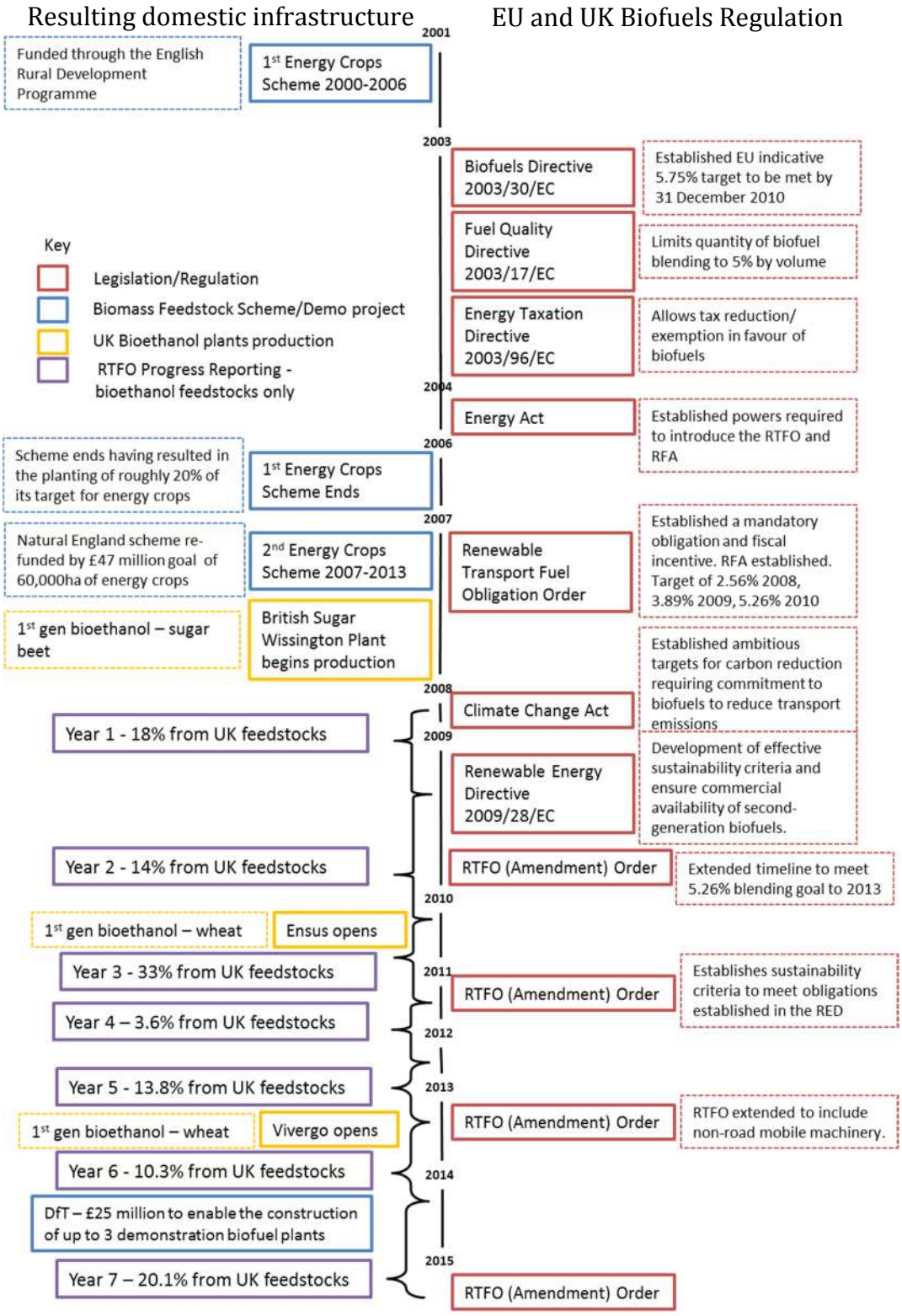
In this regard government induced distortions were positioned as de-risking the realisation of the best future outcomes. Policy contained an implicit, normative judgement, that markets are good ways of delivering future goods. The other side of this coin is that that excessive government intervention was framed as a risk of stifling the market, leading to sub-optimal developments. In effect, the government must point the way and provide the framework, but not risk overly distorting markets otherwise they may not deliver their positive benefits.

This imagined role has been the lens through which the UK government's mechanisms have been structured and mirrors broader trends discussed in the

context of agriculture previously in this chapter. The Renewables Obligation and the Renewable Transport Fuel Obligation have been conceived specifically to constrain government intervention in markets (DTI, 2003, DTI, 2007). The DTI (2000) outlined the government's desire not to distort market competition and pick winners (pg. 3) through its regulatory mechanisms. Whereas the DfT (2007) consultation on the RTFO notes that the market competition is the most efficient means of shaping the biofuels market ensuring low cost biofuels and feedstock sourcing. Therefore, despite an obligation providing a legal requirement to supply a certain proportion of biofuels, the market is allowed to determined what fuel, what feedstock and from where. Policy documents post adoption of the RTFO (see DECC, et al., 2012 for instance) have not substantively reformed the policy framework, although amendments have shaped its workings.

The RTFO has been conceived and adopted as the primary mechanisms of supporting biofuel adoption in the UK through adoption of a mandate and subsidy regime, obligating biofuel blending whilst providing fiscal reward to do so. The implications of this for the realisation of the policy vision for biofuel technologies will be explored in figure 5.2 and figure 5.3

Figure 5.2: Review of EU and UK biofuels regulation, feedstock schemes and demonstration projects, and the resulting UK biofuels infrastructure developed from 2001 to 2014.



Source: *Figure produced by the author*

Figure 5.2 highlights the regulatory trajectory and its material consequences for the development of a UK biofuels industry. The principal means of ensuring biofuel deployment has remained a single piece of regulation, the RTFO. Although amended multiple times in response to domestic and EU changes in regulation, it remains the only statutory mechanism for materialising biofuels as a technological project. Furthermore, despite claims that the RTFO was adequate for stimulating small and large scale production facilities (see DfT, 2007), the first generation industry consists of three plants, owned by well-established sugar processing interests. For example, AB Sugar, a member of the global food and retail group Associated British Foods, owns British Sugar Wissington and is co-investor in Vivergo with BP and Du Pont (Vivergo Fuels 2015). Furthermore, Ensus is owned by the Europe's largest sugar processor, Südzucker, through its subsidiary company CropEnergies Group (Südzucker 2015). The necessity of large-scale production, to meet the obligated quantities of biofuels and achieve adequate economy of scale to justify investment, means that the opportunities for exploiting subsidies for bioethanol production have flowed to well-established sugar processing businesses. This raise questions of rural development for whom given that the principal beneficiaries have been established agri-business.

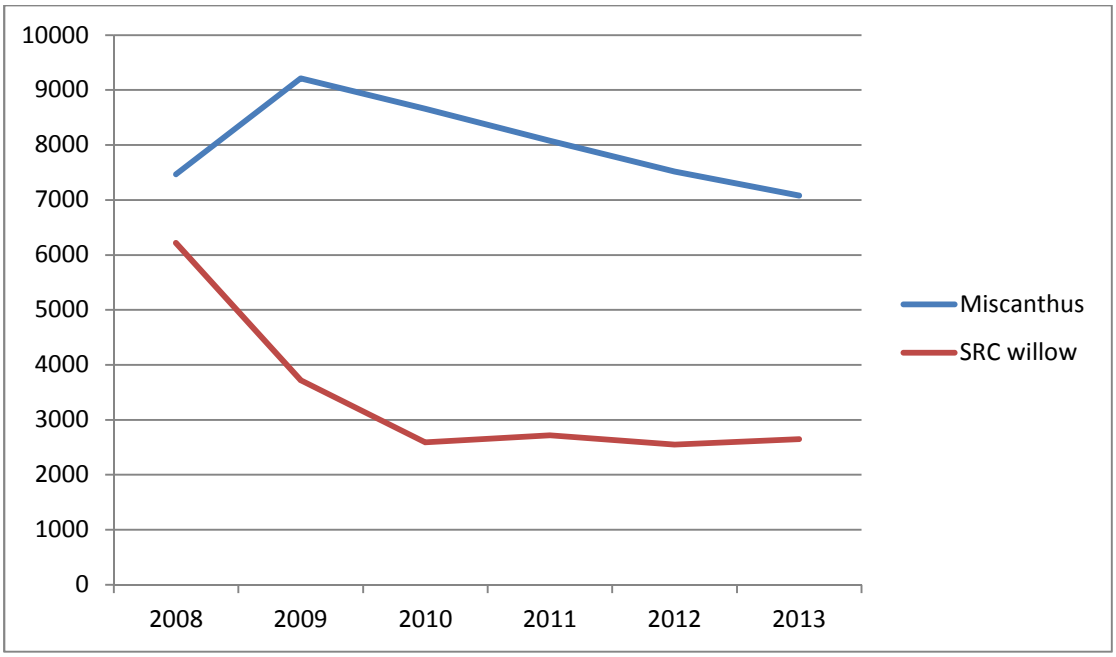
Additionally, as noted in figure 5.2 the amount of feedstock being sourced from within the UK is relatively modest. Aside from outliers of 33% in year 3 and 3.6% in year 4 of the RTFO, perhaps due to the commissioning of a new plant, and changes to the RTFO sustainability criteria respectively, the figure has consistently been between 10%-18%. This is dominated by wheat and sugar beet, suggesting the claim by scholars such as Schmid et al. (2009) that biofuels offer limited opportunities to diversify land use given that the industry relies on established crops, are well founded. Rather the opportunities for diversification rest within agri-business product portfolios. Furthermore, efforts to diversify crop options via the Energy Crops Scheme and produce biomass for bioenergy and future lignocellulosic biofuels has resulted in relatively paltry deployment totals well short of initial targets (Sherrington, et al., 2008) as emphasised in figure 5.3.

To facilitate lignocellulosic technology development and deployment the state has unlocked additional fiscal support. The double counting of RTFO certifications (a double subsidy) for biofuels produced from waste or lignocellulosic material. Investment through the BBSRC in the Sustainable Bioenergy Centre which has provided strategic investment in research around lignocellulosic conversion technologies, from crop breeding to lignin breakdown, to fermentation enzymes. Supergen, which has a wider remit to support the development of UK bioenergy in meeting strategic environmental targets in a sustainable and cost effective manner (Supergen, 2014). Finally, in 2015 the DfT announced the allocation of £25 million in funds to support the development of three advanced biofuel demonstration plants in the UK (DfT, 2015). The government has produced a landscape in which it is willing to de-risk some of the initial costly R&D investments and provide funds for developing a demonstration scale facility.

All of these are positioned as being part of the R&D necessary to enable the development of scaled-up commercially viable lignocellulosic bioethanol technologies. However, as seen in figure 5.2 this has not yet resulted in a material asset being deployed with no commercial or demonstration plant utilising lignocellulosic biomass to produce biofuels yet in operation.

Finally, in contrast to figure 5.1 that emphasised the prolific legislative basis that targeted multiple levels within agricultural systems for realising the sufficiency imaginary, figure 5.2 highlights how embedding biofuels has been undertaken with a single market led regulation with no specific mechanisms for realising a UK industry. Aside from a CAP incentive for energy crops on set-aside land which came to an end in 2009 and the Energy Crops Scheme which ended in 2013, UK agriculture has not been a site of concerted policy action. Indeed as figure 5.3 shows energy crop deployment has declined in the UK suggesting that a market for dedicated energy crops has largely failed to materialise.

Figure 5.3: Total Planted Area of Energy crops in England 2008[11]-2013 (ha)



Source: DEFRA & Government Statistical Service, 2014

Market competition has proven to be a double edged sword given that globally the EU is not a particularly competitive agricultural market (House of Commons, 2003). The consequence of importing feedstocks and fuel has been the flow of negative and positive implications to places outside of the EU, most notably, parts of the global south such as Malaysia, Indonesia, Brazil, and Argentina. The increased demand has resulted in direct and indirect land use change that it has been claimed drives agricultural expansions in biodiverse and carbon rich habitats (Fargione, et al., 2008; Spangenberg, 2009; van der Horst & Vermeylen, 2011), replaced with intensively farmed monocultures (Levidow & Paul, 2010). As previously noted, the result has been that biofuels have become the most recent chapter in a long running set of contestations over the negative environmental and social impacts of intensive agriculture.

[11] The rapid decline in SRC willow planting from 2008-09 is potentially an artefact of data collection. DEFRA considered the data for 2008 to be less robust as this was the first year data was collected (DEFRA & Government Statistical Service, 2014).

5.5 Looking to the Future

As noted in Chapter Three, the socio-technical imaginaries literature has not looked into the future, predominantly concerned with analysing the past and present. This is therefore a tentative analysis of future possibilities based on empirical analysis of the policy trajectories established for agriculture in biofuels policy and in agricultural policy at the EU and UK level.

With the 2008 CAP Health Check, direct aid to energy crops grown on set-aside (the only such aid specific to promoting energy crops) came to an end (EC, 2008). However, CAP has continued on a trajectory towards meeting multiple rural development, environmental and agricultural goals. The imagined future for agriculture remains multifunctional. The most recent agreement on CAP reform reached in 2013 is positioned as continuing what began in the 1990s (EC, 2013) tying it directly into a historic trajectory beginning with MacSharry in 1992. Embedding the provision of environmental goods has remained a key objective. New greening rules create another tier of environmental compliance, on top of direct payments linked to cross-compliance, if farmers are to receive the maximum amount of state support to which they might be eligible.

Within these greening regulations the three crop rule has most relevance to the prospects of lignocellulosic biofuels. This rule requires that farmers of arable land diversify their land use to include three crops if the farm is above 30 hectares. The largest crop must not cover over 75% of the eligible arable land and together the largest and second largest crop must not cover more than 95% of the eligible arable land (Rural Payments Agency, 2015). At first glance this might be seen as an encouraging prospect for long term dedicated energy crops, allowing farmers to meet the three crop rule through cultivating 5% of their eligible land with a low input, low maintenance crop, to ensure they qualify for greening payments, whilst enabling them to retain a high level of flexibility on the remaining land. However, it is not so clear cut. Short rotation coppice willow and miscanthus fall into the category of permanent crops and are excluded from the three crop rule because land cultivated with such crops is not considered arable land. Consequently it does not contribute to a farmer's compliance with greening regulations (Rural Payments Agency, 2015).

Whether this is intended to shift emphasis of dedicated crops away from arable lands and towards 'marginal' land or permanent grassland is unclear. However, it effectively prejudices the placement of 'permanent' crops on arable land by excluding them from a regime that rewards farmers for diversifying their crop mix[12]. Conversely, if a whole farm is planted with a permanent crop then the greening portion of the Basic Farm Payment is met as the farm has no arable land (Terravesta, 2014).

Given the relatively low level of existing dedicated energy crop cultivation it is difficult to assess the implications of these measures. However, they introduce potential barriers to the adoption of energy crops by arable farmers (unless the whole farm is to be established with energy crops). This places greater focus on livestock farmers as adopters of these crops, as they have no de facto impact on their land status, and eligibility for the Basic Farm Payment. In essence, there is an emerging disjuncture between the future for agriculture imagined within the CAP and the expectations embedded within biofuel policy for large scale energy crop expansion.

Added to this are anxieties around food security which have made a somewhat unexpected return to EU and UK agricultural policy narratives. The 2007/2008 food spikes, attributed to varying degrees to the explosion in biofuel production (see Glauber, 2008; Mitchell, 2008; Baier, et al., 2009; Kretschmer, et al., 2012; Zilberman, et al., 2012; Zhang, et al., 2013; De Gorter, et al., 2015). These factors have undoubtedly had an impact on this reappearance of food security fears, and the end of production control measures such as quotas and set-aside within CAP.

Furthermore, the influential Royal Society report *Reaping the Benefits* (Royal Society, 2009) noted biofuels as a driver for chronic food insecurity in its call to pursue sustainable intensification of agriculture as a solution. However, there is a broader landscape of change (Geels, 2002) that gives these fears greater

[12] Land planted with permanent crops still counts towards the main area based payment under the Basic Farm Payment scheme (Rural Payments Agency, 2015)

purchase. Climate change, population growth, changing diets and increased resistance of weeds and pests to chemical agents all play a role in creating expectations of a more challenging future landscape for food production. Despite an absence from EU and UK policy narratives for nearly two decades, food security is once more framed as an urgent challenge set to worsen without immediate action (Royal Society, 2009).

A return to full self-sufficient production of food is not a current target for the UK government (Welfle, et al., 2014), although DEFRA recently announced efforts to improve self-sufficiency as a policy objective (Tasker, 2015). Nevertheless, projected stresses to the global and national food system mean that food security is likely to remain on the agenda (Foresight, 2011i; Foresight, 2011ii), especially, considering that the UK has seen a general trend towards declining food self-sufficiency which as of 2014 sits at 62% (DEFRA, 2014i).

Similarly farming groups have been keen to claim this issue. The NFU for instance published a report in 2015 lamenting falling self-sufficiency in food production, from 78% in 1984 to 62% in 2014 (NFU, 2015ii). Specifically, the NFU report takes aim at complacency of the UK government in expecting continued food imports to meet the UK's food deficit in a more competitive and volatile world market as the effects of climate change disrupt supplies (NFU, 2015ii). In response the NFU suggests policy interventions to increase food production in the UK.

It is here that linkages to the so called sustainable intensification of agriculture may reconcile the tensions between agricultural futures and those encoded in biofuel imaginaries. The influential report by the Royal Society's *Reaping the Benefits: the sustainable intensification of global agriculture* (2009) brought sustainable intensification into mainstream policy circles. The report responds to the food security concerns by promoting techno-scientific innovation as a means to reconcile the demand for increased production, in the context of the challenges of climate change, food demand/insecurity, demand for biofuels/bioenergy, and population growth (Royal Society, 2009, p. 1) with the protection and enhancement of ecosystem services. The term sustainable

intensification denotes an agricultural re-ordering around new technologies that is future orientated and intended to be transformational, promising a future in which agriculture is able to produce more with less (Garnett & Godfray, 2012). Although sustainable intensification has been mooted previously in the context of the global south (for example Pretty, 1997i; Pretty, 1997ii), the Royal Society's (2009) report, has given the paradigm global scope (more specifically encompassing the agriculture of the global north) and positioned it as a means to respond to a range of challenges to agriculture specifically, and society more generally. Whether, through producing more with less a future for first generation and lignocellulosic biofuels is maintained within trajectories of agricultural imagination and change is yet to be seen.

Whether food security becomes more firmly embedded within UK and EU policy is likewise yet to be seen. However, there is potential for considerable divergence between agricultural imaginaries centred around responding to food security, and biofuel imaginaries that are centred on delivering non-food biofuels from dedicated crops and residues. In such a scenario agricultural residues would become a crucial resource. CAP has continued on a trajectory embedding greater multifunctionality at the site of the farm and within agricultural systems and the rural economy. Although this latter development has continued to make space for dedicated non-food crops, it is unclear how these crops would sit within a policy that swung back towards a food-first set of priorities. Miscanthus and SRC willow have already struggled to gain acceptance amongst the farming community as exhibited by figure 5.3.

5.6 **Conclusion**

The imagination and materialisation of new forms of agricultural socio-technical regimes in the post-war period has had profound effects on farm agricultural practices, the shape of agricultural systems and markets. As this chapter has argued, a concerted legislative and regulatory effort was undertaken, targeting multiple levels of socio-technical systems, from R&D, to advisory services, to market institutions, to the farmer and farm, which was crucial to delivering on the imagined future and realising productive increases of certain agricultural commodities. Such systemic change has not been without its consequences for

biofuels. The development of intensive, specialised, efficient and productive forms of agriculture in the UK has potentially been favourable for the emergence of first generation biofuels. The historic focus on a narrow range of food crops such as wheat, barley, and sugar beet has benefitted the domestic biofuels industry which has been able to readily utilise these feedstocks for biofuel production. However, the entrenchment of a narrow range of food crops may inadvertently create barriers to the agronomically and managerially different dedicated energy crops, the favoured feedstock for lignocellulosic production.

Through examining origins of contemporary agricultural socio-technical systems from a far earlier starting point than previous work, this chapter serves to highlight how the development of a productivist model of agriculture was linked to imaging a good future, followed by concerted effort to embed it through deliberate government intervention. This contributes to a more established literature on post-productivism (see Lowe, et al., 1993; Ward & Lowe, 1994; Wilson, 2001) which has largely engaged in examining what comes *after* productivism, taking for granted the existence and development of a productivist model. As these changes became highly controversial the eventual breakdown of the self-sufficient imaginary resulted in the emergence of a multifunctional imaginary. Crucially, imagining agricultural as the provider of multifunctional goods and services created space for biofuels to be imagined as an aspect of this. Biofuels were perceived to provide a means through which agriculture could contribute to climate change, rural development and energy security objectives.

Previous socio-technical imaginaries literature has examined the potential for competition between imaginaries (see Jasanoff & Kim, 2009; Kim, 2015) but not succession. Indeed, dominant imaginaries are shown to be highly durable in the face of challenge (Kim, 2015). In contrast, this chapter has examined the processes of breakdown and transition to a new imaginary within the agricultural context. The escalation and accumulation of several EU and UK level controversies - persistent and costly surplus, distorting trade practices, food safety scares, particularly BSE, and increased consciousness of the environmental harm resulting from intensive forms of agriculture – required EU

policy makers to navigate the highly contested arena of agricultural policy making. The process of proposing avenues of closure (with varying degrees of success) saw the coalescence of new imaginaries of agriculture shaped around multifunctionality.

However, this transition emerged over a decade and continues to evolve as agricultural practice and policy continue to be conceived as contributing to numerous rural development and environmental objectives, in addition to its productive functions. Multifunctional agriculture is therefore something that emerged as a result of a previous imaginary unravelling as a result of the changes it wrought. By tracing these processes this study contributes a valuable case to the imaginaries literature and extends its understanding of how embedded imaginaries change.

However, despite this initial framing of biofuels in the context of multifunctional agricultural systems, biofuels only found direct policy support when imagined as an energy technology of petroleum substitution. This shift in vision from an agricultural to an energy technology has worked to minimise the importance of agriculture in fulfilling biofuels as a technological project. As such the chapter highlighted how in contrast to past efforts to transform agricultural systems, biofuels has not engaged with direct intervention at the site of the farm, agricultural market, or advisory services. Instead, high level fuel market incentives have been the principal means of embedding biofuels.

In practice, market incentives have flown towards reinforcing the position of well-established sugar and food processing business and overall resulted in highly controversial first generation biofuel regimes, with a focus on the negative impacts on populations and environs in the global South as detailed in Chapter Two. Into this mix, lignocellulosic biofuels have been re-framed, not just as more efficient advanced technologies but as specifically responding to the shortcomings of first generation technologies. With new urgency the development of lignocellulosic biofuels is given the weight of delivering on the original promises of a future in which we substitute petrochemical feedstocks with biomass alternatives, in meeting our fuel and chemical needs.

This requires the adoption of new agricultural practices and technologies to deliver the biomass needed for processing. The chapter identified a number of areas of assumption making with regards to the way in which agricultural actors and systems function, and thus what is required to ensure that lignocellulosic technologies can effectively be embedded into agrarian systems of production and supply. These areas are threefold. Firstly, the configuration of agri-biofuel systems and the key actors involved. Secondly, what are the principal factors influencing these actors decisions. Thirdly, the availability of key resources such as agricultural residues and marginal land upon which to grow dedicated energy crops. The following chapters will take forward the analysis of these points of assumption and expectation making which underpin the imagined delivery of lignocellulosic biofuels as a technological project and the substitution imaginary.

Furthermore, this chapter has not just looked at socio-technical imaginaries in the past and present but also tentatively sketched out some possible avenues of emerging future transformation. CAP continues to pivot further towards delivering diversity on-farm, however this has been challenged by a resurgence of food security and food-first narratives. A possible consequence is that energy crops are potentially being undermined from a number of angles from within CAP's greening rules, as well as being threatened by a potential shift back to food-first/food security visions limiting the prospects for non-food energy crops. Whether an imaginary of sustainable intensification of agriculture as articulated by the Royal Society can reconcile the needs of lignocellulosic technologies with an increasingly food insecure world is yet to be seen.

Finally, the analysis in this chapter also raises questions about the applicability to lignocellulosic biofuels of the socio-technical imaginary concept. This chapter has justified a biofuel imaginary of substitution along the lines of demarcating its institutional support and stablisiation within EU and UK governmental departments. Highlighted the key aspects of the desirable future delivery of lignocellulosic technologies is expected to realise, and the trajectory of techno-scientific advance that is supported through the imaginary. However, I have also distinguished between the high level imaginary of socio-technical change and the more specific expectations of a UK supply chain encoded in UK policy. This

approach therefore reflects aspects of Jasanoff & Kim (2009) who undertake a high level analysis, and the work of Levidow & Papaioannou, (2013) who engage in a fine grained analysis of UK bioenergy policy. Noteably, Levidow & Papioannou's approach to the concept suggests a less united imaginary landscape, particular when viewed more closely. In either case the socio-technical imaginary concept still provides a useful lens and language for unpacking and examining embedded visions and exxpectations of agriculture in the lignocellulosic biofuel context.

6 Supply Chain Visions: Scale, Hybridity and Intermediaries

6.1 Introduction

The nature of future lignocellulosic supply chains is left largely implicit in UK policy. The intention to 'not pick winners' (see DTI, 2003; DTI, 2007; DECC, et al., 2012) has led to a policy regime in which the RTFO for instance does not currently specify feedstock, fuel, technology, or geographical preferences when it comes to producing biofuels. This raises questions about what domestic agri-biofuel system is intended to be embedded and is being embedded under current government regulation.

Chapter Five highlighted that UK policy does produce a set of expectations about the future for lignocellulosic biofuels and bioenergy more generally. This chapter examines the way in which biofuel supply chains are imagined through analysing the numerous models embedded within the *UK Bioenergy Strategy* (DECC, et al., 2012). It touches on the issues of scale, the possible integration of lignocellulosic technologies into existing biomass processing systems, and the actors involved in materialising these supply chains. I compare policy assumptions and expectations with accounts from interviews conducted with bioenergy and biofuel industry representatives, and straw merchants and contractors.

The chapter presents a component of the analysis of expectations and assumptions signposted in Chapter Five and contributes to answering research question two, focusing on the 'agricultural systems' component of the question: *What assumptions do UK biofuel policy models make about agricultural systems, decisions, and practices? How do they compare with on farm decision making, practices, values, and inter-relationships?* Examining the prospects for delivering lignocellulosic technologies at scale, the potential for integration into existing supply chains, and the actors involved in conducting the work that makes biomass available, the chapter also highlights some possible opportunities and barriers. In doing so it contributes to answering research question three: *What are the opportunities and challenges, highlighted through understanding the agri-*

energy nexus, for the future emergence of lignocellulosic biofuels? To answer these questions the chapter draws upon documentary analysis of policy documents, the broader research literature and interviews with biofuel and bioenergy industry representatives, straw merchants and contractors.

The chapter is structured into three main sections as follows. Section 6.2 examines the models within the *UK Bioenergy Strategy* (DECC, et al., 2012) and draws out four key sets of expectations and assumptions that underpin the loose vision of future biofuel supply chains. These are expectations of scale, the interaction between first and second generation biofuel technologies, and that farmers and industry are the key supply chain actors involved in realising this vision. Section 6.3 draws on interviews with industry representatives to critique and examine the issues of scale and interaction between lignocellulosic and existing biomass for energy processing industries. Section 6.4 draws on interviews with straw merchants and contractors to provide an example of a biomass supply chain, and highlights the important practical and social work undertaken by intermediaries in maintaining and constructing connections between actors. This section ends by reflecting on the implications that considering intermediaries has for emerging energy crops.

6.2 Domestic Biofuel Supply Chains: Policy Expectations

This section begins by examining the way in which UK policy has deliberately tried to steer away from explicit prescriptions outlining the desired future configurations of biofuel supply chains (sub-section 6.2.1) before moving on to discern four expectations that emerge from analysis of the UK Bioenergy Strategy (subsection 6.2.2).

6.2.1 The Bioenergy Strategy

The UK government has been keen to frame its bioenergy and biofuel policies as facilitating a broad range of technologies, "neither picking winners nor abandoning the range of low carbon technologies" (DECC, et al., 2012, p. 52). Instead, the incentive and support regime aims to establish "the market framework in which these [technology and investment] decisions are taken" (DTI, 2007, p. 14). This makes the discussion of supply chains expectations in

policy difficult because policy-makers have been keen to be seen as not prescribing any particular feedstocks, technologies or geographical configurations with regards to the emerging industry in the UK[13]. Instead, this section draws on the detailed Analytical Annex produced by AEA (2010) which outlines the modelling that informed the UK Bioenergy Strategy (DECC, et al., 2012), henceforth referred to as the Strategy. Although, because these models were "modified to reflect feedback received from stakeholders and [the] update of certain feedstock assumptions" (DECC, et al., 2012, p. 24), the Strategy is the principle document of reference. It is through the numerous separate models within the Analytical Annex, of which some are reproduced within the Strategy, that this section aims to piece together a composite vision of a future UK lignocellulosic biofuel system.

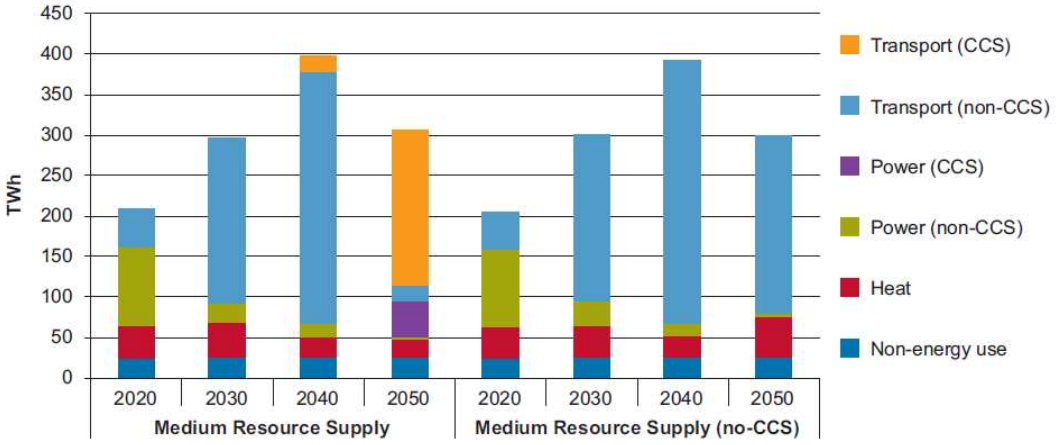
The Strategy is primarily concerned with bioenergy for heat, power and transport and represents the most recent iteration of how technical projects in these areas will deliver the substitution of fossil fuel feedstocks. Within this document, and as outlined in Chapter Five, biofuels and bioenergy are the first steps on a trajectory of "scientific advance and industrial innovation to utilise biomass to meet the increasing demands for sustainable products" (ibid, pg. 8), in essence the biorefinery. Delivering the imaginary of fossil fuel substitution requires innovation and adoption of a whole suite of energy and non-energy biomass innovations, not just biofuels. The Strategy positions biofuels and bioenergy in the context of a wider bioeconomy and the biorefinery (see DECC, et al., 2012, p. 36), continuing the expectations that were established with *A strategy for non-food crops and uses* (DTI & DEFRA, 2004; DTI & DEFRA, 2006) and expanded upon in the *UK Biomass Strategy* (DEFRA, et al., 2007). Such expectations link first generation and lignocellulosic biofuels and bioenergy because they share a similar foundation as technological projects that will further the bioeconomy and thus materialise the public good envisioned as part

[13] Although this is not to say that policy has not favoured very particular types, scales and geographies of biofuel production.

of the substitution imaginary. On a more practical level they are also expected to share (and compete over) similar biomass resources and thus assumptions made in regard to adoption of crops such as miscanthus and SRC willow create points of crossover between these technologies.

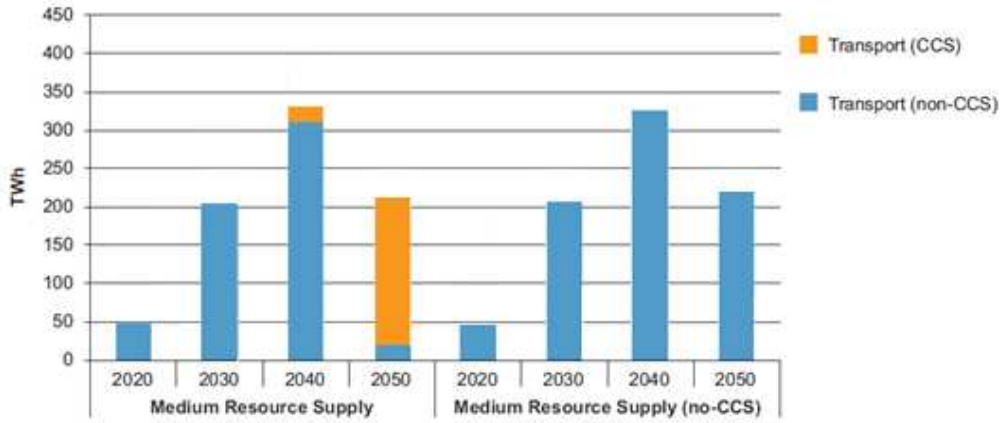
Further to this, and in contrast to early policy documents (for example, DTI, 2003; DEFRA, et al., 2007; DTI, 2007; HM Government, 2009), bioenergy and biofuel technologies have become tethered to the delivery of carbon capture and storage technologies (CCS). However, despite this linkage, the implications for the future total penetration of biofuels appear to be relatively minor. As shown in figure 6.1 and 6.2, the future biomass for primary energy allocated to biofuels going forward to 2050 is only insignificantly changed by the parallel adoption of CCS, which actually reduces biofuel penetration in favour of power.

Figure 6.1: Biomass deployment for primary energy under the Strategy's medium feedstock availability scenario with and without CCS (TWh / year)



Source: DECC, et al., 2012, p. 41

Figure 6.2: Transport biofuels only - Biomass deployment for primary energy under the Strategy's medium feedstock availability scenario with and without CCS (TWh / year)



Source: DECC, et al., 2012, p. 41 edited by the author to include transport biofuels only.

Due to the limited impact of CCS on the future expectations for biofuel production it will not be examined in detail in this thesis.

6.2.2 Distilling a Policy Vision

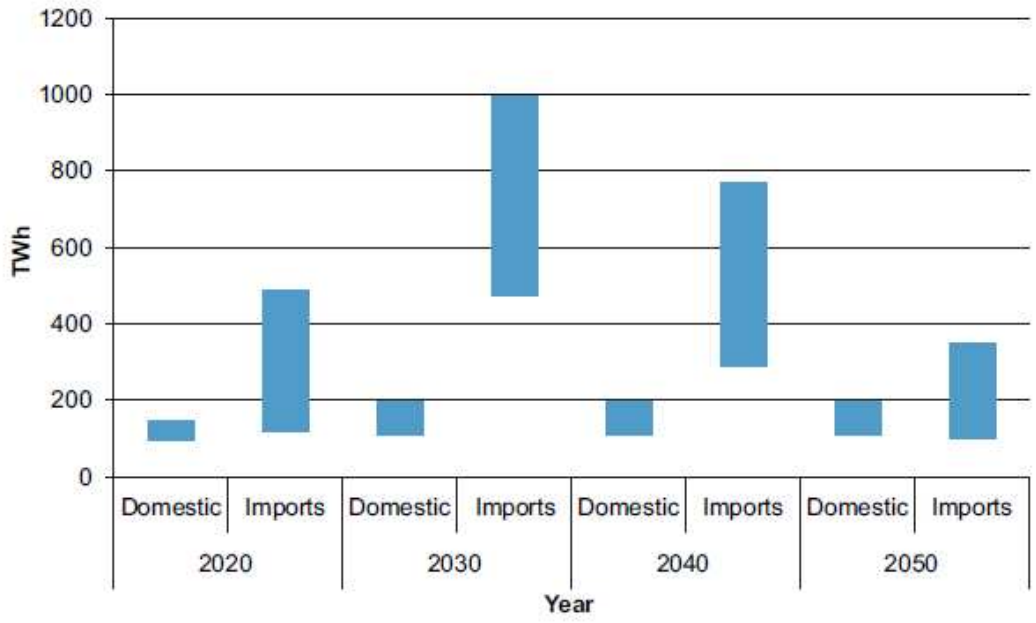
Within the Strategy I have identified four major expectations performed through modelling scenarios that together discern a loose vision of a future biofuel system. I will now examine these expectations and assumptions about the future for a UK biofuel system in turn.

Firstly, first generation biofuels are expected to persist, but decline as they "are superseded by advanced fuels" (DECC, et al., 2012, p. 32) over the medium term, shifting feedstock demand away from food crops. Significant future growth in the use of biofuels is linked to the development of lignocellulosic technologies (ibid, p. 8) due to sustainability concerns. However, the assumption of succession implies that lignocellulosic technologies will be situated in some sort of hybrid biofuel system, with food and non-food biomass fuels being utilised to produce liquid fuels. Likewise given the future vision of the biorefinery in which a suite of technologies are incorporated to processes biomass into a spectrum of marketable products and energy (Cherubini, 2010) this raises question about how the sector will be technologically configured.

In the broader literature, first and second generation bioethanol technologies are assumed to have some prospects for integration into a singular platform (Dias, et al., 2011; Giarola, et al., 2011; Havlík, et al., 2011; Akgul, et al., 2012i; Akgul, et al., 2012ii; Dias, et al., 2012). Nevertheless Suurs & Hekkert (2009) argue that in the context of innovation systems in the Netherlands, first generation and lignocellouslic technologies connect to different knowledge bases and have separate sectoral backgrounds. This suggests that the integration of these biofuel technologies is not a given. The theme of integration, nascent within policy, was an important discussion point in the interviews with industry representatives and will be returned to in section 6.3.

Secondly, the future biofuel sector is expected to source biomass from domestic and international sources. This is a long-held UK policy expectation. The RTFO was devised to promote the development of international trade and domestic capacity to produce biomass and biofuels (DfT, 2007). In the Strategy, international trade is assumed to provide the lion's share of biomass requirements; mirroring the current situation in which biomass and biofuel imports dwarf domestic contributions (DfT, 2015i; DfT, 2015ii). That said, domestic production is expected to provide a modestly expanding and stable resource going forward to 2030 before stabilising until 2050. In contrast, access to international biomass is expected to decline significantly (see figure 6.3).

Figure 6.3: Range of domestic and imported biomass supply (TWh) implied by supply scenarios from 2020 to 2050.



Source: DECC, et al., 2012, p. 26

It is the domestic resource that is the main point of interest for this thesis. In the Strategy, domestic production is framed as contributing to the establishment of "a stable and secure biomass supply base for the UK bioenergy sector" (DECC, et al., 2012, p. 26), whilst offering "a continuing source of cost effective and sustainable supplies" (ibid, p. 54). Therefore domestic biomass production is envisioned to reach a modest scale to meet the needs of a future biofuel industry. The question of scale and specifically what capacity the UK has for achieving biomass and biofuel production at large scale, will be returned to in section 6.3.

Thirdly, the Strategy identifies miscanthus and willow, grown on marginal land, and agricultural residues such as straw as the principal feedstocks constituting the domestic biomass resources modelled above. The assumptions and expectations regarding straw and energy crops grown on marginal land will be covered in Chapters Seven and Eight, respectively. As such they will not be discussed in more detail here, except to highlight them as key components for feeding the future biofuels industry in the UK.

Fourthly and finally, the Strategy places emphasis on both the development of industrial processing assets (and the technologies required to make them commercially viable) and the farmer adoption of energy crops as crucial factors in enabling the development of biofuel supply chains in the UK. Importantly, the Strategy maintains and legitimises existing subsidies and incentive regimes, which at that point in time included the RTFO incentives to biofuel producers and blenders and the Energy Crops Scheme (discontinued as of 31st December 2013) which provided direct capital grants to farmers and was administered by Natural England and the Forestry Commission. The document itself and the support mechanisms it endorsed explicitly situate industry and farmers as the key actors in facilitating the development of biomass supply chains and production chains.

The Energy Crops Scheme 2000- 2013 required farmers to have secured a supply agreement with an end user as a condition of receiving the grant. The limited subsidy regime established and unchallenged in the Strategy has an explicit demand-led emphasis. Strategy modelling assumptions support this emphasis. For example, modelling assumptions link farmer adoption of dedicated energy crops directly to price which in turn is linked to upstream industry development.

Such assumptions are also present in the broader literature. For example, Thomas et al. (2013, p. 108) argue "… farmers want security of demand before they will invest in cultivation and commit land [to energy crops]. … the requirement for long-term feedstock supply to a plant should theoretically provide this demand security…". Sherrington et al. (2008) take this further, suggesting that the lack of demand from a diverse range of energy users is hindering the market. Farmers dislike only being able to sell to power stations because they believe they offer the lowest prices due to the nature of the electricity market (Sherrington, et al., 2008).

However, interpreting farmer decision making as originating from price, which is assumed to signal sufficient demand for a product, fails to recognise the mutual nature of demand and supply that is necessary in running any biomass based processing enterprise. Investments in biofuel and bioenergy facilities require

'proofs' that sufficient and secure feedstock can be sourced, this will be covered in more detail in subsection 6.4.1.

In addition, the Strategy does not examine how this demand is translated through intermediaries into forms that have relevance to farmer decisions. Such translation may take the form of farm businesses and/or crop advisors signposting emerging opportunities or crops of interest, or contractors exploring opportunities to manage land for the purposes of certain end users. The omission of intermediaries and their role in biomass supply chains will be discussed in section 6.4 of this chapter and will be returned to again in Chapter Seven. In this chapter I will mainly identify their important role in securing feedstocks for existing biomass producers and the work that this requires. In Chapter Seven, I will build on this further in the context of straw where intermediaries are shown to have an important influence on farm decision making about straw management, and thus its availability for bioenergy or lignocellulosic biofuels.

Furthermore, a potential consequence of this farmer/intermediary interaction is that it favours the use of existing agricultural residues which have established networks over developing new crop sources that have long lead in times and a poorly established production base. This may undermine the optimistic claims made about the future prospects for energy crops, as 'demand' is channelled into specific feedstock chains that can most readily translate demand into supplied feedstock due to existing networks of intermediaries and production through current practices. I will return to this point in Chapter Seven and Eight.

In summary, this analysis suggests that UK policy envisions a future biofuels sector that consists of first generation and lignocellulosic biofuel technologies (although how these technologies interact is left unsaid), based on a modest but nevertheless important domestic biomass resource base, which will be facilitated through state interventions targeting farmers and industry. I intend to provide nuance to certain aspects of this vision through drawing on interviews with industry representatives (section 6.3). I will then move on to draw attention to the important role of supply chain intermediaries such as merchants and

contractors and the implications this has for future biofuel supply chains (section 6.4).

6.3 **Nuancing Policy Visions**

With the government aiming to not pick winners this section examines two expectations identified above from the perspective of industry actors. Firstly, this section examines the potential for lignocellulosic technologies to find synergies within the emerging biofuel and bioenergy sector in the UK (sub-section 6.3.1). It then moves on examine the issue of scale (sub-section 6.3.2), exploring what scale of biofuel industry might be supported by the domestic biomass resources identified in the Strategy.

6.3.1 Exploring Hybrid Technology Configurations

The Strategy produces a vision in which lignocellulosic and food based first generation technologies co-exist within the biofuel sector. This section is interested in exploring the nature what this coexistence might look like in practice. Will lignocellulosic processing facilities be independent of existing first generation biofuel production, will they be integrated into existing biofuel production as an extension, or as an add-on to a different biomass processing facility, bioenergy or CHP for example.

This type of integration is discussed in the wider modelling literature (Dias, et al., 2011; Giarola, et al., 2011; Havlík, et al., 2011; Akgul, et al., 2012i; Akgul, et al., 2012ii; Dias, et al., 2012), and is an important aspect of the biorefinery concept (Cherubini, 2010) that underpins expectations about the future bioeconomy. I draw primarily on interviews with industry representatives which includes bioenergy and biofuel producers, alongside energy consultants specialising in biomass sector.

The potential for lignocellulosic technologies to be integrated into different biomass processing platforms was a prevalent theme that emerged from the interviews with industry representatives. The assumption that lignocellulosic technologies might find themselves operating in tandem with other systems is not unfounded. First generation technologies have found opportunities for deployment via an add-on relationship within existing food processing

infrastructures. As the following interviewee notes this was part of a strategy to add value through diversifying their product portfolio:

> P05: let me try and put it this way, erm, … [they] were looking at building value [with] … bi-product sugar streams from their processes and they took a side stream off from a facility in *[place name removed]*, … and then worked with a company on … a continuous fermentation process to ethanol which they sold into the road transport fuel pool.

This UK experience reflects developments elsewhere. In Guatemala, for instance, fuel ethanol production is just one part in a value added chain in which multiple products are derived from the processing of sugarcane (Tomei, 2015). The potential to add first generation production technologies onto an existing biomass processing platform was an attraction for at least one incumbent processor, although the UK has otherwise seen the development of dedicated bioethanol plants. Lignocellulosic technologies are assumed to offer similar potential.

Rather than finding synergies with first generation biofuel technologies, the broader expectation from interview participants was that existing or future bioenergy facilities, paper and pulp mills or waste processing facilities should offer the greatest opportunities for a lignocellulosic plug in. As one interviewee recounted:

> P07: If you look elsewhere in Europe where … there's strong lignocelluloses biofuels industry being develop[ed] it is often in association with other industries, … for example with the wood processing industry, the paper and pulp industry.

In Europe then, the existence of systems that already handle and process lignocellulosic material was providing a niche within which lignocellulosic innovation and learning was taking place.

These prospects for integration with existing biomass processing facilities were also being explored in the UK as the following quote suggests:

RH: So have you ever been approached by a company that's interested in producing lignocellulosic biofuels?

P04: … we well we have worked a little bit with other companies that are interested in that sort of application … [then for] us to utilise the fibrous left overs, … to make sure that maximum value is extracted.

The integration with a bioenergy facility allows a number of efficiencies to be realised, as noted in the following interview:

P01: … I think for example you could develop a straw based or woody product based bioethanol plant and if you situated it next to a [bioenergy] plant similar to ours you could then provide heat and power one side, then you can provide the waste, some of the glucose type waste and so on are burnable in our type of plant, so you could actually have a fully integrated process which would use all of those.

It is unclear whether these sort of opportunities for sharing power, heat and waste as a means of developing a closed system can be realised in the context of an integrated first and second generation plant as this was not explored explicitly in the interviews. However, later in this section the development trajectories of first generation plants will be considered together with how this impacts on lignocellulosic opportunities.

Returning to an integrated lignocellulosic biofuel – bioenergy facility there are also possibilities for combined handling systems. Again first generation technologies in the UK based on wheat and sugar beet do not immediately lend themselves to integration with lignocellulosic technologies that would require different feedstocks, with different characteristics and handling requirements. Although the handling and storage of grain for industrial processing is well established, the quantities of biomass required for energy production produce new learning and technical challenges and risks. As one bioenergy facility representative noted:

P04: [Biomass] is quite different, we have had to redesign, I mean one of the key drivers at the moment is to change our materials handling systems … biomass is dry and dusty, you can't afford to let it get wet, … it self-heats quite aggressively if you don't manage that properly and can cause fires and explosions erm, … it can be hazardous to health and some biomasses can generate allergic reactions so, we have had to completely redesign our materials handling systems.

Both bioenergy representatives interviewed mentioned that they had been approached by companies interested in integrating lignocellulosic projects in the future, whilst a consultant also mentioned these emerging synergies. This suggests that integration of lignocellulosic technologies into a facility that has already undertaken the required learning and tinkering to handle biomass safely and efficiently is deemed attractive.

In contrast first generation biofuel producers in the UK were exploring different future priorities. These innovation pathways were not immediately conducive to the emergence of a lignocellulosic industry. Whereas current lignocellulosic research is concerned with grappling with the complexities of scaling up the pre-processing steps to breakdown lignocellulosic material, first generation incumbents were interested in developing more advanced biofuel molecules such as biobutanol.

Biobutanol is an attractive substitute for bioethanol with its higher energy content, lower water absorption, and thereby reducing instances of separation when blended with gasoline, alongside requiring fewer modifications to traditional engines to work at higher blends (Dürre, 2007). Therefore, the imaginary of substitution does not end with bioethanol, but instead pushes innovation to find less disruptive, more efficient and effective substitute fuels. Currently biobutanol conversion suffers from lower fermentation efficiency in comparison to bioethanol making it commercially unviable (Pfromm, et al., 2010).

Obviously the development of biobutanol does not exclude lignocellulosic technologies which would presumably be able to adapt to the different fermentation process within a biobutanol system, for example by using different yeasts. However, the different material characteristics of first and second generation feedstocks create additional requirements that mean the existing capacity and the current development trajectory of first generation plants favours the continued use of grain feedstocks:

> P05: … we are an ethanol … fuel company, the plant has the potential to be converted into biobutanol … should the most efficient route to biobutanol … be developed …. I would imagine that [would be] still pretty heftily based on grains … with the front end process that *[company name removed]* has at the moment … but that doesn't mean to say that the front end can't be changed

Therefore the potential for adding on the additional processing pathway does create options for hybrid first and second generation facilities. That said, the general theme across the interviews was that lignocellulosic technologies were likely to find greater purchase in the UK and Europe when proposed integration was into systems that already deal with lignocellulosic biomass, whether that be for energy or not.

6.3.2 Potential Scales of Biofuel Production

The scale of biofuel development has been a major point of contention. However, scale has two interlinked but nuanced dimensions within this discussion. The first relates to the scale of feedstock production and its negative externalities. As Mol (2007) notes, the large feedstock demands for biofuels have driven the environmental and social controversies associated with biofuel expansion. Particular focus has been drawn to large scale deforestation and land clearance to facilitate the establishment of large scale homogenised agricultural plantations. This has involved the destruction of biodiverse habitats and their replacement with monoculture landscapes that rely on chemical inputs to control pest species, disease and maintain soil nutrient content (Phalan, 2009). Furthermore, these agricultural expansions have displaced local people, eroding

their livelihoods as they are legally or illegally ejected from their land, shifting their roles from that of subsistence farmers to wage-labourers on the very plantations that displaced them (Tomei, 2015). In contrast to these large scale responses to EU and US policy are what Mol describes as 'local biofuel regions' (Mol, 2007, p. 305) where small-medium scale feedstock and fuel production and consumption occur within the same locality. These have not faced the same levels of controversy or scrutiny.

The second relates to the scale of biofuel and biomass trade networks. van der Horst and Vermeylen (2011) argue that considerable environmental and social harm is associated with a dominant North-South global biofuel network, which has seen investment in feedstock and fuel production move to the global South to take advantage of weak governance regimes (van der Horst and Vermeylen, 2011) whilst the global North consumes the finished product. Due to the assumption that the positive social impacts from biofuel production would emerge automatically due to the development of new markets for agricultural produce, rather than requiring specific tailoring to ensure rural development benefits flow to poor and vulnerable farmers, this North-South configuration has yielded the worst results. In essence consumers in the global North outsource the negative consequences of monoculture feedstock production to so called 'pollution havens' (Cole, 2000; Cole & Elliot, 2005). As noted by Raman and Mohr (2014), EU biofuel policies are implicated in the formation of problematic, large scale feedstock and fuel production, situated within a global trade network. EU targets, even the relatively modest initial blending goals, demand significant absolute quantities of biofuels that have not been forthcoming from domestic and inter-EU resources alone. Furthermore, national policies such as the RTFO delegate decisions regarding the type of feedstock, biofuel and the place of its production to the market.

Despite this, the prospects for domestic production in the global North are perceived as more socially equitable. "In the case of domestic production and consumption in developed countries, the social impacts are relatively minor and can be mitigated by social policies" (van der Horst & Vermeylen, 2011, p. 2442). Therefore different scales of production across different geographic boundaries

are framed differently, with large scale, export-orientated networks of biofuel and feedstock trade perceived to be socially and environmentally problematic whilst those at local, regional and national production scales are regarded as more acceptable.

As noted in section 6.2, UK policy modelling suggest that the UK has some domestic potential to develop a national biofuel system, with lignocellulosic technologies perceived as offering greater prospects that their predecessors. For example, the *UK Renewable Energy Strategy* produced by HM Government (2009) suggests:

> "It is feasible that given the development of more advanced technologies for producing biodiesel and bioethanol we could use a greater range of biomass feedstocks (crops and waste), increasing domestic supply of biofuel further." (p. 29)

As shown in Chapter Five, the flagship UK biofuels policy, the RTFO, has so far stimulated three domestic bioethanol plants. The amount of bioethanol produced from UK sourced feedstocks reached 10.3% in year six of RTFO accounting. As noted in sub-section 6.2.2, although the Strategy does not expect this situation to fundamentally change, it does expect a modest domestic capacity to develop biomass-based energy production. This was an expectation, mirrored to varying degrees, by most of the industry representatives interviewed.

However, the anticipated scale of production attainable from domestic resources differed considerably. The most optimism for expansion originated from participants that represented medium sized facilities. The following quotes are in response to a question about the capacity of the UK to develop a domestic biofuel industry based on first and second generation technologies

> P05: I think it is reasonable there is room [for] about 3 maybe 4 … plants about the size of *[company name removed]* within the UK alone.
>
> …

P04: … yes I think it could, … what the UK could do is, is utilise its land more effectively … [and develop] a diversified of fleet of small generators and that would be at a reasonable scale and would make a real contribution

In the above interviewees' opinions the UK was deemed to have sufficient unexploited cellulosic resources to provide for future expansion. But there were also limits to this expansion. As one representative put it:

P04: I don't think the UK could support a plant like Drax [on biomass]…

The amount of feedstock demanded to power a major power station such as Drax, the largest coal fired power station in the UK which is responsible for 7-8% of UK electricity demand (Drax, 2015), was seen as unfeasible if based solely on UK resources. Drax has turned to North America to source its woody fuel requirements. Therefore it is in the range of medium scale facilities that industry representatives believe the UK has the capacity to develop further on the basis of straw and energy crops.

The above limitations on the projected scale of a domestic industry were based on the perception that the UK had restricted capacity to produce sufficient feedstock at commercially viable costs in a concentrated area to minimise logistical constraints:

P06: I think there a number of challenges that the UK faced that are primarily feedstock based, … the question is can you get the scale, can you get the price that makes it effective. … [is] there sufficient area where you can get concentrated production and supply to produce in that area.

…

P07: if you add that together then with the fact that feedstocks could be produced generally cheaper elsewhere and the technology is currently being produced elsewhere I am not convinced that in the near future at least that we will be developing domestic production of liquid biofuels on a significant scale.

The scale, concentration and cost of feedstock production were all identified as major hurdles to developing an industry of significant scale in the UK. The concentration of feedstock production within a small area located around a production facility was seen as complicated in the UK due to longstanding patterns of land use and the poor uptake of energy crops.

However, this discussion of scale is also bisected by feedstock type. Agricultural residues and dedicated energy crops were deemed by different respondents as having unique challenges and advantages when it came to supplying a future industry of scale.

The following quote emphasises the key advantages of straw:

> P01: I do I do I think er I mentioned that there is purportedly 6 million tonnes of straw out there as a product that's all UK based

Indeed during the writing of this thesis, the UK has seen an expanding bioenergy sector utilising straw. This has included the commissioning of a straw fired power station at Sleaford in September 2014 (Glennmont Partners, 2014), with another two due to be completed at Brigg by early-2016 (Burmeister & Wain, 2015), and Snetterton by mid-2017 (Eco2, 2015).

But straw was not always viewed favourably with three of the seven industry representatives perceiving straw as problematic. The following quotes highlight the main issues:

> P06: we need to have … supply costs of less than $50 per dry tonne as a credible route, in order to make the process … investable.
>
> RH: Right, ok, and how do you say that compares with feedstock prices in the UK currently? Because that does seem very significantly lower than even straw prices currently in the UK.
>
> P06: … our perception is that agricultural wastes like straw … will be a relatively high cost feedstock because of the need to collect over a wider area and store them, and get sufficient quantities to make a scalable cost effective facility. … we believe that long term

agricultural wastes will be part of the supply chain but they will not be cost advantaged ones.

…

P01: … big transport issues associated with it because straw is a very low density fuel, even when you bale it it's still fairly low density and its very bulky to handle so transport costs are high so that means unless you use it as a local product …

Securing efficient returns on capital investment favours a larger scale plant. However, the dispersed nature of straw meant it was perceived as difficult to concentrate biomass production in a specific area to adequately meet the logistical requirements of a large scale biofuel or bioenergy plant. This is compounded further by what interviewee P01 notes as the low energy density of straw even as a baled product. Straw use favours more localised scales of production; it is worth noting that the three straw based power stations at Sleaford, Brigg and Snetterton were all in the 40MW region. In contrast, Drax which one respondent deemed too big to be supported solely on domestic biomass resources, currently has a capacity to produce 3,960MW from coal, and increasingly, imported wood pellets (Drax, 2015).

Although four of the seven industry respondents expressed a preference for energy crops as the feedstock offering the best capacity to supply large scale lignocellulosic developments, they expected problems. As the following quote emphasises:

P02: … when the policy [Renewable Obligation] was first thought about the aim was local, indigenous, energy crops and that just really hasn't happened at the scale that it should have.

The failure of the Renewable Obligation and the Energy Crops Scheme to stimulate energy crops means that the UK struggles against imports of cheaper alternatives. In addition, the decision to discontinue the Energy Crops Scheme means that there is no longer a capital grant to ease the high establishment costs of these crops. For P06, the modest capacity of the current UK regime, and the

unfavourable feedstock production conditions did not provide the appropriate conditions to facilitate lignocellulosic industry emergence:

> P07: I have no seen major policy support for the development for lignocelluloses biofuels … unlike other countries that are actively supporting research in the area, actively supporting demonstration and pilot plants, we don't get that in the UK, … if you add that together then with the fact that feedstocks could be produced generally cheaper elsewhere and the technology is currently being produced elsewhere I am not convinced that in the near future at least that we will be developing domestic production of liquid biofuels on a significant scale.

As the following quote outlines, other parts of the world are a more likely prospect for developing a commercial industry:

> P06: I mentioned the lignocellulosic biofuels, we believe that the two countries that are best advantaged for deployment of that at the moment are Brazil and the US, based on combination of price of feedstock and clarity of the regulatory environment.

Current market and regulatory conditions are perceived to prohibit the emergence of lignocellulosic biofuels processing in the UK. Whether the UK will become a site for these technologies once commercial viability has been established elsewhere is however still open to debate.

Furthermore, as sub-section 4.3.1 outlined, there are niche opportunities in the UK that could bear fruit in the future. The government has recently awarded £25 million in capital grants to develop demonstration scale advanced biofuel production plants in the UK (DfT, 2015). Domestic opportunities are still being explored and supported by the government.

6.4 **Complicating Supply Chains**

This section will critique the final assumption that farmers and industry are the key supply chain actors by introducing and analysing the role of intermediaries in biomass supply chains. It will primarily examine the interaction between

intermediaries and industry. Firstly, I will examine the work undertaken by these third party intermediaries (sub-section 6.4.1) before exploring the informal networks of trade that sustain the straw market (sub-section 6.4.2). Thirdly, I will briefly reflect on what this analysis means for energy crops (sub-section 6.4.3).

6.4.1 Supplying Biomass: Role of Intermediaries

A major absence from expectations of how a future domestic biofuel system will be facilitated is the role of intermediaries. This chapter is primarily concerned with merchants and contractors and the straw market. Straw is a widely traded product, important in livestock agriculture, and the market has a well-established set of actors providing services and trading straw. In contrast, energy crops have a more tentative supply chain with a history of bankruptcies amongst past intermediary companies (see sub-section 6.4.3). Due to the greater stability in straw networks, it is this supply chain that will be examined here as an example. Furthermore, the role of advisory services, another form of intermediaries influencing biomass management practices, will be covered in Chapter Seven.

As explored in subsection 6.2.2, policy modelling and incentives privilege the farmer as the crucial supply chain actor, adopting crops and practices. The only suggestion in the Strategy that other actors have a role is recognition of the difficulty in upscaling energy crop planning due to restricted capacity for establishing and harvest energy crops (DECC, et al., 2012, p. 28). This is the strongest acknowledgement that intermediary actors are an important component in constructing and maintaining biomass supply chains.

Within the wider supply chain modelling literature the role of intermediaries is devolved to 'logistical' and 'transportation' constraints (see Akgul, et al., 2012i; Akgul, et al., 2012ii). These constraints shape supply chains as they influence the models' efforts to optimise efficiency and minimise cost requirements. However, the work undertaken by intermediaries in enabling emerging and maintaining existing biomass supply chains is obscured.

The ‘middlemen’, in the context of straw chains include merchants and contractors and hauliers who undertake the physical and social work that brings the product from the field to the end user.

Baling contractors, as their name suggests, are involved in the baling and removal of straw from the fields. The importance of these intermediaries relates mainly to their provision of the capital intensive equipment required to bale and handle straw (and miscanthus and SRC willow). Gradual upscaling of all farm equipment has added to this capital investment burden for farmers. A telling theme revealed during the farm walks with arable farmers was that their own baling equipment (if it existed) was often second hand and configured to produce smaller bales for personal use or for sale to local horse owners. Baling contractors on the other hand were often able to justify larger investments due to baling across a large acreage for a number of farmers that delivered sufficient economies of scale denied to an individual farmer. Furthermore, baling contractors usually owned the equipment necessary to produce the large Heston bales which are the desired bale for industrial users (see Chapter Seven, sub-section 7.4.1) and are thus an important linchpin in the collection and baling of straw.

Straw merchants purchase the straw from the farmers or contractors, although it is important to note that many straw merchants also provide baling and haulage services. Therefore straw merchants can perform a range of roles. Here, however, I will focus on their role as a conduit for straw trading. Merchants are a focal actor that produce and maintain the linkages between farmers, contractors and end users. In this role they negotiate the sale and delivery of straw to end users whether energy producers, livestock farmers or compost producers, to give some examples. In the course of my interviews it became clear that straw merchants often negotiate some formal but predominantly informal contractual relationships with farmers and end users (see later sub-section 6.4.2).

Straw hauliers are involved in the loading, transport and unloading of straw. Although some straw merchants operated their own haulage business,

interviews suggested that this was largely a 'for hire' job. The following quotes emphasise this point:

RH: Yeah and do you run a haulage operation as well?

S03: No … we sell it for another company and they have the contacts to deliver it on the farm … as the haulier.

…

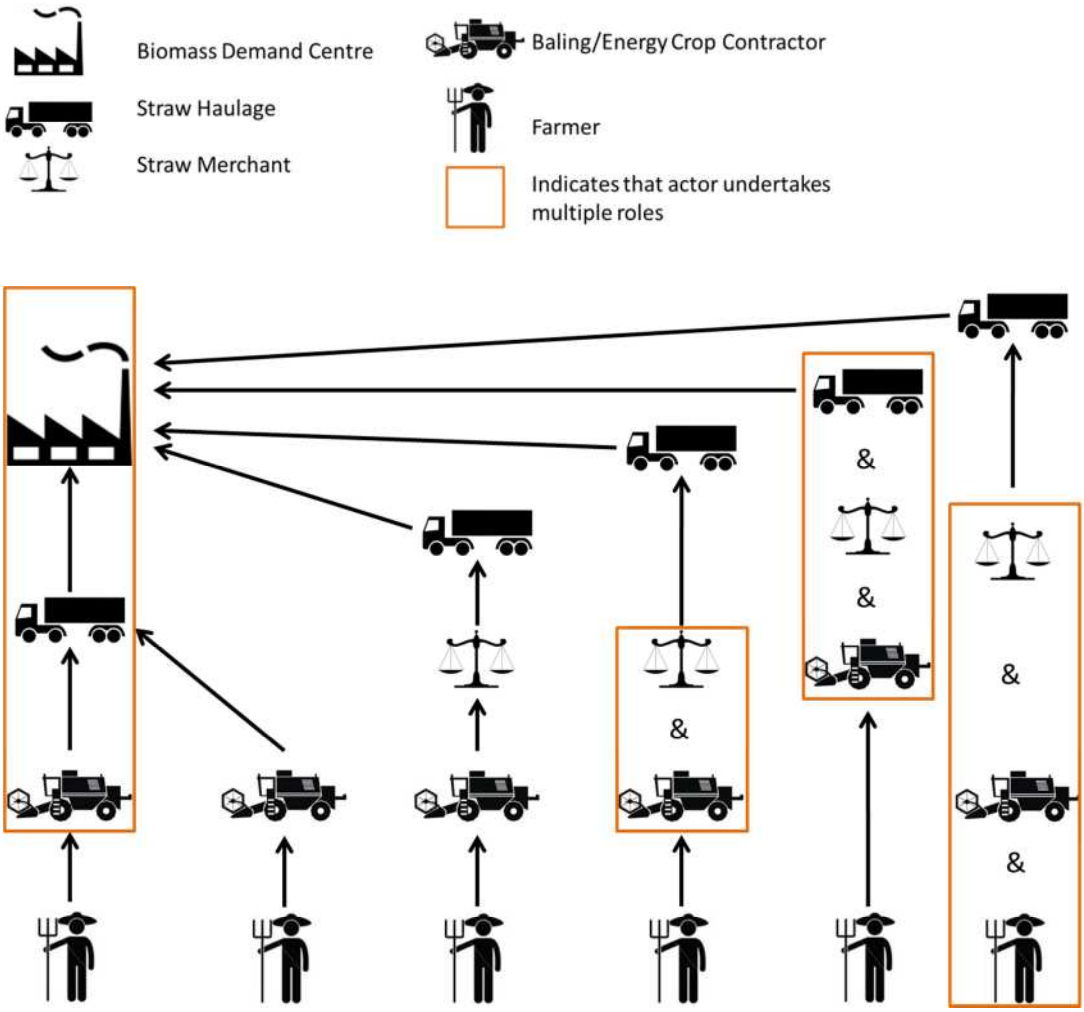
S04: No we don't run lorries, … there are plenty of people with lorries, haulage people looking for work, mostly flat beds

Outside of the straw merchants operating their own haulage the thesis did not gather evidence to suggest that straw haulage was in any way a specialist task and therefore appeared to be undertaken by general hauliers.

These intermediaries may undertake one, two or all three of the main roles outlined above; furthermore several of those interviewed were also farmers themselves. In the context of a network supplying a bioenergy or biofuel facility, each facility will liaise with straw merchants and contractors to ensure that they secure sufficient product to feed their process. In addition all straw-based energy producers interviewed sourced some of their feedstock via their own vertically integrated subsidiary that organised the harvesting, collection and transport of straw often within the near vicinity of the plant. How these different configurations come together to supply a single facility is outlined in figure 6.4, produced by the author.

Figure 6.4: The numerous actors, their potential roles and inter-relationships that facilitate a biomass supply chain

Key



Source: Figure produced by the author

As figure 6.4 shows, straw-based energy supply chains involve numerous actors, connecting a single plant to a wide range of farmers, contractors, merchants and hauliers. Therefore a single supply chain demands connections between a complex arrangements of actors, held together by informal and formal personal and contractual relationships. The importance of these third parties should not be under estimated. As the following quote makes clear the majority of feedstock is sourced via these intermediaries:

> P01: We have two lots of things, we have our own straw purchase so a business a relatively small percentage 25% of the straw we do all of the work ourselves… the remainder is all done though contracted supplies.

This raises a further point about managing these relationships. Costs and money inadequately convey the work that goes into getting straw from the field to the end user. It is important to note that bioenergy users tried to manage intermediaries in such a way as to cultivate, at a distance, a good relationship with the farmer:

> P01: … we go out to a number of suppliers … who then contract back through the process to the farm and it is making sure that we have the right relationship with the contractor and that he then passes that relationship on to the farm to make sure that it all works …

This quote implies that logistics involves much more than cost; it involves managing personal and professional relationships between different actors, both through direct and intermediary actions. Therefore relationships between farmers, third party contractors and merchants and bioenergy end users are interwoven with social connections. These will be explored in the context of the farm in Chapter Seven.

The final role of intermediaries is that of supporting energy developments through committing to supply straw. Merchants and contractors are important gatekeepers to the market. Their enrolment in existing bioenergy schemes was an important part of the business case to secure investment as the following quotes make clear:

> S07: [a energy company] couldn't get the financial backing unless they knew that they could get a supply of straw, so another company went around lots of straw merchants and we had to sign up to supply the factory
>
> …
>
> S05: Well it is quite easy to find investment to, build a plant, and it's not too difficult actually to get planning permission. None of these things go any further unless you have got somebody who is

prepared to stick their neck out to find the fuel, which is the straw or a biomass product.

Prospective energy developments routinely approached straw merchants, and not all agreed to supply straw, preferring to maintain long standing relationships with existing livestock farmers.

The relationship between straw intermediaries and the energy industry was also perceived to be having a shaping effect on the straw industry. The presence of large bulk straw buyers was noted by some as driving increased professionalism of contractors. Greater professionalism was linked to increased capital demands for new baling equipment and the need to ensure farmers continued having their straw baled. However, as a straw merchant remarked, it was energy users not farmers that had underwritten the investments:

S05: ... you know [to] offset a lot of the costs of the machinery on baling large areas of rape straw, beans and linseed and things like this for power generators the same machines will bale the barley straw for wheat, ... nobody can afford to buy the machines just to bale a bit for the farming trade.

Although this straw merchant is perhaps downplaying the scale of demand from the livestock market, the presence of bulk, large scale and, albeit relatively low price buyers was perceived as benefitting straw users, not only through underwriting the cost of new machinery but also by demanding a more efficient baling service. This has translated into improved reputations amongst arable farmers with implications for on farm practices which will be covered in Chapter Seven (sub-section 7.3.4).

Maintaining trust and good relationships between farmers, intermediaries and buyers is therefore important for facilitating baling. So far this has been examined in the context of relationships between intermediaries and the energy industry, but it also has important consequences for the resilience of local markets against external pressures which will now be covered.

6.4.2 Resilience: International Trade and Informal Agreements

Straw, as discussed in UK policy and by industry representatives, is assumed to be a UK based product, implying that it is predominantly available to UK based actors. This is supported by further assumptions that highlight the costly logistics of using straw for energy purposes. Consequently, straw is assumed to be a nationally bounded resource.

But interviews with arable farmers and straw merchants highlighted how straw is traded inter-regionally *and* internationally. The weather was a major driver of this international trade as the following quote suggests:

> S07: …they don't grow enough in Holland as they import it. Two years ago, France had a very bad [harvest], we had a reasonable harvest and so there was importing a lot of straw from the UK.

Country specific deficits in straw production and poor conditions elsewhere create annual uncertainties that impact on the market (Mohr, et al., 2016). During these occasions local UK markets are placed under considerable pressure as new entrants are often willing to pay high prices to secure the straw they need. It is here that maintaining strong local connections and good relationships becomes particularly important as a straw merchant makes clear:

> S02: Erm like I say it's not a stable market, ... one year you hear nothing from them [Dutch, French or Irish Farmers] and then another year two lots turn up and it has a massive pull on the local market kind of thing, ... they can pay more than what we can. ... you just can't compete with them like, but then again a lot of my people won't sell to them because they want me there another year.

In these instances, being a customer outside of these more established merchant networks, driven by price interest and therefore shopping around to find the lowest price, was potentially a disadvantage:

> S06: I have … 2-3 calls a week from farmers wanting to know how much I am selling my barley straw for in Cheshire and then they will turn to 2-3 other people and just buy the cheapest. They suffer a little

bit … when the demand is greater than the supply because er, we look after our regular customers.

Although both relationships are price sensitive, mercenary, price-driven strategies of sourcing straw, in which farmers take on the role of economically rational actors, becomes a disadvantage when the straw market tightens. However, my research suggests that these relationships between merchants, farmers and end users are not secured through formal contractual agreements.

Work by Glithero et al. (2013ii), suggests that farmers are often unwilling to enter into long term contracts with energy suppliers to supply straw. This was mirrored in my research but between the merchants and farmers. The vagaries of the weather impacted on the amount of straw produced and the ease with which it could be removed from the field. Understandibly, a consequence of these uncertainties was that negotiations for straw were often conducted on an ad hoc basis. Gentlemen's agreements, sealed with a handshake over a kitchen table, or in the field from which straw was to be baled, underpinned straw arrangements. Likewise the sale of straw to livestock farmers was similarly flexible and uncertain, with orders being placed as and when by the farmers. Nevertheless these arrangements were often very longstanding:

S01: I usually … carry on going to farms, going on to some farms for 50-60-70 years.

RH: So there are some long standing relationships?

S01: Yes long standing relationships with a lot of farmers

RH: Do you think that's important to your line of work?

S01: Er yeah well it is, it gives you, it gives you know it gives you a bit of satisfaction you must be doing something right,

This highlights another aspect to these longstanding connections. They provided straw merchants not just with business resilience against short term volatility in the market, but also job satisfaction.

Although at a farm level uncertainty is managed by informal arrangements, energy actors prefer to secure longer term contracts for set quantities as a means of guaranteeing supply. It is here that merchants provide an important link. In subsection 6.4.1, it was noted that securing supply arrangements was an important part of the investment case for prospective bioenergy projects. In contrast to farmers, merchants are potentially more able (due to dealing with larger quantities of straw than an individual farmer) and interested (due to securing investments in machinery) in signing longer term contracts. As the following straw merchant notes:

> S07: … [we] sign[ed] up to supply the factory for a 15 year period…

Merchants are therefore actors through which large scale industrial users can gain a level of security and resilience against volatility in supply which is limited when dealing directly with farmers.

In summary, intermediaries undertake a significant amount of the work that enables bioenergy facilities to meet their feedstock needs, whilst maintaining professional and personal connections that bring a significant amount of resilience to straw markets in the face of new entrants. Their absence from modelling obscures this important work and the following section will briefly reflect on the implications of some of these findings for considering the future prospects for energy crops.

6.4.3 Intermediaries and Energy Crops

This section has so far argued that intermediary actors are important to the functioning of the straw market. If this is the case, in what is the role of these actors in the context of dedicated energy crops? Energy crop establishment whether for miscanthus or SRC willow requires specialist equipment that is unlikely to be owned by the farmer who instead contracts out establishment and harvesting services.

Energy crops contractors and intermediaries have had a difficult history. However, it has been the bioenergy plants that have been a major stumbling block with varying implications for the future prospects for energy crops in the

UK. The Ambient Energy project, which proposed to use 3000ha of SRC willow, failed to gain planning permission in 2000 due to sustained local opposition (Upreti & van der Horst, 2004). But the most prominent was the collapse of the ARBRE project in 2001. Consisting of 1800ha of SRC willow planted by local farmers and a power plant utilising gasification technology, the ARBRE scheme near Eggborough (Yorkshire) constituted the biggest single planting of energy crops in the UK at the time (University of Cambridge & Scottish Agricultural College, 2005). A promising future turned to farce when the plant closed after eight days of operation due to technical issues, the contractor managing the crops went insolvent, and numerous farmers were left with planted willow, no contractor and no end buyer. This failure, has cast a long shadow over more recent efforts to stimulate the market by firms such as Terravesta (Adams & Lindegaard, 2016).

This debacle ended on a more positive note. The farmers involved established Renewable Fuels Ltd which took over the contracted management of the crops, and in 2004 developed proposals to supply Drax with the willow for co-firing (Drax, 2004). This episode has impacted on farmer analysis of the prospects for willow (Sherrington, et al., 2008). Although not the only factor, willow planting has remained stagnant (DEFRA, 2013).

Miscanthus has not seen an episode as significant as the ARBRE project failure. Nevertheless it's had its own share of problems. Companies selling and undertaking the contracted management of the crop have fared little better. As one agronomist noted:

> A04: … the miscanthus has had a chequered history; with the companies seem to be going bankrupt on a 5 yearly cycle almost really.

Straw merchants and contractors are important links in the chain, undertaking a significant portion of the land management and harvesting, building and maintaining relationships with farmers to produce biomass for energy users. Therefore, the instability of these actors is likely both a symptom and contributor to the continued lacklustre uptake of energy crops.

The Strategy's assumption that the right price will achieve adoption of miscanthus on anywhere between 0.72-2.80Mha of UK agricultural land[14] masks the hard work that needs to be undertaken in supporting intermediaries *as well* as upstream and downstream actors, if energy crops are to become established and widespread in the UK.

6.5 **Conclusion**

This chapter has aimed to discern and nuance a number of policy expectations about possible future domestic lignocellulosic biofuel supply chains. Despite the UK government's proclaimed reluctance to back specific technologies or configurations of biofuel production, four key areas of expectation and assumption making where identified: scale, technological integration, feedstock sources and supply chain actors. The first, second and fourth were examined in this chapter, the third regarding feedstock sources from agricultural residues and energy crops on marginal land, will be dealt with in Chapter Seven and Eight, respectively.

As Jasanoff & Kim (2009) argue, imaginaries are a collectively shared vision and are powerful precisely because of this. Although this has largely been explored in the context of imaginaries resonating with the wider public it also requires important groups of actors tasked with actually delivering the material artefacts of the vision to also be on board. This is particularly relevant given that government has no role in directly investing in biofuel production infrastructure instead establishing a market framework. Therefore the chapter has examining the vision for lignocellulosic technologies held by important industry actors. Building on the work of Levidow & Papaioannou's (2013), which suggests that high level imaginaries have the potential to mask competing visions between different groups, the chapter has shown that the imaginary of substituion masks potential disjuncture and cohesion between the state and industry visions for lignocellulosic technologies and their deployment in the UK.

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[14] This is between 4% - 15% of the UK agricultural land.

Section 6.3 drew upon interviews with industry representatives and explored issues of scale and technology integration. It highlighted both the mixed perceptions of prospects for developing a large scale lignocellulosic sector in the UK as well as opportunities for integrating lignocellulosic technologies into existing biomass processing platforms. With regards to scale, greater optimism was expressed for medium scale developments in line with existing bioenergy developments such as those at Ely, and Sleaford. Whether this scale is commercially viable for lignocellulosic technologies is yet to be seen. Beyond this scale would likely require the model employed by Drax which imports wood from North America due to insufficient feedstock being available in the UK.

Despite these scale limitations some optimism was expressed with regards to integrating lignocellulosic technologies into bioenergy production facilities with some tentative and emerging enquiries to this effect. The logic for this integration stemmed from the advantages gained through sharing feedstock handling with the waste material from the lignocellulosic processes feeding back into the combustion plant. In contrast, first generation production currently employs different biomass handling and processing technologies. It is obviously conceivable that this could be changed. However, first generation operators were interested in developing more advanced molecules over methods of processing different biomass. Therefore bioenergy facilities have the potential to provide a niche within which lignocellulosic technologies are initially deployed, integrating biomass handling, heat, power and waste disposal into a single system.

Furthermore, it contributes to the imaginaries literature by emphasising the prospect for divergence between a state imaginary and industry visions. This is particularly relevant in a world where neoliberal methods of governance predominate. With biofuels, governments have eschewed direct intervention or ownership of assets. This raises questions for the imaginaries literature not able to be explored here around the prospects for resistance emerging from the very industries and corporations that are expected to embed the material infrastructures and deliver technological projects. Equally, it touches on an finding of Levidow & Papaioannou's (2013) work in the context of bioenergy

policy in the UK, which is the suggestion that a cohesive high level imaginary acts as an umbrella to mask potentially competing visions.

Additionally, the biofuels literature has so far not engaged significantly with industry visions for biofuels. Instead it has favoured analysis of policy visions, the consequences of EU and UK regulations and their outcomes, as well as components of the various controversies and policy responses to this. By directly interrogating these industry held expectations this chapter contributes to addressing this research gap, expanding the understanding of the prospects for lignocellulosic technologies in the UK from an industry perspective.

Finally, section 7.4 explored the broader array of actors involved in biomass supply chains. The farmer is routinely positioned as the key actor in policy and the wider literature resulting in the neglect of other significant actors in the agricultural system. This chapter highlights the key role of intermediaries who play a vital role in an array of on-farm operations and in the straw market. Merchants and contractors establish and maintain contacts with farmers, they are more willing to sign long contracts with buyers, and they own much of the large scale machinery necessary to produce the largest bales desired by industry. For the straw market, intermediaries were shown to be crucial. This is an area ripe for further academic study as the literature on this group of actors is practically non-existent (see Ball, 1987 for a dated example). They also require greater consideration from policy makers aiming to deliver future socio-technical change to agricultural markets, whether as a result of biofuels or adoption of another upstream technology.

Although the policy neglect of intermediaries as important is perhaps admissible in the context of well-established straw markets, the lack of direct support for energy crop intermediaries has contributed to their instability. High profile bankruptcies have cast a shadow over the industry, which alongside stagnant demand has undermined the expansion of energy crops at present. The collapse of contractors who carry out the specialised work required to establish and harvest energy crops is likely to contribute to investment uncertainty, highlighting the unstable market within which they are attempting to operate.

This is particularly problematic if energy crops are to have a 20 year field life. Furthermore, the difficulties in developing a contractor base to undertake the specialist management of dedicated energy crops has not only undermined the attractiveness of energy crops, but also negatively affects the capacity to upscale planting of the crops if market or regulatory conditions change. If capacity is to be increased to meet energy crop expectations then intermediaries must be acknowledged as an important group requiring policy support.

7 Imagining Straw: Competing Uses and Material Complexities

7.1 Introduction

Straw has been identified as a key domestic resource; presently produced in significant quantities through traditional arable practices (DEFRA, et al., 2007; DECC, et al., 2012). As highlighted in Chapter Five, agricultural residues, framed as surplus to existing markets, or as wastes, have been situated as feedstocks that sidesteps land use change and food versus fuel concerns (RFA, 2008). Additionally, they are perceived to offer greater opportunities to embed the benefits of biofuel production, rural development and energy security, in the UK (House of Commons, 2003; House of Lords, 2006). Straw is therefore crucial to embedding lignocellulosic biofuel supply chains as a readily available surplus resource. This chapter explores the way in which straw is modelled within biomass resource assessments that have informed UK policy and research programmes. In particular I highlight the tacit assumptions embedded within these models through comparison with farm level practices and decisions regarding straw, and accounts of straw management from agronomists and straw merchants. This chapter draws attention to how straw management decisions, and the material heterogeneity of straw act to create barriers to energy use in certain instances.

The chapter presents the second component to the analysis of expectations and assumptions signposted in Chapter Five and contributes to answering research question two, focusing on the 'decision making and practices' component of the question: *What assumptions do UK biofuel policy models make about agricultural systems, decisions, and practices? How do they compare with on farm decision making, practices, values, and inter-relationships?* Through examining straw as an on farm resource and as a material, the chapter also highlights a number of additional opportunities and barriers to the use of straw in lignocellulosic biofuel systems and therefore contributes additional answers to research question three: *What are the opportunities and challenges, highlighted through*

understanding the agri-energy nexus, for the future emergence of lignocellulosic biofuels? To answer these questions the chapter draws upon documentary analysis of policy documents, the broader research literature and interviews with farmers, agronomists, straw merchants and contractors.

The chapter is structured into three main sections as follows. Section 7.2 briefly outlines some of the historical policy developments and actors involved in influencing straw management, before highlighting how straw has fallen off the statistical radar with no information gathered on quantities produced. The section then examines a number of studies that have aimed to cast light on the availability of straw for energy. I then explore some of the key assumptions made by these studies regarding the construction of straw as a resource. Section 8.3 then details how farmers manage and relate to straw within the context of their farms and the role of agronomists in influencing on farm decision making, particularly with regards to incorporation. It then moves on to analyse the role of merchants and contractors in facilitating the baling of straw, and the importance of trust in sustaining these relationships. Section 8.4 moves on to consider straw as a materially heterogeneous resource, with different straw types, qualities and bale sizes impacting on the availability and desirability of straw to different end users who have differentiated preferences. The section ends by drawing attention to opportunities brought into relief by considering material heterogeneity.

7.2 Imagining Straw: Expectations and Assumptions

This section first outlines the ways in which straw is situated within biofuel policy, and the expectations that suggest straw is largely available and a desirable feedstock for energy uses in the UK (sub-section 7.2.1). I will then examine how straw is situated in agricultural policy, drawing attention to past developments and intermediary actors that influence its management at present. The section ends by reflecting on what is (un)known about straw as a resource and the particular puzzle this creates for modelling its resource potential (sub-section 7.2.2). Finally, I examine biofuel modelling assumptions and expectations for straw within biofuel policy and academic modelling literature (sub-section 7.2.3).

7.2.1 Biofuel Policy Expectations

Straw is identified in numerous biofuel policy documents as a potential future resource for lignocellulosic biofuels. As such it is an important component in the delivery of a future lignocellulosic biofuel industry and thus is a key domestic resource underpinning an element of the future feedstock needs for delivering the substitution imaginary. Likewise, as noted in Chapter Five, in response to first generation controversies lignocellulosic technologies utilising straw is framed as one of the means of sidestepping controversial land use conflicts. For example the Gallagher Review identifies "encouraging technologies that utilise appropriate wastes and residues" (RFA, 2008, p. 9) as a means of developing a genuinely sustainable industry[15]. Therefore the ability to use straw underpins the claimed sustainable credentials of these emerging biofuel technologies.

Likewise straw has been identified by the Royal Commission for Environmental Pollution (RCEP, 2000; 2004) as an existing indigenous biomass resource that is potentially available in significant quantities for energy purposes. Its main advantages stem from its production from long established and well known land management practices and technologies (Glithero, et al., 2013i). Positive expectations also stem from the existence of Ely power station in the UK, generating electricity from straw since 2000 (EPRL, 2015) and Denmark's long running energy strategy that enables the burning of straw in medium to large scale CHP facilities (Faaij, 2006). These developments are suggestive that the logistics of straw based energy are indeed viable. The DTI (2003) *Energy White Paper: The Low Carbon Economy* signposted the government's interest in utilising farm residues and wastes for production of advanced biofuels. Indeed, the DEFRA-DTI (2006) report *Creating Value from Renewable Materials* exclaimed with excitement the prospect of biorefineries establishing the basis for a new bio-based economy (ibid, p. 31). The report drew particular attention to a case study of the Spanish Abengoa Bioenergy plant (ibid, p. 32) which was

[15] The Gallagher Review also identifies marginal and 'idle' land as contributing to the same goals, claims which are examined in Chapter Seven.

expanding to convert wheat straw into bioethanol, and the prospects this held for the UK. Further aspects of straw's favourable image relate to the perception that it is surplus to existing market requirements in several UK regions and therefore exploitable without negative consequences (with straw incorporation practices assumed to be due to a lack of market) (Biomass Taskforce, 2005). Therefore straw has been considered a viable and readily exploitable feedstock related to the production of heat, electricity and advanced biofuels.

A further component in informing a turn to agricultural residues and wastes has been a negative view of imports in driving damaging agricultural expansions in the global south. Therefore indigenous resources, most notably straw and energy crops grown on marginal land, have become framed as key sources of cellulosic material to feed the emerging domestic bio-economy in the UK:

> "It is feasible that given the development of more advanced technologies for producing biodiesel and bioethanol we could use a greater range of biomass feedstocks (crops and waste), increasing domestic supply of biofuel further." (HM Government, 2009i, p. 29).

Likewise the *UK Bioenergy Strategy* (DECC, et al., 2012) signposts agricultural residues as a key category for future biomass expansion, arguing that, "The greatest growth in domestic supply is expected to come from agricultural residues and perennial energy crops." (ibid, p. 22). The report continues to estimate between 3.7-5.0 million odt of agricultural residues will become available for energy by 2020 (see ibid, p. 32), although this figure is not exclusively straw and includes residues such as seed husks. Therefore straw is an important component of the domestically configured lignocellulosic biofuel industry.

However, these expectations are firmly rooted in responding to the needs of emergent and contested liquid biofuel technologies and policies. There has been an absence of discussion or reflection on how straw is positioned in the context of agricultural policy making and practices. This will now be examined.

7.2.2 Straw: Agri-Policy Change, Current Status and Key Actors

There are two notable agricultural policy interventions that have shaped the regulatory and advisory landscape with regards to straw. In 1993, the government imposed the *The Crop Residues (Burning) Regulations* (1993) which banned the burning of straw in the field with significant management implications (Silgram & Chambers, 2002). In the 1980s straw burning was used to dispose of a significant proportion of cereal straw. MAFF (1982) statistics suggest that roughly 41% of wheat straw was burnt annually, although this dropped to 10% of barley and oat straw, highlighting different management preferences for different straw types. However, in anticipation of the approaching ban, burning in the field had reduced to 14% (wheat) and 6% (barley and oats) by the early 1990s (Silgram and Chambers, 2002). This burning ban resulted in a regulatory required shift towards incorporation or baling (Silgram and Chambers, 2002).

The period after the burning ban saw straw being recast from a waste, controversially disposed of through burning, to a nutrient and organic matter resource mobilised in policy initiatives to mitigate and reverse the impacts of intensive cultivation on soil both nationally (Environment Agency, 2004) and globally (Global Assessment of Soil Degradation, 1990).

In the UK this has taken the form of best management practice advice (Ingram, 2008). These voluntary guidelines (see DEFRA, 2003; 2006; 2009 for examples) aim to improve resource management, benefitting the environment and also reducing input and management costs (Ingram, 2008). The most recent cross compliance requirements published in 2015 (DEFRA, 2015i; DEFRA, 2015ii) suggest organic residues and wastes, retained in the field either through incorporation on upon the soil surface, enable farmers to meet their requirements regarding the need to provide soil cover, reduce erosion risk, maintain soil structure and maintain organic matter.

Additional to the structural, organic and erosion protection benefits associated with straw incorporation, straw also has nutritional value. The nutritional value of incorporating different straws, their nitrogen, potassium (potash), phosphate

and magnesium content is for the most part well established. This information, and increasing its availability to farmers through agronomists, received greater attention from the mid-1990s onwards with growing recognition for the need for a more proactive soil protection and management policy (Ingram, 2004), to reduce nutrient load and leaching risk by better calculating soil nutrient values. Translating this information into on farm practical contexts is perhaps not quite as straight forward (Tsouvalis, et al., 2000; Ingram, 2004).

Table 7.1 provides information on the nutrient content of different straws. Each number represents kg of nutrient content per tonne of fresh straw.

Table 7.1: The nutrient content of different straws, kg/t

Straw	Phosphate kg P_2O_5/t	Potash kg K2O/t	Magnesium kg MgO/t
Winter Wheat/Barley	1.2	9.5	1.3*
Spring Wheat/Barley	1.5	12.5	1.2*
Oat	1.6	16.7	2.2*
Oilseed Rape	2.2	13.0	n.d
Rye	2.1*	10.0*	1.0*
Pea	3.9*	20.0*	1.7*
Bean	2.5*	16.0*	1.8*
Linseed	1.6*	9.2*	n.d

Source: HGCA, 2009

Note: n.d means no data, *best estimates based on limited data

Nitrogen values are more difficult to pin down, however Michigan State University (Gross, 2013) provides figures for wheat straw containing 5.9kg N/t, whilst figures provided by the Crop Observation and Recommendation Network (Crop Observation and Recommendation Network, 2008) report nitrogen content of up to 8.1kg N/t . As emphasised in the above table different straws have different nutrient values. Equally some of these nutrients will be lost due to decomposition and leaching which can be considerable. Impacted by the depth

the straw is incorporated, Christensen (1986) reported nitrogen losses due to leaching at between 7%-40% for barley straw. Likewise the decomposition of the straw results in nitrogen competition in the soil (HGCA, 2009).

Therefore, straw management decisions now encompass the need to assess:

> "nutrient management by budgeting, reducing and targeting artificial and organic fertilizers; timing cultivation and operations to avoid soil damage and reduce erosion risk; reducing cultivations to prevent structural damage to soil and save energy and labour costs; promoting and managing soil organic matter to improve soil structure." (Ingram, 2008, p. 406)

A consequence of this expanding scope of land management best practice to include knowledge of production technologies, environmental processes, legislation, and regulation has been the positioning of agronomists as essential advisors to arable farmers (Ingram, 2008) and a shift in advice towards a 'whole farm approach' (Ingram & Morris, 2008). Crop consultants increasingly work very closely with arable farmers giving essential advice (Pedersen, et al., 2004) and are a key set of actors influencing on farm straw management decisions.

Further to this, incorporation of straw through farm yard muck, an important means of building organic matter (Nicholson, et al., 2014) has become regionally contingent. One of the implications of attempting to realise the sufficient food imaginary has been the progressive specialisation of certain regions (Walford, 2003). Arable areas are increasingly isolated from livestock enterprises and a straw for muck exchange is not always possible. Therefore the result of evolving advice, regulatory change and regional specialisation which has isolated arable and livestock areas from each other, has meant a gradual shift from a preference for baling straw with 79% of cereal straw baled in 1995 (Silgram & Chambers, 2002), to 40%-50% of straw being directly incorporated in 2012 (Stoddart & Watts, 2012).

As covered in Chapter Six, intermediaries and contractors were highlighted as crucial actors undertaking the logistical work required to secure the large supplies of biomass for end users. At the other end of the supply chain these

intermediaries are also an important part of the agricultural industry. They provide labour, machinery and services that enable farmers to undertake field operations without the time and finances needed to pay additional staff or buy machinery (DEFRA, 2014ii). Drawing on information from the Farm Business Survey and the June Agricultural Survey conducted in 2014, DEFRA (2014ii) estimates that for cereal farms, between 30-42% of larger[16] farms and 16-24% of smaller[17] farms contract out straw baling services on some portion of their land. As was argued in Chapter Six and will be built upon further in this chapter, intermediaries such as merchants and contractors are a key group, whom undertake a significant proportion of the work required to bring straw to market.

Yet, despite its established status as a tradable product, and in arable management systems, straw remains something of an enigma. Whilst the food portion of the crop, the grains and oilseed are well monitored and quantified, the straw market is poorly catalogued with no comparable statistics collected by DEFRA (DEFRA, 2013). Likewise there is evidence that farmers do not accurately measure the amount of straw produced (Montforti, et al., 2013). The changes wrought in the post war period as a means of fulfilling the sufficiency imaginary, which drove the quantification and monitoring of agricultural outputs was not a homogenous process. Straw although a crucial component of the crop morphology has remained poorly documented and off the statistical radar. This has resulted in uncertainty with regards to the total amount of straw produced, and what proportion of this is baled or incorporated. In addition the expansion of energy markets for straw has raised questions around what portion of incorporated straw would be baled if new markets emerged, or if already baled, what proportion of existing supply would be diverted into new energy markets? It is these questions that have driven the modelling of straw as a biofuel resource.

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[16] Denoting farm size is based on the Standard Labour Requirement classification scheme. A larger farm is understood as a farm that requires more than 3 full time staff (see DEFRA, 2014iii).
[17] A smaller farm is understood as requiring less than 3 full time staff.

This section has briefly outlined some of the important events and regulatory shifts that have influenced the management of straw. It has also highlight some of the intermediaries that influence on farm decision making and whom undertake key management activities. Finally, I have highlighted the unevenness to policy and practitioner knowledge about straw, in particular the absence of information regarding the amount of straw produced within the UK and its availability for use. The following section will now take this forward exploring the ways in which modelling has tried to quantify straw availability for energy uses and the assumptions it embeds in the process.

7.2.3 Modelling Practices and Assumptions

The four modelling reports examined and critiqued in this section are Copeland and Turley (2008), AEA (2010), Glithero et al. (2013i), and Glithero et al. (2013ii). The Copeland and Turley (2008) report was prepared for the NNFCC, and its concluding figures for straw availability were referenced by the participants in three interviews with biofuel industry representatives (one) and straw merchants (two). This suggests that the report's findings have filtered into expectations of straw availability amongst some actors in the supply chain. In addition the figures for straw availability were re-produced and complemented by another two studies in the AEA (2010) report. The AEA report directly informed the DECC et al. (2012) *UK Bioenergy Strategy* (see pg. 24 & 26 for examples) and DEFRA expectations about available biomass for energy (see DEFRA, 2013). The Glithero et al. (2013i) and Glithero et al. (2013ii) publications were outputs of the BBSRC Lignocellulosic Conversion to Ethanol project (LACE), a major inter-disciplinary project exploring avenues for lignocellulosic bioethanol production conducted in the UK. In different ways these models have informed policy and research expectations and assumptions with regards to the availability of UK straw for bioenergy and lignocellulosic bioethanol production.

All four resource modelling exercises outlined above are interested in the questions of how much straw material exists, what are the barriers to making straw available and under which conditions will more farmers bale it. The methods utilised to model answers to these questions will now be briefly covered. With regards to determining potential total straw production the

models utilise crop production areas, grain/crop biomass ratios and ratios for recoverability. Copeland and Turley (2008) utilise this approach but do not publish the exact figures used. However, this methodology is clearly shown in the ADAS (2008) report from which figures were also directly incorporated into the AEA report (see AEA, 2010, p. 36)

> "The three main arable crops of wheat, barley and oilseed rape represent nearly 80% of the cropped area of 4.3 million ha, producing 21.7 million tonnes of grain per annum. Straw residues represent 49% of total above ground biomass of wheat and barley and 70% of oilseed rape. Total UK straw production is therefore estimated at 23.1 million tonnes per annum. Allowing for stubble and efficiency of baling only 60% can be recovered which is calculated to be 13.9 million odt." (ADAS, 2008, p. 5)

However, as noted by Glithero et al. (2013ii) both the ratio of biomass residue to seed and the recoverable residues to seed vary considerably. Scarlat et al. (2010) in a review of the existing literature on crop biomass to seed ratios note a wide range of ratios between 0.6-1.75 for wheat, 0.9-1.8 for barley and 1.1-1.7 for oilseed rape. In addition recoverable residues were estimated to vary between 30% - 60% (ibid). Variability in these figures relates to different on farm practices, e.g. cereal variety, use of growth regulators, harvesting techniques and technologies, climate and soil conditions (Montforti, et al., 2013).

As a result Glithero et al. (2013i) and Glithero et al. (2013ii) draw upon a farm level survey methodology. The Farm Business Survey, utilised to inform both these studies, asked questions relating to straw use, volumes baled, crop cultivations, contract implications and straw incorporation. This allowed for a regionally sensitive set of estimates of straw production based on collecting farmer observations of straw/grain ratios and crop production areas.

These totals were then reduced dependent on assumptions made regarding existing market use. Therefore, whilst Copeland & Turley (2008) estimate that cereals and oilseeds produce roughly 11.9 million tonnes of straw per annum (p. 7), once existing markets and some prospective energy developments are accounted for, they estimate a surplus of 4.9 million tonnes.

This leads to the next set of questions, how to unlock this surplus? In all models price is a prominent factor. Copeland & Turley (2008) estimate a minimum price of £32/t for straw on the basis that this remuneration adequately encompasses the loss of fertiliser and will encourage most of these farmers to bale and sell. The AEA (2011) report outlines a number of barriers to baling straw which are presumed to be overcome by price – in this case a varying electricity price is assumed to trickle down to farm gate straw prices. The higher the electricity price the higher the straw price and the greater the number of easy and hard barriers that are overcome[18]. Money is thus positioned as the lubricant of overcoming resistance to the pressure to increase straw baling.

A more nuanced approach is taken by Glithero et al. (2013i) and Glithero et al. (2013ii) in expanding these straw supply considerations to include contractual arrangements in terms of timeframe, price linkage - for instance to fertiliser values – and volume conditions. Under acceptable contractual (1-3 year supply contracts) and price (+£50t) conditions, Glithero et al. (2013i) conclude that "Arable farmers in England would be willing to sell 2.52 Mt of cereal straw for bioenergy purposes nationally and 1.65 Mt in the main cereal growing areas of Eastern England" (p. 161) which equates to a potential bioethanol yield of 478–549 Mlof (p. 168).

Within all the models the farmer is explicitly or implicitly the privileged decision making agent and the straw is merely an object over which decisions are taken. This simplifies the number of actors involved, both in influencing on farm decisions, and within the straw supply chain. As was explored in Chapter Six, the farmer is a single actor within an array of formal and informal connections that influence the pathways through which straw moves. Furthermore, the models to

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[18] *Easy constraints include*: Dispersed nature of resource compared to demand, lack of long term stable policies to enable investment, regulatory and political uncertainty, lack of grants for capital investment for supply, lack of storage and processing facilities.
Hard constraints include: Competition for feedstock, the poor yields of straw in some years, concerns about impact of bioenergy on prices of other use, dispersed nature of resource that is not currently being utilised

varying degrees implicitly assume that baling is the preferred management option. Therefore where farmers do not bale, this is assumed to be due to issues of lack of market and insufficient price. For instance AEA, refer to an ADAS report that suggests that only 2% of farmers would not bale at a sufficiently high price (£60/t). This is somewhat tempered by Glithero et al. (2013i) who note that many "farmers that currently chop and incorporate their straw are not willing to bale straw for bioenergy purposes, as indicated by the 43% of chopped and incorporated straw that farmers would not sell for bioenergy." (p. 168)

All the studies attempt to provide an estimate of the total amount of straw that the UK produces. This act implicitly positions straw as a homogenous object or at the very least an easily exchangeable product, despite being generated through the production of a range of combinable crops. In this regard oilseed rape straw, which is predominantly not baled, is highlighted in all the studies as a potential area of expansion that would not impact on existing supply chains. Although AEA (2010) and Copeland & Turley (2008) note the technical differences in the energy profile of oilseed rape with regards to combustion or lignocellulosic conversion, these are positioned as being overcome through upstream technical fixes. Therefore technological innovations are deemed sufficient to overcome the difference between straws, producing fungible commodities. This obscures the material heterogeneity between straws both from different and the same crops that will be explored in more detail in section 7.4 of this chapter. Therefore, not only do the studies homogenise straw as an exchangeable object across different uses, they also ignore the cultural factors that influence the baling of some straws over others.

Yet with regards to the farmers who do bale Copeland and Turley (2008), in the final paragraph of their article, touch upon an important point. "Current spot farm-gate prices for straw are only around 84% this value [£32/t expected to be the threshold at which straw is baled on the basis of their calculations] but there is no slump in supply." (ibid, p.16). This alludes to other issues influencing the decision to bale and that price is but one factor.

The final element of modelling work is converting this feedstock potential into bioethanol potential. Not all models complete this process. However, Glithero et al. (2013ii) do, suggesting the following biofuel potential:

> "Given the estimated 1.45 Mt of cereal straw that is currently incorporated into the soil from arable farm types… this feedstock could generate 482.9ML of ethanol. … approximately 1.5% equivalence of the 20,649 M L of petrol consumed in the UK" (pg. 316-317).

Through this process these models work to produce a depiction of reality in which straw becomes a viable resource that could provide a significant contribution to renewable energy and biofuel targets. This performative role contributes to making the imagined future and its technological projects seem attainable and thus legitimating the efforts to achieve the substitution imaginary. The contention of this chapter is that these models foreground, obscure and simplify the frictions that are involved in the material realities of straw management and markets which have implications on how the imaginary is delivered. This creates the potential for divergence between the policy facilitated efforts to realise the imagined future and the reality that is achieved. The next section will begin to address these possible points of divergence in the context of on farm straw management practices.

7.3 Managing Straw: To Bale or Not to Bale?

This section examines the reasons incorporation is a valued as an on farm practice independent of price considerations (sub-section 7.3.1), in particular drawing attention to the role of agronomists in influencing on farm decisions towards incorporation over time (sub-section 7.3.2). The section will build upon the analysis of intermediaries in Chapter Six to explore the role of trust between straw merchants/baling contractors and farmers in persuading farmers to bale (sub-section 7.3.3). Finally, I will reflect on how the baling of straw does not readily translate into the availability of straw for all straw users. Geographic location and inter-personal relationships have a powerful influence on straw availability that needs to be accounted for.

7.3.1 Managing Soil: Role for Straw

The models critiqued within this chapter position the farmer as the principle actor, and price as the major/overwhelming influence on their decision making. This simplifies the processes and actors involved. Whilst not wishing to demote the farmer as a crucial agent, or dismiss the importance of price in driving practices, both of which are important themes within the data collected for this thesis, my investigation highlights the presence of other actors, materials and factors that influence the decision making process. In particular, modelling inadequately addresses how these factors interact, and often situate incorporation as a valuable management practice.

Not all fields are the same, exposed to different weather, water availability, solar intensity, but importantly composed of different soils. The soil and the assessment of its needs by the farmer and/or agronomist is an important influence in the decision making process. The necessity of encountering the soil in the arable production process is fraught with friction. The need to consider the impacts on soil that result from baling was reflected across a range of interviews with different actors. For example, a straw merchant discusses the factors that influence whether a client bales his straw:

> S06: I think it depends on the soil type actually, for one man he chopped one field for about 25 years because it seems to be the structure of the soil, then he bales a lot on other fields you know.

Farmers, interacting with their soils, over time, and through different conditions are often well aware of the needs of their different fields (Tsouvalis, et al., 2000; Ingram, 2004; 2008). For instance, the following farmer incorporated the majority of the straw produced, whilst baling a small amount for personal use. Which fields were baled depended for the most part on a complex five crop – seven year rotation. However in the case of two fields incorporation was conducted every year due to the perceived needs of the soil:

> RH: So what would you say are the key advantages and disadvantages of incorporation?

E05i: Two fields need it really.

Ongoing assessments of soil requirements are often not so clear or annually consistent. In these circumstances, the changing demands of the soil are interpreted by the farmer and agronomists. The following quotes nicely illuminate the role of the agronomist in interpreting the soil and its requirements with implications for straw baling:

A02: Well it depends how I advise them, if I see [poor] soil condition, if I see problems with the drainage or with the organic matter in the soil then I will ask them to plough it under.

…

A09: I am actually encouraging people to chop more on some of the heavier land just to try and bulk organic matter [heavier land refers to clay soils]

In these cases the advice is for the farmer to incorporate the straw as a means to rectify a perceived deterioration of the soil. In the former additional weight is given (by the agronomist) to their role in determining straw management on the basis of their assessment. However, the farmer as principle land manager holds the final judgement and they may ignore the agronomist's advice due to their own empirical assessment or value judgement that interprets the potential loss of future soil condition and organic matter as a risk worth taking.

Sometimes the properties of the soil facilitate certain management practices rather than throwing up objections to the ways in which farmers may wish to manage it.

A03: ... we are on land that naturally provides a lot of potash so even with straw removed on a lot of these clays we won't need to add more potash for the next 100 or so years, so quite happy to sell straw

In this instance the nutrient value of the soil, notably its potash content, means that the fertiliser value of the straw is diminished. Although it might still be

retained to boost organic matter, in these instances the high potash content lubricates the decision making apparatus with regards to baling.

Although straw can provide nutrients to the soil, incorporation is not a straightforward and problem free option. The encounter between the soil, the straw and the weather is not guaranteed to be harmonious. Here the farmer and the agronomist attempt to tailor the management practices to accommodate the biophysical properties of the soil under different weather conditions and attempt to smooth its encounter with the straw to ensure the latter decomposes as desired. If not then the incorporated straw can become a fly in the soup rather than the positive soil conditioner it is imagined to become through incorporation and decomposition. This can be navigated in different ways:

> A01: ... you get slabby straw on the eastern clay you get a lot of, you get worse slugs so, and if you get a big slab of straw at plough depth there will be that slab of straw and you it's not the best thing to happen really so getting a good nice mix [during cultivation is needed]
>
> S05: If it's wet weather its better being baled if it's possible, erm because if it goes in the ground it sits there sour and nothing happens.

This 'slabby' or 'sour' straw is the result of a situation in which straw when ploughed at an inappropriate depth in wet ground fails to decompose properly. The encounter between the straw, the weather and the soil results in disruption to the following crop through reduced vigour and yield. However, the quotes above point to different management options, the one provided by the agronomist is to modify the cultivation practices and machinery set up to provide a better mixing of straw and soil. The latter from a straw merchant favours baling. The judgements in the above examples are clearly informed by the actors' respective positions in the arable production chain, but also play out in farmer decision making. Incorporation has risks and benefits and in this regard the farmer's discretion returns to the fore. The following two quotes are

from farmers who judged the risk of 'sour' straw differently, with implications for their approach to straw management:

> H07: ... one problem when they plough it, they plough it in too well these days and it forms a layer and it doesn't rot, it doesn't disappear, that is my worse thing about it, we have had it causing a drainage problem. [farmer who baled all straw]
>
> E05ii: ... the fact that it has to rot down er, and [can] cause possible problems in another way. I think the benefits [of incorporation] outweigh the other. (farmer who mainly incorporated straw)

For Farmer H07, the risk of drainage problems and 'slabby' straw is part of the decision to bale all the loose straw, whereas for Farmer E05ii the drawbacks associated with sour straw were deemed insufficient to overturn the favoured practice of incorporation and its other benefits. These types of value judgement were present in other aspects of management that have implications for straw. Compaction, a well acknowledged phenomenon in the literature (Håkansson, et al., 1988; Soane & van Ouwerkerk, 1995; Ball, et al., 1999; DEFRA, 2003; DEFRA, 2015ii) was a major cause for concern in relation to baling. The numerous passes over the field with baling and straw gathering equipment increased the risk of compaction of the soil. The judgement often swayed strongly in favour of incorporation in instances of wet weather, both due to the desire to reduce compaction risk but also the pressure to ensure the timely establishment of the following crop in optimum conditions. Subsequently the weather drove considerable seasonal variation in straw supply due to these concerns. All straw merchants outlined the weather as a major driver of their job and determinant of market supply. This was also an issue touched upon in Chapter Six which highlighted the international consequences of poor weather.

The factors highlighted here bring to the fore the way in which soil shapes the straw management process, different soils having different requirements and capacities that are accommodated in different ways, with different outcomes for baling straw. In addition, historical developments have changed advice regarding how to best manage soils with incorporation becoming a key practice. Although

this is hardly a controversial claim, the soil as a material of importance in the decision making process is absent from the modelling studies discussed in this chapter. Where it is discussed it is in the narrow context of nutrients. Copeland & Turley (2008) calculate the need to compensate farmers for the potential loss of nutrients due to baling and removing straw. On farms however, soil is an object of active management and assessment, and incorporation is presented by many agronomists and valued by farmers as being highly beneficial to soil health, structure and organic content, in addition to the nutritional value of straw. Quantifying the financial recompense required to meet additional nutrients therefore obscures the other work straw incorporation does. Finally, this is not to say that incorporation is a given or without its own risks. Individual farmers risk/benefit judgement differed with regards to straw and influenced their willingness to incorporate and perhaps risk knock on yield impacts due to poor decomposition.

7.3.2 Advising Incorporation

Agronomists have over time also had a substantial impact on the availability of straw in the market. As discussed in sub-section 7.2.1 best practice advice and regulatory demands regarding soil management have favoured the incorporation of straw into soil as a means of deriving a number of important benefits with regards to structure, organic matter, and erosion. All the agronomists interviewed favoured the incorporation of straw and advised as such and their close working relationship with farmers was deemed to have an influence.

As one straw merchant remarked:

> S05: No there's been a undersupply for about 5-6 years, … the main of cause of the problem has been … well two things. One was the erm, massive push, by, advisory authorities telling them they had to incorporate it.

This reveals a tension between straw merchants aiming to encourage baling to further their business whilst agricultural advisory services have shifted advice to incorporation. At the same time it reveals the disjuncture between agricultural and biofuel policy trajectories highlighted in Chapter Five. Whereas agricultural

policy favours incorporation as part of a future orientated strategy to increase/maintain soil health, biofuel policy is working against the grain, looking to incentivise increased levels of straw baling. Whether these energy/agri trajectories can be reconciled, for instance through coordinating straw extraction with increased availability of digestate from anaerobic digesters as a soil conditioner and source of organic matter, is currently unclear.

7.3.3 Trust and Baling

In Chapter Six the role of trust and long standing relationships was discussed in the context of how it structured the pathways through which straw was traded and therefore to whom it was made available. Relationships between arable farmers, merchants and end-users had impacts on the ability of new entrants to access straw. In this section trust is discussed in the context of incentivising farmers to bale their straw. As noted previously (sub-section 7.2.1) straw merchants and baling contractors undertake a significant portion of the straw baling and carting on farms and therefore strong relationships between these intermediaries and farmers is crucial to future availability of straw.

All straw merchants interviewed had close working relationships with arable farming neighbours, friends and family. Due to the retreat of many farmers from owning their own baling equipment, particularly as baling equipment had got larger and more capital intensive, baling had progressively become a job performed by contractors. Trust between these actors is an important part of the understanding between farmers and contractors. As the following straw merchant makes clear:

> S03: I've got 3 balers running around and they are looking [after] 5-6 customers they see a baler pretty regularly. ... And then then it builds up and builds up over the year on a trust basis. They trust that we have the, er, capacity and the ability to do the job we say were gonna do given a fair crack with the weather.

However, trust involved not just the understanding that the job would be done correctly but that the farm would not be contaminated as a result of baling contractors spreading blackgrass seed between farms.

Blackgrass is a grass species that is common across Western Europe particularly England, France and Germany (Moss, 2013). Simplified crop rotations, the dominance of winter cereals and a shift towards minimum tillage have encouraged blackgrass expansion and persistence as a problematic weed in arable production (Moss, 2013). Even low levels of infestation can reduce yield of winter wheat by 2-5% whilst modest infestations of 12-25 plants/m^2 can result in yield losses of 0.4-0.8 t wheat/ha (Bayer CropScience, 2012). To provide some context, on the basis of the September 2014 wheat price of £103.2/t (DEFRA, 2015iii), a yield loss equivalent to the above figures would equate to a per hectare profit reduction of £41.2 – £82.5[19]. Understandably farmers who do not have blackgrass problems on their land are keen to keep it that way.

> A08: …we are in an area where there is very little blackgrass so quite a lot of farmers are wary of contractors coming in and spreading blackgrass onto their farms when they come with the balers.

The consequences for straw merchants of damaging that relationship of trust was the reluctance of farmers to bale in subsequent years, and in the most serious cases complete relationship breakdown and a shift by the farmer towards incorporation. The following quote is from a farmer for whom those bad experiences had signalled the need to change on farm practices:

> E05i: ...we use to have somebody come and bale it but ... we have been let down badly over the years, so after that we stopped working with them and decided to incorporate it.

This represents the experience of a small number of farmers interviewed. Whilst these farmers had moved towards a system of incorporation, others purchased

[19] High levels of blackgrass can also lead to increased risk of ergot infection (a fungus). If this infects the wheat in sufficient levels then there is potential for the grain to be rejected by millers due to a human and animal health risk (Casswell, 2014).

second hand baling equipment as a means of 'protecting' their land from contamination.

Maintaining trust in existing relationships often translated into a strong reputation in the farming community. For example the following merchants began trading in 1958 and their reputation and the community networks through which that reputation passed was an important part in maintaining their business. These two quotes, from different parts of the interview, reflect the importance of these connections from the perspective of the straw merchants.

> S01: it's mainly our customers are like word of mouth and repeat orders that's the mainly what we are doing. ... we are a well-known name in the trade like.

A good reputation and trust within existing relationships boosted farmers' confidence that baling straw would not impact on the timeliness of subsequent cultivation and establishment of following crops. Good personal and professional relationships between supply chain actors therefore provides a means of facilitating the baling of straw.

Two agronomists remarked during interviews that the emergence of energy producers onto the market had sparked interest amongst a cohort of incorporating farmers in baling their straw once more. This was linked by those agronomists both to potential for an increased (or expectation of an increased) price for the straw, but also a trend amongst baling contractors towards greater levels of professionalism and therefore stronger community reputations.

Therefore, changing landscape of contractor professionalism, trust, and good reputations continues to shape trends in the straw market, perhaps counter balancing the shift towards incorporation.

7.3.4 Baling to Availability?

The previous sub-sections have highlighted the different types of knowledge, expertise, professional and personal work that influences the management of straw. However, if, as the models assume, increased demand and thus price of straw does incentivise increased baling how does that translate into availability

for energy users. Increased straw in the market does not directly transfer into increased availability for all actors.

Geographical location was found to be important. In areas of the country dominated by the livestock industry, such as the Sefton Coast, the decision to bale was almost a given due to strong demand, and long standing connections with livestock farmers in the area. However, this does not mean that straw incorporation and its associated nutrient value was not an important managerial consideration. Interviews with farmers revealed that straw was often traded for manure between neighbouring arable and livestock farmers. Therefore baling was contingent on a return of muck to the providing farm to replace lost nutrients and organic matter. Often such exchanges were made on the basis of gentlemen's agreements with no money changing hands, again pointing to the informal and inter-personal relationships that sustain the straw market. In these instances, baled straw does not translate straightforwardly into what is accessible straw as price is unlikely to sever this relationship.

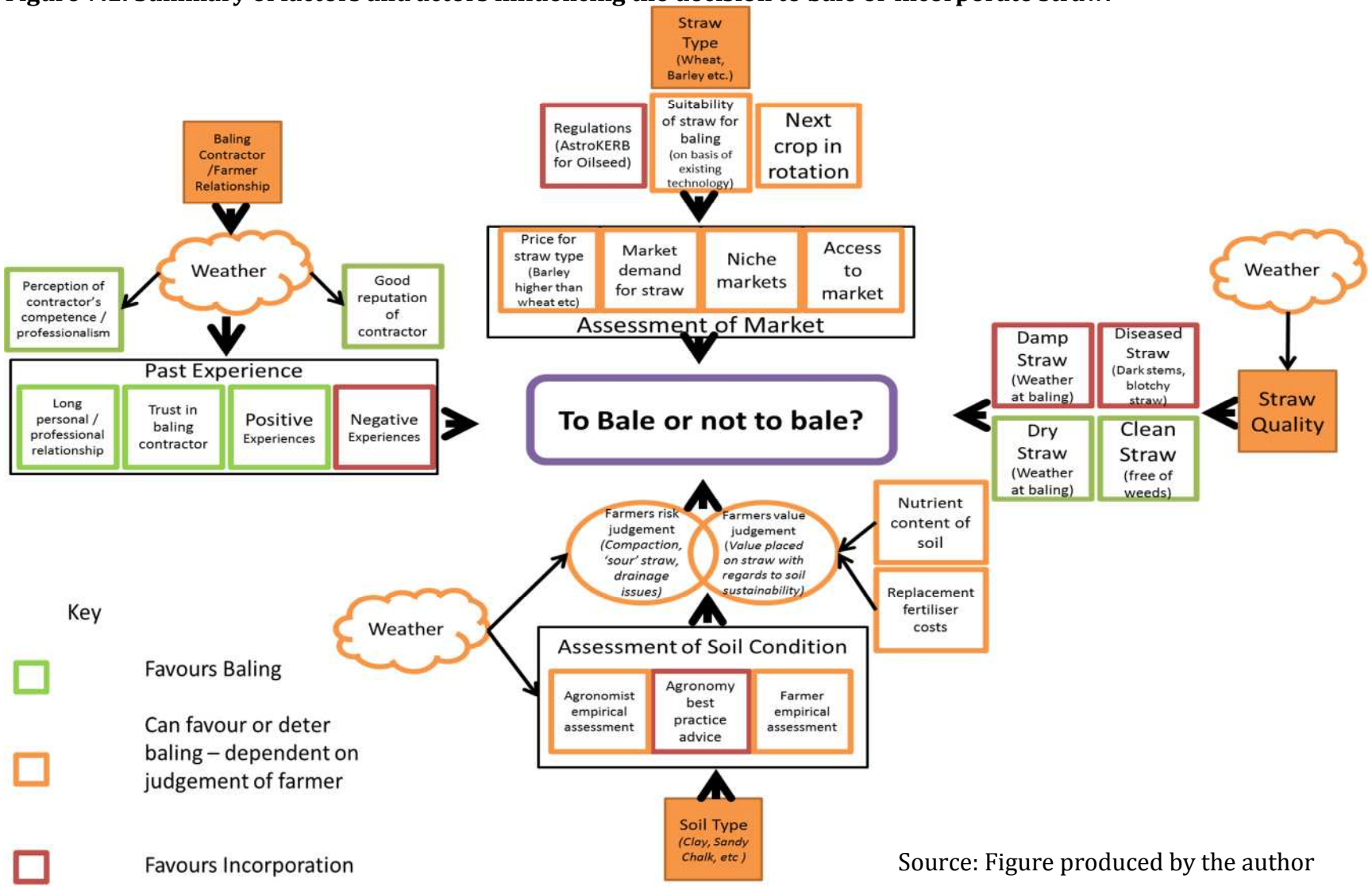
The important take away point from a more national perspective is that a proportion of the baled straw supply is locked into specific socio-economic pathways that emerge and shift on the basis of personal and community relationships. Quoted below is an arable farmer who originally baled all his straw and transferred it to his father's dairy unit. Upon his father's death, the dairy herd was sold. With no more animals needing straw, it became available on the open market being sold in the first year to Ely power station. However, this did not persist with a more permanent arrangement emerging on the basis of existing personal inter-relationships:

> RH: Can I just ask how did you get into selling it [straw] all for carrots?
>
> E02: … well the farm locally that grows quite a big carrot crop, ... I knew the chap who was the manager, … I don't know whether he came to see me or whether I rang him up, but we have over the last few years and they sent the big baler, bale it, stack em and them bring the lorries in.

These informal personal connections are entangled within the commercial relationship and the result is often particularly resilient links as emphasised earlier in this chapter and in Chapter Six.

Expectations of access on the basis of price alone simplify complex networks of interpersonal relationships that are important in determining who can access straw and the pathways through which it moves, as well as influencing on farm decision making that must account for numerous factors independent of the market. The range of actors and factors that influence the on farm decision to bale or not, and thus the potential availability of straw in the market are summarised in figure 7.1.

Figure 7.1: Summary of factors and actors influencing the decision to bale or incorporate straw.



Source: Figure produced by the author

7.4 **Material Complexities**

This section examines straw as a materially heterogeneous product, noting how this diversity shapes which markets certain types, bale sizes and qualities of straw flow into, as well as the actors that are interested in purchasing said straw (sub-section 7.4.1). The section will then discuss oilseed rape straw specifically as a potential opportunity that emerges from management practices, and the material characteristics of the straw (sub-section 7.4.2).

7.4.1 Not All Straw is Created Equal

Straw is a differentiated product both in terms of the crop it originated from and how it was baled. Wheat straw is predominantly used for livestock bedding, whereas barley and oat straw are routinely combined in animal feed as roughage (Copeland and Turley, 2008). Oilseed rape straw is likely to be incorporated in the field due to issues with baling and harvest practices (ibid). Although some of these differences are acknowledged in the modelling literature, the consideration that different straws and bale sizes have preferential and differentiated markets is not. Therefore not all straw is equal and readily transferable between markets. As the following quotes highlight different straw products are demanded on the basis of a range of technical and personal choices:

> S06: Erm the power stations and the processors like er wheat straw erm, the straw factory, the pelleting plant likes wheat straw because it's more brittle it chops up better and it's more of a consistent product
>
> …
>
> S07: … some farmers, prefer to bed with barley straw some prefer to bed with wheat straw, they all have their preferences
>
> …
>
> S05: Yep, erm, er, the rape straw primarily really at the moment it goes for power generation.
>
> …

S03: Yes so there is, erm, our barley straw goes … into the pet bedding industry for processing.

Straw merchant S06 highlights a poignant aspect, namely the brittleness of wheat straw which make it suitable for processing and therefore favoured by those users that desire to process the straw into pellets for combustion. Likewise, these preferences are not always technical. As S07 makes clear the preferences of the farmer, their value judgements over the suitability of different straws for bedding their animals, impact what farmers are willing to purchase.

Furthermore straw is demarcated based on a loose set of informal quality criteria revealed in interviews - 'poorer' quality straw (read damp) is used in mushroom and compost production, while 'clean' straw (read free from weed seed) is often used in carrot production where it receives a slight premium. Although informal for the most part, energy producers have formalised moisture content quality criteria due to their more stringent requirements as excessive moisture content lowers the heat generated in combustion. Whether lignocellulosic biofuels can take advantage of a range of different types of straw might be a key aspect of whether they are able to create a space within the straw market. In particular, with regards to accepting straw with high moisture levels, several straw merchants remarked that a decline in the mushroom compost industry had left gaps in the market for the dampest straw, a prospect that lignocellulosic technologies might be able to exploit.

Bale size also influences who is able and willing to utilise the straw, different bales finding different uses due to personal but also logistical preferences. As the following quotes highlight, different users in the livestock, straw processing and energy industry prefer different bale sizes (and different straw types) on the basis of their handling infrastructure:

S05: Erm, power generators want the biggest bales because they are an industrial user, erm, the large dairy farmers they're not bothered, they will take the same sized bales, but after that the sheep men and people who are dealing with calf pens or whatever they want the smaller bales.

However, the diversity of bale sizes was also a point of tension with numerous sizes on the market meaning that securing the preferred size is not always possible. Resistance is generated by the limitations of the handling machinery and practices, the preferences of a particular end user for certain bales and a diverse market of bale sizes, as the below quote emphasises:

S01: The power stations are quite strict on what bale they'll tek,

RH: Is that the Heston bale?

S01: Er no they will tek anything 1.2m wide.

RH: Right ok.

S01: The[y] originally said they'd just have the big Heston's… but they've not the product.

In this example the restrictive capacities of the power station handling infrastructure *made* straw more scarce and therefore some flexibility in bale size range was required as a means of ensuring that sufficient straw could be processed. However, in times of scarcity even bales in that expanded range may be scarce. As the following quote highlights this then requires costly measures to rectify this shortfall:

E02: You see when we sold the straw bales they were round ones, and they couldn't fit these round ones in their burner and they had to re-bale everything.

For one straw merchant the current situation, in which a diversity of bale sizes and handling systems creates a highly differentiated market, was analogous to the VHS and Betamax conflict:

RH: Do you think the type of bale changes what uses it's appropriate for?

S01: Yeah yeah, it's a bit at the minute it's a bit like the video record[er]s, you know when there was VHS and Betamax … in perhaps 10-15 years there will be a standard size bale that farmers

> are happy to use and the processors can use and the power stations can use.

At this crossroads between type, quality and bale size, straw flows into different production streams depending on its material qualities. If all straw is not created equally, of the same quality or bale size, then what does this mean for overarching national statistics? As these quotes highlight even if straw exists in sufficient absolute quantities the prospective resource available to a single user may be significantly influenced by the ability of their handling system to deal with a diversity of bale sizes, although a work around, such as the costly re-baling of straw may be a possibility. This feature may be exacerbated by the entrance of external, international actors in local markets as covered in Chapter Six previously. By focusing on the problem of feedstock availability nationally or regionally, the models create implicit assumptions that all straw is equal. This masks the frictions generated in the market through different straw types, qualities and bale sizes being present. Ensuring a flexible system for handling and processing straw within lignocellulosic biofuel technologies may be equally as important in ensuring the success of these emerging technologies as the actual quantities of straw that are estimated to exist.

7.4.2 Imagining Surplus: Oilseed Rape Straw

A key consideration within all the modelling studies is the existing markets for straw. A means of navigating the potentially significant implications for existing markets is utilising oilseed rape straw which is currently incorporated in significant quantities. Oilseed rape straw is identified as presenting a potentially large resource into which lignocellulosic biofuels could expand thereby delivering the imaginary without impacting on existing markets. Glithero et al. (2013ii) identify 700,000 tonnes of rape straw in England that is potentially available for energy purposes. Copeland and Turley (2008) and AEA (2010) both estimate that around 2.5Mt of rape straw exists in the UK. Although it is discounted from the AEA study due to the combustion characteristics of rape straw being deemed unsuitable. But combustion is not a requirement for lignocellulosic biofuel processing. At present rape straw is widely incorporated, with Glithero et al. (2013ii) putting rape straw incorporation at 87% in

comparison to the figure for wheat that stands at 36%. These calculations are suggestive of a large and unexploited resource that is ripe for exploitation in energy systems.

Yet in identifying this resource as available the studies do not engage with the factors that currently lead to oilseed rape straw being overwhelmingly incorporated in comparison to wheat and barley straw. Although rarely discussed in depth in the interviews, two straw merchants and an arable farmer illuminated two reasons why oilseed rape straw is not widely baled. These relate to the way in which oilseed rape encounters land management practices for which the straw is of secondary concern. This first is with regards to harvesting the straw:

> S06: ... a lot depends on the combine really ... with rape straw because if it smashes it up it is very easy to chop and spread so ... the arable farmer can go in with his cultivator ... so we tend to get rape straw when the straw chopper breaks down and things like that.
>
> H01: I did bale my rape straw once ... the problem with rape straw is it is it so brittle ... [later in the interview on the same subject] the baler came and he only got half of it and there was a big mat of straw and so I couldn't top work it so I had to plough it which put my costs up.

Both these quotes point to the fragility of the rape straw when it encounters current combine and baling equipment. Whereas earlier the brittleness of wheat straw was highlighted as a positive characteristic for later processing, the brittleness of oilseed rape straw presents a major barrier to in field management. In the example of H01 the encounter resulted in an undesired change to cultivation methods, using a more expensive means at that. In this regard the availability of oilseed rape straw is produced through practices that

aim to reduce the resistance of oilseed rape straw to conventional management practices.

This fragility is not restricted to harvesting, with the advice on livestock bedding materials provided by EBLEX[20] (2011) noting that round rape straw bales need handling carefully as they are less robust. Round bales have also been reported to be difficult to roll out (EBLEX, 2011). This raises questions about the ability of rape straw to withstand the industrial handling facilities required to maintain continuous production envisaged in energy and biofuel production facilities.

As the noted by a producer already familiar with handling wheat and miscanthus straw, the handling of the biomass presents a number of major challenges:

> P04: ... one of the key drivers at the moment is to change our materials handling systems. I mean biomass is dry and dusty, you can't afford to let it get wet, … it self-heats quite aggressively if you don't manage that properly and can cause fires and explosions ... and biomass dust … can be hazardous to health and some biomasses can generate allergic reactions so, we have had to completely redesign our materials handlings systems.

Therefore, utilising a more fragile straw could present major technical challenges within the logistical apparatus of the processing facility in which the friction generated could quite literally result in explosive outcomes.

The second aspect relates to changing chemistry and resistant weeds, in particular the weed blackgrass. As noted previously blackgrass is a major weed in cereal production that can cause significant yield loss. Farmers' efforts to control blackgrass has resulted in recourse to more potent herbicides resulting in an escalating resistance problem and diminishing chemical control (HGCA, 2014). One strategy has been for arable farmers to deploy new generations of chemical inputs as a means of controlling resistant blackgrass, as well as poppies

[20] Now the Agriculture and Horticulture Development Board: Beef and Lamb

and mayweeds. These strategies may benefit the energy industry. ASTROKerb offers one such chemical for oilseed rape that has a number of restrictions on how the subsequent oilseed straw can be used (DOW Agrowsciences UK, 2015).

> S05: … the rape straw primarily really at the moment it goes for power generation. There used to be quite a market for it, but they've altered the rulings er for some of the chemicals that they put on which means it can only go for that, erm, you can't put it into the feed chain … That's relatively new is that. ... Because of the use the new chemical ASTROKerb.

Therefore, the emergence of ever more resistant weed species and the resulting methods of navigating these problems, may provide an inadvertent boon to the use of oilseed rape straw in energy, although this assumes the fragility of the material can be overcome through changing practices that accommodate the oilseed rape straw adequately.

7.5 **Conclusion**

Policy highlights agricultural residues, already produced through traditional practices of arable production, as a readily available source of feedstock. However, although collected on a wide range of agricultural produce, production statistics have a blind spot with regards to straw. Biofuel policy modelling has engaged with the following question. How much straw is there? At what price will farmers make it available for energy users? This chapter has examined four studies that have approached these questions, informing UK research and policy expectations (Copeland & Turley, 2008; AEA, 2010; Glithero, et al., 2013i; Glithero, et al., 2013ii).

Analysis of these studies highlighted the way in which straw quantities are derived from grain-to-biomass ratios and cropping area with the availability of straw assumed to correlate with market price. This construction of straw privileges market uses over non-market and on farm applications, again assuming that farmers are driven by economic decisions making. Furthermore, straw is modelled at a national and regional level and is assumed to be a homogenous material commodity. Only oilseed rape straw is singled out in two

of the studies (Copeland & Turley, 2008; AEA, 2010) due to its combustion characteristics.

In exploring these assumptions in the context of on farm decision making and the broader range of actors involved in influencing straw management decisions, the following three areas were discussed.

Firstly, the decision of whether to bale or incorporate was examined to tease out the value judgements, and actors involved in on farm decision making. As a result, simplistic notions that a farmer is primarily concerned with deriving direct financial gain from the management of their straw were questioned. In particular, incorporation of straw into the soil was examined as a potentially valued practice, linked to the desire to ensure swift crop establishment, maintain soil health and the weight of agronomic advice that favours incorporation.

Secondly, I identified the tensions between straw merchants and contractors, and agronomic advisors whom pull the straw market in different directions. Changing best practice and burning bans had reframed the use of straw from a controversial burning hazard to a valuable resource important in managing soils. Agronomists were a key group of actors who had pushed forward this advisory position into on farm practices; working closely with farmers to interpret the value of straw incorporation for soil health. All agronomists interviewed favoured incorporation and a straw merchant had noted the impact this had had on the straw market reducing availability. On farm interactions are the usual site for studying the impact of agronomists (see Ingram, 2008; Ingram & Morris, 2008). This chapter examines how agronomic advice creates broader trends that have implications for existing and emergent industries. Such analysis highlights this as a potential site for further reflection and examination by rural sociologists.

However, the chapter also highlighted how baling contractors are important actors, undertaking a significant proportion of baling work in the UK. For baling contractors, developing trust with clients was a key part of the business and crucial to maintaining relationships and therefore sourcing straw. As touched upon in Chapter Six the increased professionalism of the baling sector, linked to

the capital intensive nature of machinery investment, but also the demands of an emergent bioenergy sector, had renewed interest in baling straw amongst some farmers currently incorporating. Furthermore, it once again points to the importance of merchants and contractors for which there is currently a dearth of research within the wider literature on agriculture and which this study contributes to filling. Furthermore, this analysis highlights the important non-economic factors and the roles played by intermediary groups that influence on farm decision making and the broader landscape of straw use and availability.

Thirdly, the material heterogeneity of straw as a product was drawn out along three lines: type, quality and bale size. Taking account of the different material characteristic within straw market drew attention to the following opportunities and potential barriers. Low quality straw, damp or perhaps diseased, might be an area that lignocellulosic biofuels can take advantage of due to the decline of the mushroom compost industry and the inability of the heat and power industry to use damp straw. Flexible handling infrastructure was noted as an important consideration in order to avoid imposing feedstock scarcity by only being able to process a narrow range of bales. Oilseed rape straw is a potential growth area but it will require careful tailoring of harvest and baling equipment as well as on site handling practices, due to how brittle the straw is.

Although previous work has endeavoured to estimate quantities of straw potentially available to an emerging energy market, these studies have homed in on economic factors in the process ignoring complex technical, social and bio-physical factors that underpin on farm decision making with respect to straw. This chapter has sought to address these shortcomings and has consequently highlight the importance of a more nuanced understanding of farmer decision making towards understanding the supply of straw for bioenergy purposes.

Finally, this highlights a further component to the resistance facing efforts to embed an imaginary, namely, the feedstock material itself. The chapter has repeatedly touched upon how straw is a heterogeneous entity with varying quality, brittleness, dampness, and bale size impacting on how it is and can be used. Materiality has been a subject explored in the wider literature on

technology transition and future imagination (Shove, et al., 2014; Shove, et al., 2015; Selin & Sadowski, 2015). This chapter highlights how once the vision for lignocellulosic feedstock chains moves from a policy formulation level and into on the ground contexts, these forms of resistance come readily into play. Straw is not a homogeneous and fungible feedstock; when material difference is brought into focus the contingent nature of feedstock availability is made clearer. It requires a product that can be baled, is baled to the 'right' size for a particular business, and is of sufficient quality. For technological projects reliant on raw material conversion, this highlights a rich vein of analysis within which to expand conceptualisation of resistance within the socio-technical imaginaries literature.

Overall the chapter highlights the value to the socio-technical imaginaries literature of conceptualising resistance as emerging from everyday practices and material heterogeneity. Doing so adds a further layer of nuance to the ways in which imaginaries may be shaped in unexpected directions or stalled, outside of state vs activist citizen contestations. Resistance as described here is the result of emergent market conditions which are influenced by a wide range of annually variable factors, values, materials and practices.

8 Mapping Marginal Land: Practices, Values, and Technology

8.1 Introduction

Cultivating energy crops on so called marginal land has been an important means of aiming to differentiate lignocellulosic technologies and feedstocks from first generation predecessors. As examined in Chapter Five, the Gallagher Review (RFA, 2008), which aimed to address food versus fuel and land use controversies, was key to this linkage between marginal land and energy crops for lignocellulosic technologies. Marginal land is assumed to be available and viable for energy crop cultivation, as well as not being central to existing food production regimes. Further to this, energy crops on marginal land have been identified as a major growth prospect for domestic biomass production (see, RFA, 2008; HM Government, 2009; DECC, et al., 2012). This chapter examines the way in which marginal land has been constructed as a UK policy category and subsequently mapped, before moving on to juxtapose this with on farm understandings of land in the UK and how these become sites of resistance to adoption of energy crops.

The chapter presents the third and final component to the analysis of expectations and assumptions signposted in Chapter Five and thus contributes to answering research question two, focusing most prominently on the on farm 'practices and values' component of research question: *What assumptions do UK biofuel policy models make about agricultural systems, decisions, and practices? How do they compare with on farm decision making, practices, values, and inter-relationships?* Finally, by highlighting the disjuncture between marginal land as a policy concept and marginal land as understood in farm contexts this chapter contributes additional answers to research question three: *What are the opportunities and challenges, highlighted through understanding the agri-energy nexus, for the future emergence of lignocellulosic biofuels?* In answering these questions the chapter draws upon documentary analysis of policy documents, the broader research literature and interviews with farmers and agronomists.

The chapter is structured into three main sections. Section 8.2 briefly touches upon the historical engagement with marginal land as a category of land before moving to examine a number of interlinked studies commissioned by research councils and DECC which mapped the availability of marginal land in the UK explicitly for the purposes of bioenergy policy. This section will examine how marginal land is constructed and the assumptions this embeds. Section 8.3 then details how farmers perceive marginal land as a concept when applied to their farm, analysing some of the adoption barriers this creates, as well as some of the wider shortcomings of applying the concept in farm contexts. Finally, section 8.4 explores how marginal land is not a static concept. The section will primarily explore how land quality is understood on farms through use and practice, which are subject to change over time. This has consequences for on farm uses of land and its suitability for alternative uses.

8.2 **Mapping Marginal Land**

This section explores the policy origins of marginal land as a suitable and desirable site for energy crop cultivation (sub-section 8.2.1), and examines the assumptions and expectations for marginal land within policy and academic modelling literature (sub-section 8.2.2).

8.2.1 Marginal land: Policy Origins and Current Status

The contemporary discussion on using marginal land to grow perennial energy crops for lignocellulosic biofuels is the most current point in a long and shifting history of debate about how to utilise marginal lands to solve socio-economic or environmental conundrums. The establishment of the Forestry Commission to co-ordinate domestic timber production following the First World War would eventually result in large quantities of the uplands and marginal land being converted to coniferous plantations (Forestry Commission, 2015). However, post-war experiences with prolonged rationing meant marginal land was called upon to provide more than just timber. Ellison's (1953) *Marginal Land in Britain* discusses the need to improve marginal land, as a means of bolstering beef and sheep productivity and the UK's scant meat supplies. As discussed in Chapter Five, improvement of marginal land was an important post-war activity to boost

food production. This suggests long-standing tensions over using marginal land and competition between forestry and agricultural uses.

In addition, the use of marginal land for growing perennial crops utilised in energy systems is not a particularly novel one. In the 1980s, McElroy and Dawson (1986) discussed the potential to use marginal land in Ireland for growing short rotation coppice to fuel rural bioenergy facilities and possibly lignocellulosic ethanol production. The potential multitude of uses of so called marginal land is suggestive of the elastic nature of marginal land as a concept (HM Government, 2009i). Indeed, in 1932, Peterson & Galbraith (1932) in their article, *The concept of marginal land,* attempted to provide a definitive set of criteria by which to define marginal land as a response to what they perceived to be the glib and convenient use of the term to define any number of land types and contexts. Their definition considers marginal land to be "the "poorest" land which can be "remuneratively" operated "under given price, cost, and other conditions." (Peterson & Galbraith, 1932, p. 296). For Peterson & Galbraith, a rigorous analysis of these individual components highlights the essentially shifting character of what can be considered marginal at any given time; this will be returned to in Section 8.4.

Most recently, energy crops grown on marginal land to supply lignocellulosic biofuels were brought to the fore of biofuel policy by the Gallagher Review (RFA, 2008) in response to concerns over the indirect impacts of first generation biofuels. As the report notes, policy must ensure "agricultural expansion to produce biofuel feedstock is directed towards suitable idle or marginal land ..." (RFA, 2008, p. 7). This claim tackles the problem of potential negative consequences from land use change, due to expansion of cropping, or the use of prime existing agricultural lands for energy (Nuffield Council on Bioethics, 2011), through shifting policy attention to the prospects of utilising underused, marginal or perhaps spare lands. Thereby through deploying energy crops on these lands in conjunction with lignocellulosic biofuel technologies, a pathway to a truly sustainable industry is deemed possible (RFA, 2008). However, simply stating the providence of using marginal land is insufficient. Through mapping marginal lands the attainability of delivering sustainable lignocellulosic

technologies in the UK is reinforced through 'showing' the presence of significant quantities of domestic marginal land. Under the right conditions this is then presumed usable for energy purposes.

This claim has not been without its detractors, with authors such as Booth et al. (2009, p. 113) arguing "The basic premise recommended by the Gallagher Review, that biofuel crop production should be segmented to appropriate idle or marginal land, is unlikely to stand up as a viable option when put to close scrutiny". Likewise the premise of the Gallagher Review also signals a shift from early policy documents, most notably the RCEP (2004) report, *Biomass as a Renewable Resource.* This report noted that energy crops grown on "the lowest quality land … could also result in reduced yields." (p. 11). Thereby rather than being a solution, marginal land was a problem impeding high yields. However, the claims made within the Gallagher Review have taken a position of prominence. This was most notable in the UK Renewable Energy Strategy (HM Government, 2009) in which marginal land was claimed to reduce food versus fuel conflict risk and negative environmental consequences of greenhouse gas emissions due to indirect or direct land use change.

Although not referred to explicitly as marginal land the definition of sustainably sourced biomass provided in the DECC et al. (2012) *UK Bioenergy Strategy* includes references to "biomass feedstocks that have not been sourced from high carbon stock land (e.g. peat land or virgin forest) or land that is required for competing uses (e.g. food)" (DECC, 2012, pg. 10). This mirrors aspects of the definition provided by the Gallagher Review that marginal land refers to land not used for food production (due to abandonment or unsuitable conditions), whilst firmly incorporating the Renewable Energy Directive (EU, 2009) sustainability criteria with regards to not converting land of high carbon stock.

Although the connection is not made explicit in policy, the targeting of marginal land to grow perennial energy crops folds the use of marginal land into earlier expectations about the domestic deployment of such crops reaching around 350,000 hectares across the UK by 2020 (DEFRA, et al., 2007). The connection between these objectives and marginal land as preferential for the siting of

dedicated energy crops is made more explicit in the modelling studies conducted under the Rural Economy and Land Use Programme (RELU) biomass project[21] (Haughton, et al., 2009; Lovett, et al., 2009) and those commissioned by DECC (Turley, et al., 2010). Therefore domestic availability of marginal land for energy crops is an important component of realising the substitution imaginary detailed in Chapter Five. In addition, energy crops are identified by the *UK Bioenergy Strategy* (2012) as the feedstock with the most potential for future expansion. Despite some contestation, dedicated crops on marginal land have become positioned as a configuration that is important in delivering a more sustainable and domestically focused bioenergy and lignocellulosic biofuel industry in the UK.

8.2.2 Expectations and Assumptions

In the context of UK energy policy, Shortall (2013) conducted a study that aimed to tease out the embedded assumptions relating to the framing of marginal land. This identified three main policy framings: first, land unsuitable for food production; second, ambiguously defined lower quality land; and third, economically marginal land. For Shortall (2013), the first two definitions relate to lower quality agricultural land that is not suitable for food production. However, as a means of fulfilling the future vision of significant biomass being drawn from these lands to sidestep land use conflicts, several normative assumptions are contained within this definition. Principal among these assumptions is that a significant amount of marginal land is available for productive cultivation and that energy crops can be targeted to this land. Modelling has been an important aspect in legitimising these assumptions. The third definition, economically marginal land, defines the marginality of land on the basis of its break-even economic margin (Turley et al, 2010). This break-even point is contingent on the set of dominant agricultural practices and market conditions within which the land is utilised. Many of these assumptions are implicitly and explicitly embedded within the modelling efforts which serve to

[21] A research programme funded through the ESRC, BBSRC and NERC research councils.

legitimate these normative claims through 'illuminating' the marginal land in the UK and its potential to contribute to government targets.

However, what Shortall (2013) does not investigate are the tacit assumptions implicit within this definition of marginal land, in particular, the way in which the above framings, despite nuanced differences, all ground their definition in relation to agricultural needs and practices. Alternative framings of land value, from biodiversity, nature conservation or recreational perspectives for example, are not deployed.

This is an important omission in the context of an increasingly multifunctional countryside and especially when, as in the case of biodiversity and nature conservation, agriculturally marginal areas are generally more species rich (European Environment Agency, 2004) and therefore central to conservation and biodiversity enhancement efforts. This is a feature often recognised in agri-environmental schemes. In the UK, both past and recent schemes (including the Environmentally Sensitive Areas, Countryside Stewardship Scheme, Higher Level Stewardship, Entry Level Stewardship and the new Countryside Stewardship Scheme), have typically concentrated on land at the margin between intensive arable and grassland production (Hodge & Reader, 2010) or at the margins of intensive systems (field margins, corners and hedges), as a means of preserving and enhancing biodiversity.

Furthermore, analysis suggests that land placed within the compulsory set-aside scheme, the main goal of which was to reduce crop surpluses, was often in areas of the farm that were agronomically and/or spatially marginal (Crabb, et al., 1998). Furthermore, it has been suggested that halting cropping of such areas subsequently had some environmental benefits, supporting birds, other wildlife and plant species increasingly excluded from intensively managed land (Firbank & Wilson, 1995; Fuller, et al., 1995; Krebs, et al., 1999).

In contrast intensification of agricultural activity favours a small range of dominant species (Kleijn, et al., 2011). These intensively farmed, prime agricultural lands are therefore framed as impoverished from a biodiversity perspective and of marginal value to re-establishing biodiverse landscapes when

contrasted with less-productive extensively farmed areas (Kleijn, et al., 2011; Merckx & Pereira, 2015).

These tacit assumptions around marginal land have carried over to contemporary efforts to model the amount and location of marginal land in England and Wales for the production of perennial energy crops. Three key modelling studies, Haughton et al. (2009), Lovett et al. (2009), and Turley et al. (2010) will now be discussed below. These reports share a number of authors, and built upon each other. The first and second were conducted as part of the RELU programme, whilst the latter was directly commissioned by DECC and undertaken by the Food and Environment Research Agency[22] (FERA) in conjunction with ADAS (see DEFRA, 2009). The studies have been highly influential, informing policy and later modelling with regards to marginal land in the UK (see special issue GCB Bioenergy, 2014 - Smith, et al., 2014).

In brief all the articles critiqued here are interested in ascertaining the amount of marginal land available in England and Wales, and the economic, social and environmental impacts of cultivating this land. Haughton et al. (2009) are particularly concerned with assessing the biodiversity impacts of utilising marginal land for energy crops, noting that SRC has beneficial impacts on numbers of butterfly indicator species. Lovett et al. (2009) are concerned with devising criteria to exclude from consideration non-marginal land, land of cultural and environmental importance and land that is unsuitable due to biophysical properties. The remaining land was then correlated with Natural England's yield mapping to assess productive prospects and land use competition arising from its cultivation. Turley et al. (2010) combine aspects of the earlier studies, expanding the scope to include consideration of urban biomass potential from brownfield land for example.

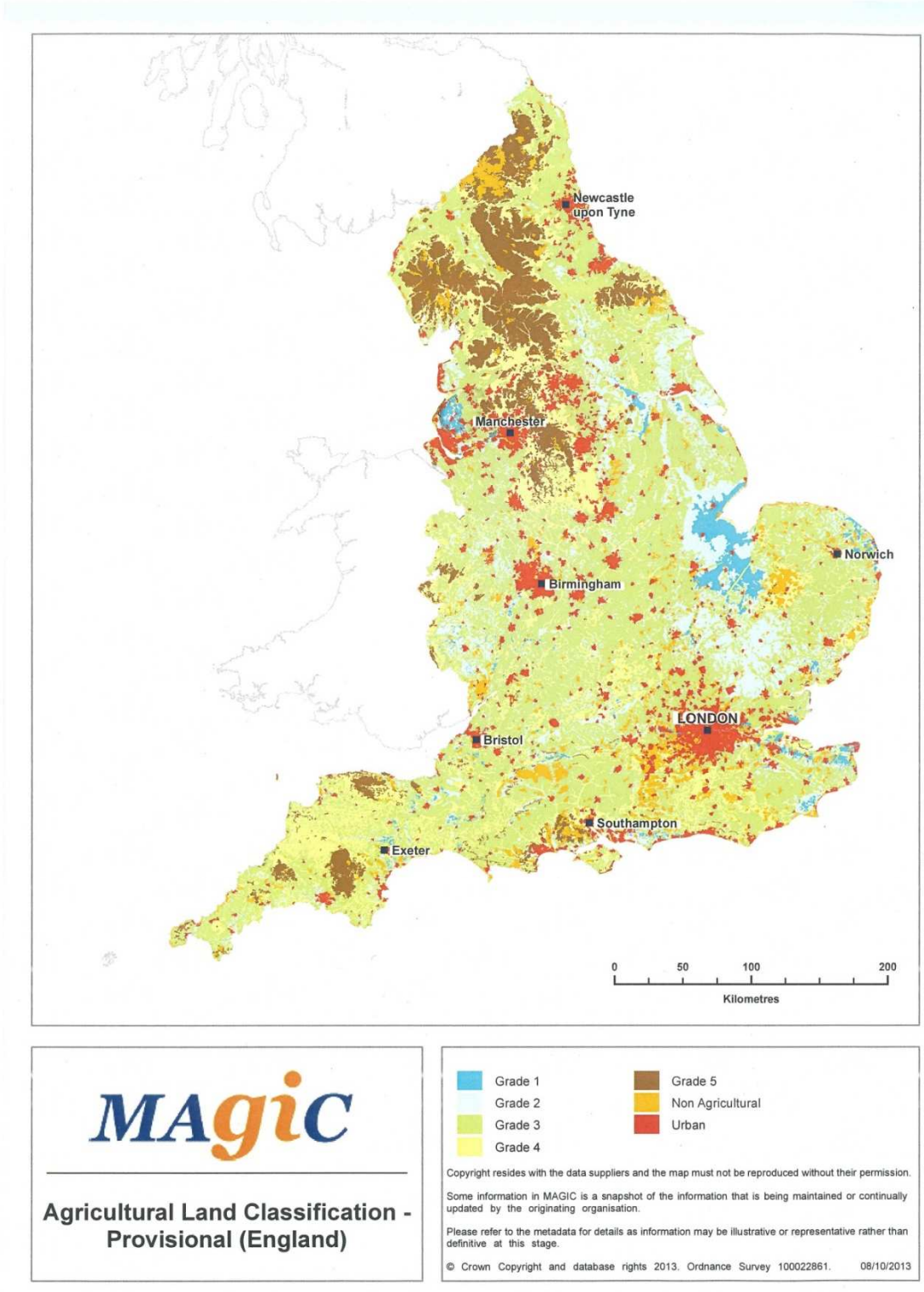
The models rely on two main exercises, both utilise geographic information systems (GIS) mapping. This immediately shapes what can and cannot be

[22] FERA is an executive research agency of DEFRA.

included. For example the use of cartographic software allows 'steepness' to be an applicable category for differentiating suitable and non-suitable land and identifying its location in the UK. This is facilitated by comprehensive mapping of the UK by the government owned company Ordnance Survey. In comparison 'farmer pride in land', which as I will argue has implications for understanding how land quality is produced on farm, is difficult to determine, nor does it have a geographically reproducible proxy. Thus through using GIS mapping software prominence is immediately given to biophysical categories that are already deemed important, have been quantified, and can be displayed in the form of a map. The means through which marginal land is produced through including and excluding certain biophysical categories will now be explored.

A consistent indicator drawn upon to facilitate the task of assessing the marginality of land is the Agricultural Land Classification (ALC) scheme which ranks land based on its productive capacity for cropping which is then reproduced in a map format (Figure 8.1). Grades 1 to 3a are considered the most valuable and versatile lands whilst Grades 3b to 5 are considered moderate to very poor (Natural England, 2012). Firstly the ALC scheme frames land as a productive resource for crops – prime arable land is synonymous with quality land. This obscures the many ways land is used in agricultural systems which will be detailed later in this chapter. Secondly, the descriptive notes that accompany the ALC scheme differentiate Grade 3 into 3a and 3b, however existing grade maps (see Figure 8.1) do not make this differentiation and therefore this less precise grading is transferred into assumptions made by the models.

Figure 8.1: Agricultural Land Classification (Provisional) - England

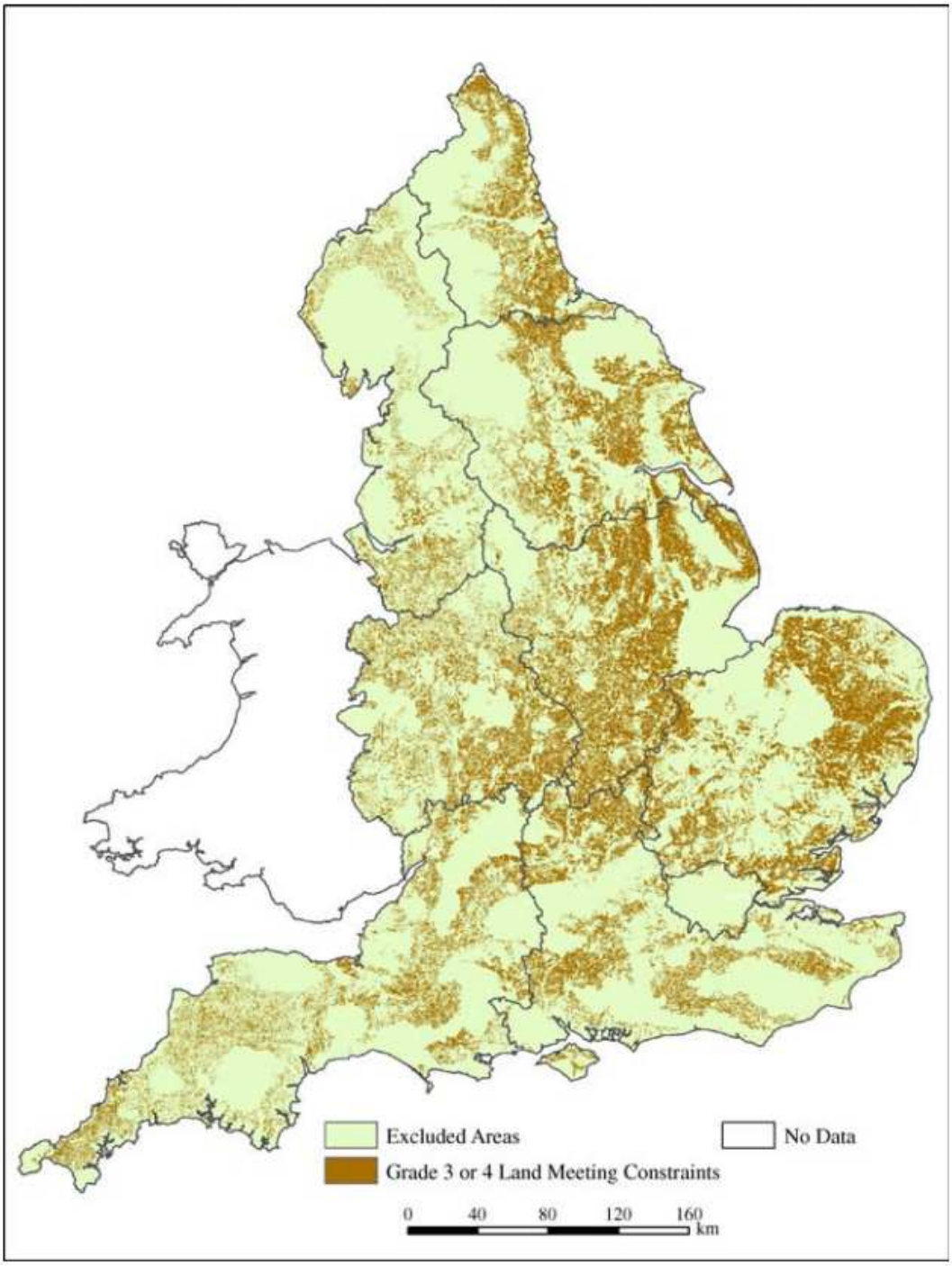


Source: Magic, 2013

With this as a starting point, land is then excluded on the basis of eleven 'planting constraints'. Whilst this terminology conjures up assumptions regarding

biophysical and practical constraints on cultivation it includes a number of 'social' (i.e., culturally important and/or legally protected landscapes) factors. These relate mainly to the aesthetic impact of growing new crops (particularly miscanthus) in certain landscapes (Turley et al, 2010) and the perception of public resistance being generated by energy crops disrupting these landscapes. This framing means that the exclusion criteria developed by Lovett et al. (2009) (and used by Turley et al. 2010) focuses primarily on legally protected cultural heritage landscapes (ancient monuments etc.) and Areas of Outstanding Natural Beauty (AONBs) and National Parks. The production of this definition results in the map shown in Figure 8.2, reproduced here from Lovett et al. (2009).

Figure 8.2: Land on ALC grades 3 or 4 and outside of the 11 planting constraints[23]



Source: Lovett, et al., 2009, p. 29

[23] 11 constraints/exclusions relate to, soil suitability, conservation habitats, slope steepness, urban areas, rivers, lakes, other designated areas afforded protection, cultural heritage sites, sensitive landspaces, improved grassland.

The result of such an exercise is twofold. Firstly it highlights how the failure to capture the difference between grade 3a and 3b land means that large areas with a reputation for intensive cereal production are captured as potentially marginal in this assessment, with regional concentrations in the West and East Midlands, alongside parts of the East of England. Secondly it illuminates the general absence of any National Parks and Areas of Outstanding Natural Beauty in central England (see Appendix 4 for a map of these designations), which accounts for many of the major areas of exclusion. The exclusion of these areas reinforces historical judgements about what can be considered a landscape of 'natural beauty', whilst ignoring the way in which English and Welsh National Parks and AONBs owe their form to thousands of years of ongoing and changing patterns of material alteration due to human exploitation and occupation (MacEwen and MacEwen, 1982). Most recently, this has included the changes wrought in the name of realising the sufficiency socio-technical imaginary which 'improved' of vast tracts of agricultural land in these areas and resulted in regional specialisation of agriculture away from traditional mixed farming (MacEwen and MacEwen, 1982), continuing the evolution of these landscapes.

The final set of assumptions to be examined relates to the way in which barriers are formulated on the basis of these mapping activities. Turley et al. (2010, p. 7) note that "the area identified represents the maximum possible area; the actual area available will depend on policy developments, economic circumstances, social trends, ecological factors, and logistical limitations and is likely to be much smaller". Policy development relates to the uncertainty surrounding continued fiscal support provided directly to dedicated crops and the biofuel/bioenergy sector, economic considerations relate to farm-gate prices of energy crops versus alternative cultivations, whereas ecological factors and logistical limitations deal with the biophysical properties of the land, its slope, nutritional properties, water availability, climate, distance to infrastructure and end users. This ignores the numerous interactions and relations that are important in the creation of on farm barriers to adoption such as historically rooted trajectories of farm development, the maximisation of existing farm enterprises to the land holding, and the practices and values that inform how land is valued by farmers.

Finally, and with regards to delivering legitimacy to claims that the lignocellulosic technologies are indeed viable to fulfil the socio-technical imaginary, these studies produce claims suggestive of the achievability of government targets with regards to dedicated energy crop deployment, without negative environmental (Haughton et al, 2009) or food security impacts (Lovett et al, 2009). As Turley et al. (2010: 3) attest:

> "The utilisation of 'idle' and marginal land resources for biomass, ... could help to deliver a significant proportion of the UK targets for renewable energy as announced in the Renewable Energy Strategy (RES) for 2020 ... Alternately, if the priority is to produce biofuel feedstocks, then up to 18% of the RES renewable transport fuel energy target (10% by energy) could be met ...".

Hence these studies are an important component in performing lignocellulosic biofuels as an attainable technical project through identifying adequate resources to fulfil the feedstock needs, whilst underpinning claims that these crops can deliver good future outcomes. Furthermore, the models create a situation in which a seemingly dormant resource, 'marginal land', is poised for exploitation to deliver beneficial outcomes without the negative consequences associated with first generation biofuels. This leaves further work to be done in the form of modelling how this marginal land will be unlocked and barriers to energy crop cultivation overcome. As noted in the previous chapter, this is mainly focused on economic means with the UK Bioenergy Strategy (DECC, et al., 2012) expecting significant uptake of SRC willow (between 0.93 and 2.42 Mha) and miscanthus (between 0.72 and 2.80 Mha) if gross margins on the crops reach £241/ha and £526/ha respectively. The primary focus of this chapter is less on critiquing the rational economic perspective of farmer decision making, covered in Chapter Seven in relation to straw, and more on the disjuncture between technocratic definitions of land and the practice and value driven understandings held by farmers.

8.3 **Framing Solutions - Creating Barriers**

This section examines how energy crops and marginal land are discussed in farm level contexts (sub-section 8.3.1), before highlighting the different barriers this creates to adoption of these crops by farmers (sub-section 8.3.2 to 8.3.4).

8.3.1 Not the 'Good' Land

The policy framing of marginal land as a solution to food versus fuel conflicts and land use change concerns relating to first generation biofuels was mirrored within farmer interviews. This primarily relates to the particular framing of food versus fuel as a problem and farmer orientated prioritisations of how land should be used. Likewise it is important to acknowledge that the food versus fuel conflict was a central point of reference for a number of farmers with regards to biofuels. As a result a majority of farmers perceived first generation biofuels to be morally objectionable, as they took food from the mouths of the poor and hungry. That said only a small cohort of farmers strongly rejected the use of arable crops for producing fuel and energy rather than food or feed. For the most part the objection to first generation biofuels utilising food and feed produce was linked to more nuanced arguments against the use of good quality or the best land. Farmers to varying degrees argued that good land should be prioritised for food, whereas the use of poor land for growing biofuel products was less of a problem. This framing is highlighted in the following quotes drawn from farmers operating livestock, mixed and arable enterprises respectively:

> NW02: … if it is good land then it's for producing food.
>
> …
>
> E02: using a bi-product is one thing, but when you actually put grade 1 and grade 2 aside [for] non-food crops … it's not something that you want to erm, probably rush into.
>
> …
>
> H04: I don't agree with this … you know land, good farming [land] out of production to go into energy.

This is initially suggestive that the policy framing of marginal land as a site for energy crops finds certain synergies with how farmers value land, which subsequently influences the uses they say it should be prioritised for. Amongst a small number of the farmers, the objection to the use of good agricultural land for energy crops was linked to the suitability or desirability of cultivating marginal or poor land in its stead. An arable farmer highlights this linkage:

> H08: I am a bit against producing biofuels and things off good land that can feed people, if they can … make use of poor land well that's fine … that's a sensible thing to do …

Again, this quote suggests that some farmers share a similar language for the framing of energy crops and marginal land. However, the definition of marginal land was often left ambiguous in the context of this discussion about shifting energy feedstocks from 'good' to 'poor' land.

Farm walks provided opportunities for discussing marginal land in context and therefore pinning down what the term meant to the farmer. Farmer-based definitions of marginal land consistently included examples of land shaded by woodland, steep hill sides, fields or areas of fields (corners) difficult to access or land prone to flooding or water logging. As will be discussed later, in the context of any single farm, 'quality' or 'marginality' is produced through the interaction of on farm practices, prevailing market conditions and relationships with neighbouring farmers or government schemes. Therefore a static definition of 'marginal' is problematic. Agronomists were more forthcoming with regards to providing a definition and unsurprisingly, given their role, they usually framed marginal solely in terms of ability to consistently produce a high yielding crop:

> RH: When you say marginal …
>
> A05: Marginal as in not able to produce a good cereal crop year in, year out

A major implication of the connection between energy crops, particularly willow, and marginal land was that farmers persistently framed energy crops as specifically *for* marginal land, as follows:

RH: Have you ever considered dedicated energy crops at all ... miscanthus or short rotation willow?

H03: No I haven't, as I say, all our land is in decent twig[24] and you can only be doing that for land that isn't very good for productivity really.

…

RH: is there much information provided on miscanthus and SRC willow?

A05: No … I don't have any of my guys interested in that basically because we are not on marginal land …

Unfortunately, although farmers favoured the use of poor land for energy crops in general terms, in the context of their own farms this became a major barrier. These barriers seemed linked to two main themes. The first relates to the alternative options for so called marginal land which will be covered in more detail later in this section. For now, however, it is important to note that marginal land has multiple management options. For arable farms the most common was the utilisation of a farm's 'marginal' land for livestock production, either by the farmer or through a rental agreement with another farmer. Within livestock enterprises the poorer quality grassland was often used to graze dry cows or sheep.

The second relates to the pride farmers took in their land and the way this translated into farmers never considering *their* land to be sufficiently marginal to justify energy crops. Indeed the link to poorer land meant some farmers considered energy crops to be a 'second rate crop':

[24] Twig is understood as meaning condition

H09: It never struck me as fitting our farming systems; it's all such good arable land it seems such a shame to grow second rate crops really.

The unwritten subtext to this is that by growing these crops the farmer is admitting that their land is itself second rate. As Burton (2004) notes, the look of crops and land conveys symbolic value, communicating to the wider farming community the quality of the land holding and importantly the farmer's skill in managing it. It is notable that during farm walks farmers consistently showed the parts of the farm they were most proud of, whilst on numerous occasions literally pointing to fields with a more prolific weed problem from afar. The following quotes made during farm walks emphasise this point:

H01: This is the best. I have brought you to my best field

…

H02: I am not going to show you my black grass.

It is therefore important to reflect on the symbolic implications of growing an energy crop particularly when they are routinely framed as being for 'bad' land. When this frame encounters the farmers' pride in their land and their desire to emphasise their skills as a 'good farmer' it produces a significant point of friction that inhibits the uptake of energy crops. Burton (2004) argues that existing commercial agricultural practices confer symbolic values that enable farmers to establish their identity as 'good farmers' as well as exhibit their skills (and thus status) within a wider community of peers. This resulted in certain instances of 'roadside farming' in which more visible areas of the farm received increased attention and expense (Burton, et al., 2008).

Furthermore he highlights how a 'good farmer' identity is challenged by agri-environmental, forestry and diversity schemes that do not provide adequate space for farmers to exhibit their skill, identity *as farmers,* and sense of achievement producing food (ibid: p. 196).

As further quotes in this section will emphasise, energy crops being framed as *for* poor land becomes highly problematic when farmers do not consider their land

to be poor (or at least not poor enough). In the context of Burton's argument, energy crops through the 'eyes of a good farmer' signify poor land. This is compounded by energy crops being a 'hands off' crop after initial establishment. Perennial energy crops due to the structure of the stand and plant requirements do not lend themselves to routine applications of herbicides, fungicides, or fertilisers. Whilst low input may appear attractive from a carbon or energy balance accounting perspective this characteristic essentially removes the ability of farmers to actively exhibit their skills.

This disrupts the farmer's ability to produce the traditional symbols of a being a 'good farmer' impacting on their sense of identity, and social standing. Neat and clean fields are deemed important symbols of good crop management (Burton, 2004; Burton, et al., 2008). In contrast perennial crop plantations favour ground level plant communities that would be usually be controlled chemically by the farmer. Additionally, over winter, miscanthus stands dead, and willow dormant, before harvesting in the spring. This is a very different form of management and produces a very different aesthetic to what would be a 'normal' over winter field, potentially conflicting with farmer preferences for tidy fields (Burton, 2012).

Burton (2004) suggests acknowledging the importance of these symbolic and cultural values encoded in the aesthetic symbols of land management, and enabling their reproduction in new forms of land management to ease adoption of new practices and technologies. This requires a re-examination of the singular focus on economic-based incentives for delivering change (Burton, et al., 2008) and attention to how energy crops can be managed to produce neat and tidy fields.

The symbolic meanings associated with energy crops and how they conflict with traditional practices of production is an area that this thesis is only able to touch upon. However, the empirical evidence suggests that it is an important factor influencing resistance to energy crops.

Finally this was not something restricted to arable farmers. As previously noted models fail to differentiate grade 3 land into 3a and 3b land when categorising marginal land due to shortcomings in data. This captures a large amount of UK

arable land, for example in the East of England, as was shown in Figure 8.1. Even if this differentiation is made and marginal land is defined as grade 3b and 4, these are two categories dominated by the UK's permanent and temporary grasslands. Although in the ALC quality is synonymous with arable land, the managers and owners of this land were no less proud of their land and its quality than arable farmers, framing it as prime grassland. The following quote is from an interview with a dairy farming couple, managing a mixed enterprise dominated by grassland. It highlights their pride in the quality of the land and how this judgement acts to exclude energy crops:

RH: So have you ever considered erm, growing any energy crops at all?

NW05ii: But that one tends to be a crop for poorer land doesn't it, and we haven't got any poor land, it's all.

NW05i: Well it would grow willow.

NW05ii: Anything will grow willow but you don't put willow on stuff like this.

Therefore, whilst all farmers consider some of their land to be of poorer quality than other parts of the holding, in all but one interview where the farmer had considered growing energy crops, it was never marginal *enough.* This acted as a means to justify why these crops would not be grown on the farm, despite considering poorer land as a suitable site for energy crops. In summary, although supportive of the use of marginal land for energy crops, land suitable for this use was routinely externalised outside their own holdings. When situated within the context of the farmer's values and connection to their land, 'marginal land for energy crops' caused significant resistance to adoption.

On a final note, although no farmers interviewed had adopted energy crops, a number of agronomists had clients who had grown energy crops on a portion of their land. In these instances the marginal land of the holding was routinely the land preferred by the farmer when deploying these crops, as observed by one agronomist:

A08: One field was poorer quality and one field was prone to occasionally flooding … they struggled to keep er winter cereals growing sensibly on it so that was the reason they put the miscanthus in yeah.

This suggests and corroborates the claim made in the modelling literature that when planted energy crops are grown on more marginal land. However, the adoptees of energy crops remain in the minority and for the majority of farmers interviewed the concept of 'energy crops on marginal land' acts as a barrier when it encounters the means through which land is valued on the farm.

8.3.2 Marginal Land is Marginal

The viability of energy crops on an individual farm level is beyond the scope of the models reviewed in this chapter. In this context, interviewed farmers more closely reflected the earlier concerns of the RCEP (2000; 2004) reports, noting that marginal land had the potential to deliver marginal yields and therefore poor returns compared to alternative types of land. For the farmers, poor margins were just one factor; one of the major concerns was the limitations marginal land places on the ability to successfully establish energy crops. This most often related to land that was deemed marginal due to its propensity to flood or become waterlogged, often linked to soil type. Heavier clay soils were most likely to be implicated, as was the case for two farmers, the first an arable farmer, the second a livestock farmer:

H07: … if I had a go it would be right down at the bottom corner of the farm where it is a little bit prone … [to] flooding, very heavy land I think I would struggle to get it started off, once you got it going it would be OK. A good year you know you'd probably get it established whereas nine times out of ten you would have a big bare patch same as what there is now you know.

…

NW04: No no, we haven't, basically I wouldn't, our land is very heavy clay land and if you were to start running about it on big machines then

> you are going to make an awful mess of the land, so it's a non-starter on here. … a lot of the fields are quite undulating, so it is not easy to plough.

These cases represent how marginal land as an on farm and as a modelled category produces problems for energy crop cultivation. The quote from H07 documents land that was able to be cultivated, part of a larger field producing combinable crops, but was considered by the farmer marginal due to persistent flooding. Its marginality in the context of the farm made it a potential site for energy crops, however, the high risk of crop failure remained a barrier.

NW04 is referring to permanent grassland, which would fall into marginal land as a modelled category. Although suitable for livestock grazing, in this case sheep and a small beef suckler herd, the soil type and land topography meant this 'marginal land' was unsuitable for energy crop cultivation. In both these cases 'marginal land' remains marginal for energy crop production. Modelling these logistical barriers as price negotiable obscures the risk and work that would be required to establish the crops on these particular sites.

The impact of cultivation on marginal land is not without direct and indirect consequences for the future of the crops. As the following interview exchange with an independent agronomist highlights:

> RH: Does that [planting energy crops on marginal land] restrict the crop in any way or is that not really an issue?
>
> A04: Yeah I think it does, it is in the poorer parts of the farm. You know so, it isn't in the best productive land [and] the margins haven't really … [made] people think well that is something I want to be supporting. … our job is about improving the grower's return. So if we can't see that it's better than [what] he's got there is not a lot of interest in it.

Furthermore, as noted in Chapter Six companies selling miscanthus and SRC willow have had a chequered history riddled with uncertainty.

The knock-on effect of these poor returns and lack of dedicated companies selling the crops was diminished interest from independent advisors in sourcing information on energy crops to relay to farmers. In cyclical fashion, agronomist interest in energy crops was related to the community 'buzz' surrounding them. Maize was a good example of this shifting landscape of community interest in different crops due to its increased profile as a feedstock for anaerobic digestion. This buzz had implications for agronomists' strategies of sourcing and relaying information:

> A01: I thought let's have a look at this and see what is going [with regards to energy crops], and I think I should do maize at the moment, there is increasing amount of maize everywhere and I think we should talk about the economies and whether it is viable for them.

The absence of engagement in energy crops by agronomists is problematic due to their role as a conduit of information sharing amongst a community of farmers. Agronomists are a key means through which farmers seek and receive information about the "changing technologies of production, legislation, environmental processes, and policy issues" (Ingram, 2008: 406). Despite group learning being another important means of farmer knowledge exchange, encounters with agronomic advisors remains as a powerful means of communicating to the farming community which is highly valued by the farmer (Fearne, 1990; Angell, et al., 1997; Ingram, 2008). The value placed on agronomists was an important theme that emerged from the interview data. The following quote nicely emphasises how the agronomist is valued for providing more than just technical advice on crop management:

> H08: But yeah I mean it's a big thing is agronomy … we sort of say he's doing that over there, and he's like yeah he's doing alright or I wouldn't do that over there … and if he sees someone doing alright he will be like try this so it's not just agronomy it's the whole package you see, and they know who's doing what with people and who to get in contact with …

Therefore perceptions of energy crops, created through cultivation on marginal land resulting in poor results, bankruptcies of energy crop companies and limited information on the economics and practicalities of production, undermined interest from agronomists. The result is the absence of an important group of actors who have a role in the potential 'soft' sell of energy crops to farmers, whilst the companies involved in the hard sell have struggled to remain solvent.

8.3.3 Spare land?

The notion that land is spare or otherwise idle was entirely absent from farmers' discussion of land and the land market in their area. Indeed the opposite was consistently expressed, particularly in the North West amongst livestock farmers. In these circumstances land was already firmly embedded within existing management regimes and the farm enterprise had been maximised around the restraints of the available land. The notion of land being taken up for energy crops would therefore require a reconfiguration of the farm enterprise. The following quotes are all from livestock farmers asked if they had ever considered planting energy crops on their land:

> NW12: No cause we do not have the land, we only have enough land to be able to keep the animals that we have got so it's just a waste of time even thinking, contemplating anything else, wouldn't be so bad if we had lots of land and thought we could do a bit of that and a bit of that but we haven't.
>
> …
>
> NW11: No, no, no, no, you mean taking some land up? As I said before we needed the land to feed the cows.
>
> …
>
> NW02: … we haven't enough land available to turn into any of these energy crops.

The response from NW11 was particularly memorable due to the incredulous look on the farmer's face at the suggestion of taking up land for something that did not feed directly into the dairy and calf rearing enterprise. However, this was not restricted to livestock farmers. Arable farmers also maximised their current cropping activities on their land holding, although this was sometimes disrupted:

> H007: 534 acres, there is about 524 that goes through the combine. We grow two wheats, barley and then rape and the little bit missing this time is because of wet weather [flooding had left a part of a field originally sown with wheat fallow] and we've an electric cable going across the farm [requiring significant works rendering some land unworkable until the construction was finished].

Therefore the notion of spare land was entirely absent from interviews. Furthermore, it is also absent from discussions of land in the wider farming literature. The rise in land rental values and purchase prices is suggestive of a highly competitive market for land both for agricultural and non-agricultural uses, although as of 2016 this has started to subside (Daneshkhu, 2016). This is likely indicative of a mature land market and agricultural system which was noted by Booth et al. (2009) to be the main cause for questioning assumptions about availability of marginal lands.

8.3.4 Options on the Horizon

Whilst the last section notes the existing uses of land and the ways in which farm activities are maximised to derive value from existing land holdings, there is also the issue of emerging options and requirements for land. The modelling literature whilst acknowledging existing uses does not grapple with the potential for competing emerging uses of land. Set-aside would be an obvious historical example of a CAP policy that changed land use and management pattern, the most recent re-negotiation of CAP is no different. The negotiations, concluded in 2013, have changed existing measures and placed new requirements on land and farmers (EC, 2013). Most noticeably, this includes the compulsory 'greening' measures. This additional tier of requirements requires farmers to adapt to and achieve three obligatory practices, "namely maintenance of permanent

grassland, ecological focus areas and crop diversification" (EC, 2013, p. 7). The ongoing negotiation of CAP therefore directly impacts on the emergence of new management requirements and land use considerations. Furthermore this land remains an important resource for other renewable energy technologies. Although renewable energy policy is in a process of evolution in the UK, for example the recent announcement of changes to the Feed in Tariff, and Renewable Obligation subsidy mechanism, at the time of writing these incentives remain and are expected to do so until 2016 (DECC, 2015).

The most notable development in the context of renewable energy includes the emergence of ground based solar in certain areas. The following quote from a farmer considering such an option highlights why this is attractive:

> H04: basically we don't really know what to do with it,… if we get a lot of rain it will stand water and this fella came up and he was … like put it down to a solar farm and we are not that far off considering the idea, so we would be open to that.

Solar was therefore a means of making a problematic field profitable. Both wind turbines and ground based solar were deemed attractive due to the farmer's role often being minimised to renting the land to a second party:

> H01: Yes I was quite interested in the ground based solar panels … basically with that particular system, the company lease the land from me, I don't do anything I'll just receive a very good rent per year … it is also quite attractive because … it would take some of my poorer land out of production as well.

This meant a lucrative return on existing farm resources without significant capital from the farmer to develop them. Whereas the land take of wind turbines is minimal a land based solar array is perhaps more comparable to an energy crop development. However, even in this instance, land based solar creates the potential to add value in a way that energy crops do not as the following quote emphasises:

H07: You really need to be into sheep because they expect you to graze it under them and between the panels … you want plenty of sheep or somebody lined up to keep it grazed down …

Whether this is a barrier or an advantage may be dependent on the location of the site and the amenability of the farmer.

In comparison an energy crop plantation is single use, with no current options to create additional in-field value. This was noted by an industry representative as a potential barrier to developing a more extensive feedstock base for energy crop material:

P02: Well erm well what it needs to be done is to start rewarding farmers for the fringe benefits. The fringe benefits are very significant with willow; in particular you get lots of biodiversity on your land.

Although, these factors are not specific to considerations regarding marginal land, they are aspects of the wider landscape within which energy crops are competing. Equally, although dedicated energy crops fair favourably in comparison to intensive arable systems with regards to biodiversity, changes in land use nevertheless displace and alter the services provided by said land, such as food, feed, water regulation, carbon sequestration, aesthetic value, or recreation (Coleby, et al., 2012).

Modelling focuses on the economic decision between different crops therefore obscuring the wider set of land based energy systems being sold to farmers that are often more lucrative, do not require direct farmer investment, and in some instances can be deployed without significant land take or disruption to other farm activities. When situated within this context energy crops lose out:

H03: Well the wind turbine route was quite simple they were going to pay between 30 and 60 thousand a year just to have it sat there, … It's a bit more lucrative than a field of miscanthus grass, you know what I mean.

The above quote highlights a major disjuncture in profitability that exists between energy crops and some of the alternative renewable energy technologies that are being sold to the farming community. In this regard the assumption that £241/ha and £526/ha (gross profit) for SRC willow and miscanthus respectively could stimulate the conversion of between 3-13% of UK agricultural land to energy crops (DECC, et al., 2012) appears far less realistic. Renewable energy, whether directly owned or through a lease agreement, is obviously not available to every farmer and comes with its own disadvantages. For example, a usual lease agreement will last for 25 years, in which land is tied up and requires access to outside parties, with sometimes considerable disruption during construction (which may have implications for use after the project end), whilst placing management obligations on the landholder (Anthony, 2013). However, the presence of these options helps create an environment of lucrative renewable possibilities. In comparison energy crops provide comparatively low and uncertain returns, and are without a body of intermediaries involved in a soft or hard sell of the crops.

8.4 **Producing Marginal/Quality Land**

This section examines how land quality and marginality is produced through the interactions between practices and technologies of land management, the farm enterprise, values, markets, and regulation. When value is constructed and flexible this opens up opportunities as well as identifying more barriers to the adoption of energy crops.

8.4.1 Making Marginal Land

The technical assessment of marginal land contained within the modelling literature reviewed previously in this chapter obscures the way in which marginal land as an on farm category is produced through the interaction of numerous factors. Although these factors are often related to physical characteristics of the land - its steepness, soil type, and propensity to flood - how that land is made marginal requires encounters with other policies, such as set-aside, as well as technologies and practices. It is through the frictions that occur during these convergences that land is made marginal in certain instances. The

consequence is that lands which may have previously been economically and practically viable to cultivate are made marginal. Therefore marginal land is not a static category and might shift once more to viability depending on future changes to practices or on farm technologies, as the following quotes highlight:

> H03: We've got [a bit of land] that is just plenty steep enough to farm, … That's been aggravated because I got a bigger sprayer two years ago and its dodgy on the hillside. [the land is cultivated for wheat and the farmer is considering an alternative venture, Christmas trees]

> H05: … we have taken [land] out of production for ELS [Entry Level Stewardship scheme] and such because we have been aware of buffer zones for water courses but these have been areas where they are difficult to get vehicles in.

In these instances the trend for large farm machinery means that certain parts of fields are no longer accessible, or in the case of H03, safe to cultivate. The understanding of marginal at the farm level therefore includes land that is made marginal through the general trend towards increased economies of scale and larger machines. For example the Claas Protector combine harvester produced between 1968 to 1972 had a header width of between 2.6m and 3m depending on the header variant (Harvestop, 2014i). In comparison, the Claas Lexion 740, the smallest of the Lexion series currently in production, has a header width of between 7.5m and 9m (Harvestop, 2014ii). This is to say nothing of the changes to the tractor in terms of increased size and horsepower which has implications for the size of tractor led machinery that can now be operated.

The increased capacity and output of machinery comes with additional cost and time implications relating to its set up and running requirements. As one farmer noted, this meant that smaller fields were not commercially viable to cultivate with crops, not because they could not grow a good crop but because the cost and time involved in harvesting was now prohibitive:

> H05: Combines are a high capacity machine and we have like a one and a half acre paddock, by the time we have put the header on, driven

round the outside and taken it off again, it's half a day gone and it's not cost effective.

Previously, these pressures have favoured a trend towards large field sizes and larger farms (see DEFRA, 2012) due to the requirement to achieve certain economies of scale to produce the conditions in which new larger machines become efficient. Despite regional variations (linked to specialisation), increased average field size has been an enduring development of the self-sufficient imaginary. For example, between 1945 and 1994, in pastoral areas such as Somerset, field size increased from 5.5ha to 9.5 ha. During the same timeframe, in areas such as Cambridgeshire where arable specialisation diminished requirements for boundaries to secure livestock, field size expanded from 6.5ha to 16ha (Robinson & Sutherland, 2002). However, with the inception of hedgerow regulations in 1997, new barriers to boundary removal where created (Natural England, 2014) and this trend has been arrested with field size and boundaries having stabilised (Gallent, et al., 2015).

The field referred to by H05 was bounded by a hedgerow. Although this was not explicitly mentioned as *the* reason for maintaining the field, hedgerow regulations have in many cases removed the capacity of farmers to easily merge these fields into larger land parcels and this was likely an important factor. In these instances marginal land is produced through the ever changing frictions that result from the encounters between a field, the machinery required to manage it and government regulation. In this context a small field has become economically marginal to cultivate and harvest as a core enterprise moves towards greater economies of scale.

This may provide a window of opportunity for energy crops. With smaller fields marginalised within the context of the core farm enterprise it creates room for agronomists to present different options, such as energy crops, for these smaller fields:

A01: I did go around all the crappy little fields, not that you wouldn't want miscanthus on a crap field you know what I mean but it … might turn a better margin.

A low input crop that sidesteps the cost-prohibitive nature of managing a smaller area might become attractive in this context, although, it would still rely upon appropriately sized machinery to ensure cultivation is practically and economically worthwhile.

The downside relates to the feasibility of only putting a small portion of the farm into a new venture. From a risk perspective this might seem advantageous. Many of the interviewed farmers when asked about planting energy crops preferred the idea of a small area as a test plot, but this is not without implications. Economically and practically, the cultivation of a small portion of the farm in a different way might undermine the core enterprise, especially if it causes redundancy of existing farm infrastructure, diminishes the value of sunk investments, changes the configuration of the farm or crop rotations, and causing disruptions to current management regimes. As an industry representative noted:

> P04: … you know if you have got a farmer who has got 80% of his land is high grade agricultural it might not be worth his effort to develop the 20% that isn't …

An additional consideration is that on farm marginal land is often embedded into existing systems of farm management and revenue creation. The most repeated example of this observed during the farm walks was the now replaced ELS agri-environmental scheme[25]. In this way small parcels of marginal land scattered around the farm can be made productive through enrolment in government schemes which are often tailored to ensure minimal disruption to the main farm enterprise. Additional options for larger plots of land that were observed during the interviews and farm walks included small livestock enterprises, rental to the

[25] During the time period within which interviews were conducted the ELS scheme was in a process of transition towards being replaced by a new Countryside Stewardship scheme. This process appears to be causing significant resistance from the farming community at present with reduced uptake. However, given that the previous ELS scheme had many agri-environmental options that required only small plots of land or interventions that were at the margins of intensive systems, it is unlikely to translate into significant opportunities for energy crops.

equine trade or neighbouring farmers, production of hay for pet and equine markets, and an off-road motorbike course. As of 2014, roughly 55% of the UK agricultural area was within voluntary agri-environmental schemes (DEFRA, 2014i), whilst nationally 57% of farms have diversified their activities in some way to provide additional economic opportunities (NFU, 2015). Therefore the deployment of energy crops on a farm's marginal land might disrupt existing uses that are produced through the ability of farmers to connect their land into a range of different regulatory, agricultural and non-agricultural options for use.

A potentially significant and emerging means through which land is made economically marginal relates once more to pesticide resistant weeds such as blackgrass which was considered in more detail in Chapter Five. All the agronomists interviewed and several farmers, discussed blackgrass as a major challenge to continuing commercially viable cultivation of land with annual crops such as wheat, OSR and barley. As noted in Chapter Five, blackgrass can have a significant impact on yield whilst also contaminating the harvested crop leading to buyer rejections. As one agronomist notes, this influenced a farmer's decision to plant miscanthus:

> A06: … there was big block [of miscanthus] that went into reasonably nice land to be fair but they had issues with grass weed so they took the opportunity to put that land in at that stage.

Problems controlling grass weed populations were an emerging factor influencing some farmers to explore alternative production methods and crops as combinable crops became economically marginal. In these contexts, miscanthus might offer a viable means of controlling blackgrass. The following quote is from an agronomist, on whose family farm miscanthus had been planted over the entirety of the 400 acre holding. The main enterprise had previously been combinable crops. Blackgrass played a role in this decision:

> A09: It's [miscanthus] vigorous and tall, within the miscanthus the first couple of years there seemed to be a lot of blackgrass in the rows but that has disappeared … Certainly within the rows now if

> you walk it there is very little blackgrass growing so from that point of view it has died out.

However, unlike other options for managing blackgrass through a change in cropping (see below for examples), the miscanthus has a much longer field life. This creates frictions where the farmer is looking to quickly return the land to previous systems of cropping. The consequence is a trajectory that favours the adoption of shorter term and more flexible options. The two farmers interviewed whom discussed taking their land 'out of production'[26], preferred grass lays harvested for silage in one case, and grass seed in the other, over miscanthus or SRC willow. These arrangements benefited from pre-existing relationships between neighbouring farmers, through which machinery was contracted, and the greater level of flexibility these management options involve.

8.4.2 Grassland is Good?

A key finding from the modelling literature is that when defined through static technical criteria, poor land is plentiful in the UK particularly when identified as grade 3 and 4 land within the Agricultural Land Classification Scheme (Lovett et al, 2009). These categories consist of a significant proportion of the UK's arable lands, and temporary and permanent grasslands. If we ignore the arable land captured in these exercises as an artefact of the shortcomings of the ALC mapping data, this leaves permanent and temporary grasslands.

However, interviews with livestock farmers question the interpretation of this land as marginal. Although uncontroversial, it is important to reflect that the land holding and the farm enterprise are co-produced, therefore marginal arable lands are often embedded within livestock systems for which the same land becomes quality grassland for grazing. Indeed livestock farmers interviewed never positioned the production of grass in a negative light, indeed quite the opposite:

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[26] 'Out of production' despite the nature of the suggestion more accurately means out of combinable crop production. Not the end of agricultural activity.

NW03i: So you are limited on your cropping that you can do, so we are stuck to grass,

NW03ii: Grass is the best.

…

NW12: We only grow grass we don't grow anything else. We are good at growing grass.

In this regard 'grass as good' is linked to how the farm has been shaped by the limitations of the land. The inability to grow arable crops does not signal an end to agricultural activity, therefore livestock dominated systems of management in areas suited primarily to grass production meant that quality is produced through redefining the criteria of 'good' land within a particular set of practices.

Likewise the varying quality of grassland was also accommodated through different livestock management systems. Across the livestock farmers interviewed, land was an important shaping factor influencing the nature and scale of the farm enterprise. The larger holdings containing productive grasslands often had a core enterprise focused on dairying. If the farm was smaller in size with a larger variation in grassland productivity then a sheep or beef rearing/fattening enterprise was more likely. The small number of upland farmers interviewed specialised in rearing sheep which were grazed extensively on the uplands. In many respects this was an important component in maintaining the character of the upland landscapes. The sheep were then sold to be fattened elsewhere in the region or country. This is all very uncontroversial, however, in the context of discussions of marginal land and bioenergy the production of quality through changing of factors is absent. The production of quality causes significant resistance when it comes into contact with crops for supposedly 'poorer' land as livestock farmers were just as likely as arable farmers to consider their land too good for energy crops.

Therefore, the way in which land is used, and how that shapes and is shaped by agricultural activity, produces a farm-level understanding of quality that is completely absent from modelling assumptions. The connection made between

energy crops and marginal land therefore becomes an unnecessary barrier to their deployment rather than a positive characteristic of these crop varieties and their potential cultivation.

Finally, the predominance of livestock enterprises producing meat and dairy challenges claims that cultivating this land with energy crops will minimise impact on food production. As highlighted in this chapter most farms had maximised their core enterprise in terms of the land holding and as such any reduction in available land for silage and grazing would increase reliance on bought in feed, escalating the tension between land for food, feed, and fuel.

8.5 **Conclusion**

The desire to link lignocellulosic biofuels with feedstocks grown on marginal land as a means of navigating food versus fuel and land use controversies created a set of questions for biofuel policy. How much marginal land is there? How much feedstock can it produce? And what are the implications of using it? This chapter has examined three influential modelling exercises (Haughton, et al., 2009; Lovett, et al., 2009; Turley, et al., 2010), tracing the construction of marginal land within them, and how they have mapped marginal land in the context of energy policy in the UK.

This analysis highlighted the way in which marginal land is mapped through utilising GIS mapping practices and sources of data such as Ordnance Survey and the ALC scheme. Consequently, marginal land is constructed as a static, primarily biophysical category, with notable exclusions relating to cultural, legal, and environmentally significant locations (National Parks, AONBs, and SSSIs). When these maps are combined with Natural England yield mapping (Turley, et al., 2010), and economic based decision modelling (DECC, et al., 2012), highly attractive estimates of the UK's theoretical potential for biomass production from energy crops on marginal land emerge.

However, land is valued in diverse ways by different groups (van der Horst & Vermeylen, 2012). These alternative judgements are missed by assessment of biophysical properties. How do these generated definitions of marginal land

hold up when compared with on farm understandings of land quality, value and use? Two main areas were discussed.

The first involved discussions of energy crops and marginal land at the farm level. It highlighted an initial agreement with the notion that marginal land is a suitable site for energy crops, and that energy crops are considered as appropriate *for* marginal land. Unfortunately, this linkage produced considerable resistance in context of their own farm, as farmers did not regard their land as marginal *enough* to be a site for energy crops. An unwritten subtext to this conversation is that if energy crops are for marginal land, then adoption signals to the wider farming community that your land is poor. These symbolic factors are an important component reflecting farmer values and practices with regards to exhibiting themselves as skilled good farmers (Burton, 2004). Energy crops, framed as for marginal land disrupt these symbolic values. However, the farmer has previously been neglected in this regard, with a focus on the symbolic and cultural values attached to landscapes by the public, and concern that dedicated energy crops would disrupt established landscapes (Karp, et al., 2009). Therefore this work expands work on the cultural and symbolic value attached to land by farmers into the new context of emerging technologies, as well as contributing a further perspective to discussions on the value of land.

Furthermore, farmers' discussion of land highlighted its scarcity. Additionally, available land is embedded within existing practices. Significant work has gone into forming agricultural activities into existing configurations and any change that disrupts this has the potential to undermine that work, as well as requiring significant time, investment and additional work itself. Resistance to delivering the imaginary emerges from the inertia of existing on farm configurations. Farmers are not vocal protesters against energy crops, but nevertheless these forms of resistance have done more to limit the potential of dedicated energy crops than public protests. In contrast, farmers were unsurprisingly more attracted to low risk, minimal impact, renewable energy diversifications which also offered potentially more lucrative returns or value added.

This also highlights a way in which resistance to embedding socio-technical visions can be minimised by tailoring technologies to synergise more effectively with existing systems. As Burton (2012) suggests in the context of agri-environmental schemes, considering farmers cultural and aesthetic preferences, and adopting prescriptions to incorporate them even partially, might go some way to alleviating farmer resistance.

The second area dealt with how land and management activities are highly heterogeneous, producing a flexible understanding of quality and marginality on farms in contrast to the static assessment of land value in models. Most obviously, different sectors use land differently. Grasslands identified as marginal through modelling can be characterised as prime grassland by the livestock farmers working them. Secondly, marginality is determined by individual farm configurations between the core enterprise of the farm, practices, technologies, markets, regulation and values, which are subject to change over time.

Two important factors involved in this change were resistant weeds and changing machinery size and capacity. This creates opportunities and barriers. If energy crops can be positioned as a management option for resistant weed problems then farmers may be attracted to them, although a long field life raises questions about future flexibility. In addition, small or steep areas of land, difficult to manage with ever larger machinery might be cultivated if energy crop machinery and practices can accommodate these conditions.

These reflections bring something akin to the landscape as described in the multi-level perspective framework (Geels, 2002) into play. If the socio-technical vision for lignocellulosic technologies does not change, the landscape within which this vision is situated will continue to change over time. Eventually this may create conditions more conducive to energy crops if they prove a means of managing resistant weeds, or can be cultivated on land abandoned to traditional management due to increased machinery scale. Therefore, the socio-technical imaginaries framework might be developed further to incorporate consideration of the evolving landscape of change within which imaginaries take shape and act.

This chapter has also highlighted that marginal land as a concept tells us very little about the prospects for energy crops and the potential land available to plant them on. Instead, it argues that referring to a static concept of marginal land introduces unnecessary barriers. Rather energy crops need to be situated in a broader context that accounts for the cultural, economic, practices, technologies, and values that shape land use and change. This might require crop breeding that incorporates these on farm and community values, as well as the needs of the lignocellulosic biofuels industry.

9 Discussion & Conclusions

9.1 Introduction

Liquid biofuels straddle the nexus between agriculture and energy, requiring socio-technical change in energy and agricultural regimes. Despite this crucial linkage, consideration of how existing agricultural practices, decision making, farmer values and actor inter-relationships may enable or hinder the development of current and future biofuel supply chains has been neglected.

This thesis aimed to examine the ways in which biofuel policy imaginaries envision agricultural systems, actors and practices in the UK, through scrutinising the assumptions and expectations about agriculture embedded in policy through modelling exercises, and critiquing these assumptions through comparisons with on farm decision making, practices, values and inter-relationships.

This aim was channelled into three specific research questions:

- How do biofuel and agricultural policy imaginaries compare and contrast over time in the UK? How has policy attempted to materialise them into practice?

- What assumptions to UK biofuel policy models make about agricultural systems, decisions, and practices? How do they compare with on farm decision making, practices, values, and inter-relationships?

- What are the opportunities and challenges, highlighted through understanding the agri-energy nexus, for the future emergence of lignocellulosic biofuels?

Qualitative research methods are used to address these research questions. In total I conducted 48 semi-structured interviews, this included seated and farm walk style interviews with farmers, and phone interviews with agronomists, straw merchants, contractors, and biofuel/bioenergy industry representatives

and consultants. Interviews were complimented by documentary analysis of UK and EU legislation, regulation and policy concerning agriculture and biofuels from 1945 to 2015. Analysis was inductive and interpretative, identifying the most salient themes and topics that emerged from the data.

9.1.1 Overall Conclusions

The analysis conducted in this thesis points to the following key conclusions with regards to each research question.

How do biofuel and agricultural policy imaginaries compare and contrast over time in the UK? How has policy attempted to materialise them into practice?

Past agricultural change driven by post World War II imaginaries for sufficient food, has entrenched systems of production that prioritise the intensive and efficient production of food. As Chapter Five argued these systems of production became contested due to their environmental, fiscal and animal and human health implications from the 1980s onwards, in the process destabilising the sufficient imaginary that sustained continued direct intervention. Since then the CAP has moved towards embedding multifunctional agricultural systems. This shift has opened up space for biofuels and energy crops as part of the value added from agriculture. However, the resurgence of food security narratives, partly due to the emergence of first generation biofuels may shift CAP once more to food first priorities, creating issues for lignocellulosic biofuels reliant on non-food energy crops. Whether this can be reconciled by the so called sustainable intensification of agriculture is yet to be seen.

Furthermore, productivist practices and institutional arrangements were the result of concerted activity, fiscal and regulatory intervention, and innovation and technology adoption. Analysis in Chapter Five examined the sustained legislative program in the post war period which established market arrangements to protect farmers from volatility, awarded capital grants for machinery, subsidies for fertiliser, invested in research into new crops, livestock, methods, pesticides and herbicides, and advisory services that ensured that new technologies and practices were adopted. In comparison, the current regulatory agenda for biofuels is based only on the RTFO as the sole mechanism to bring

about change in the liquid fuel market and thus the agricultural market. Analysis in subsequent chapters has gone on to examine the work that goes into sustaining current agricultural systems of practice, highlighting that price alone is not always enough to overcome entrenched values, ways of working and doing, as well as sunken capital and infrastructure.

What assumptions to UK biofuel policy models make about agricultural systems, decisions, and practices? How do they compare with on farm decision making, practices, values, and inter-relationships?

This thesis has argued that UK policy and previous academic studies of lignocellulosic biofuels have drawn on modelling approaches as a means of performing the interface between emergent lignocellulosic industry and agricultural systems. These models embed particular assumptions with regards to three main areas: supply chains, decision making, and biomass and land resources.

A central component to the analysis has been interrogating the way in which a reliance on modelling as *the* means of sketching out the present and the future, serves to privilege certain types of knowledge, obscuring a more nuanced understanding of the complexities, values, practices, technologies and decision making influences at play. For example, as examined in Chapter Eight, mapping marginal land to inform policy expectations draws upon knowledge pertaining to the characteristics that can be given cartographic form. This is then enacted in producing expectations about the amount, availability and suitability of this land for producing dedicated energy crops. In the process, what this land is used for currently, economic and non-economic value derived from those uses, how it is embedded in specific modes of use, the values that are entangled within said use and the desires and demands of those managing it are absent. Whereas some of these are potentially map-able (current use), others such as farmer pride in their land are harder to establish and map. The consequence is that some aspects of agriculture systems and material characteristics are foregrounded, whilst others are obscured and ignored.

This thesis has highlighted the following factors that are obscured as a result of the reliance on modelling. Firstly, how agricultural intermediaries such as merchants, advisors and contractors despite being important supply chain actors have been ignored in policy modelling and the incentive regime. However, they influence farmer decision making with regards to the adoption (or not) of certain practices, through providing advice, machinery, labour, and other services. Secondly, how on farm decision making is constructed through the interaction of numerous factors that is beyond the purely economic. Thirdly, biomass and land resources are materially heterogeneous which has consequences for availability and use of these resources for energy.

What are the opportunities and challenges, highlighted through understanding the agri-energy nexus, for the future emergence of lignocellulosic biofuels?

The analysis conducted in this thesis and summarised in this chapter points to a number of opportunities and barriers for the future of lignocellulosic biofuels.

Chapter Six examined industry perspectives on the future for lignocellulosic biofuels and identified some modest prospects, particularly for medium scale developments, perhaps in conjunction with existing bioenergy facilities which would allow for synergies in biomass handling infrastructures. The ability to utilise lignocellulosic technologies as an add-on to existing facilities was deemed to be a possible niche in the UK within which to foster lignocellulosic development. However, the economics of feedstock production and regulatory landscape was perceived as being challenging, discouraging the emergence the lignocellulosic technologies, although perhaps not preventing their adoption once technically and commercially proven elsewhere.

Feedstock availability was examined in Chapter Seven and Eight with regards to straw and energy crops on marginal land respectively. Straw was highlighted as offering a mixed bag of opportunities. Chapter Seven examined the on farm decision making in the context of straw, in the process highlighting incorporation as a valued practice, advised by agronomists for managing soil health. This contrasts with modelling assumptions that prioritise baling and the sale of straw. However, the material heterogeneity of straw means that there are spaces in the

market. Low quality, damp straw for instance could be suitable for lignocellulosic biofuels, and currently has limited market outlets. Likewise, oilseed rape straw is often incorporated due to its brittleness. If lignocellulosic operators were able to effectively bale the straw then this could be another opportunity. Indeed, these opportunities might grow further if resistance of weeds to herbicides continues to escalate and the requirement for new chemicals creates further regulatory consequences barring straw from use in livestock production. Straw is therefore the feedstock with most imminent prospects for exploitation.

In contrast if dedicated energy crops are the future 'growth area' for biomass production in the UK (DECC, et al., 2012), more needs to be done to support intermediary actors that conduct crucial work. The emergent energy crop market has suffered from unstable intermediaries which has had consequences on farmer assessments of the crops viability, as well as UK capacity to increase production if market demand did increase significantly.

Similarly, if lignocellulosic biofuels and bioenergy are to be realised then current regulatory frameworks for embedding and materialising these technologies require reform. At present they have not brought about sustained change. Energy policy has treated agriculture as responding solely to market signals; this ignores historical experiences that analysis in Chapter Five suggests required concerted action over many years.

Whether emergent lignocellulosic technologies are able to take advantage of domestic biomass resources is yet to be seen due to the commercial nascence of the technology. Equally, evolving agricultural imaginaries may shift trajectories away from dedicated non-food crops on the basis of reappearing food security concerns.

Building on the summary presented here the following four sections further unpack the main findings of the thesis linking them to relevant bodies of disciplinary and theoretical literature, highlighting the novel contributions to each. Section 9.2 highlights findings and novel contributions to the socio-technical imaginaries literature. Section 9.3 highlights findings and novel contributions to the rural sociology literature. Section 9.4 and 9.5 continues this

for the biomass and biofuels literature and agricultural economics literature respectively. Section 9.6 reflects on the main research limitations and draws attention to areas of future research and provides the closing remarks.

9.2 Key Reflections: Socio-technical Imaginaries

This section is broken into four sub-sections, the first (sub-section 9.2.1) examines the possibility of imaginary succession an as yet unacknowledged prospect within the literature. The second (sub-section 9.2.2) reflects on the potential for looking into the future, not just looking at imaginaries of it. The third (sub-section 9.2.3) on everyday resistance and fourth (sub-section 9.2.4) on materiality, highlight the value of engaging in a more fine-grained analysis of the process of embedding. In particular it reflects on the space this can create to feedback into the future imaginary and highlight necessary actions required to embed imagined futures.

9.2.1 Imaginary succession: breakdown and transition

The concept of socio-technical imaginaries provides space for the possibility of imaginaries competing and alludes to the prospect of imaginaries being superseded (Jasanoff, 2015i). However, none of the existing literature examines this process.

Chapter Five engages with this prospect describing a process of breakdown, as the promised agricultural future turns to nightmare and transition, as newly imagined futures emerge from this process of undoing. The unravelling of the post-war sufficient production imaginary emerged from the convergence of a range of controversies in the 1980s related to the fiscal, environmental, human and animal health, and social consequences of the agricultural practices and institutional structures that sustained the productivist era. In response to internal (costly surplus, biodiversity decline) pressures to maintaining existing agricultural regimes and external pressures (e.g., from the World Trade Organisation), the EU's Common Agricultural Policy was gradually restructured as food security fears were replaced with costly and controversial surpluses. Over time, subsequent CAP and UK regulation moved towards embedding multifunctional landscapes as agriculture become reconceptualised as a sector

providing more than just food and fibre (Potter & Tilzey, 2005). Agri-environmental schemes, set-aside, cross compliance, farm diversification, and upstream diversification have all been components of this increased multifunctionality, although with varying degrees of success.

This finding highlights how new socio-technical imaginaries can evolve as a result of challenging conditions causing the previously dominant imaginary to lose wider salience as a desirable future. The multifunctional imaginary was not presented as a fully formed alternative but rather emerged and gained traction as a result of almost two decades over which the sufficiency imaginary became contested and the institutional arrangements that supported it became increasingly untenable.

As was noted in Chapter Five, this transition to a multifunctional imaginary served to create a more robust platform for biofuels to be adopted. Instead of being envisioned as responding to a solely agricultural problem of surplus, or an energy problem of oil shortages, biofuels are situated as providing an upstream development that diversifies agricultural markets whilst contributing to wider societal goals such as climate change (see EC, 2000iii).

This finding opens up space to consider what happens if imaginaries are tied to sectors rather than technologies. So far the imaginaries literature has focused in on futures that are explicitly attached to particular forms of science and technology, such as nuclear power plants (Jasanoff & Kim, 2009), mines (Storey, 2015), genetically modified organisms (Chen, 2015; Smith, 2015) and nanotechnologies (Burri, 2015). What is highlighted here is the prospect for established or emerging technologies to be re-imagined as a result of a dominant sector-based imaginary breaking down and a resulting transition. Biofuels did not fundamentally change as a technology, however, the transition enabled them to be situated in a more desirable position to receive government support and be embedded.

This presents a novel contribution to the imaginaries literature's understanding of competition, presenting the first empirical case of imaginary succession and

highlighting the myriad forces involved in the process of breakdown from within and without the agricultural socio-technical system.

9.2.2 Everyday Resistance

The imaginaries literature has, to date, engaged with resistance primarily as occurring through explicit forms of protest and dissent to government imaginaries and efforts to embed them (see Jasanoff & Kim, 2009; Felt, 2015; Kim, 2015). However, this thesis has argued that resistance is not only limited to this high level policy environment but also finds itself rooted in the interaction of new technologies with entrenched practices of management, decision making, and cultural values.

Chapters Seven and Eight have focused in on these forms of everyday resistance from farmers and intermediaries and their emergence from multiple factors. Farmer's resistance to energy crops or the sale of straw was linked to established ways of doing which were far more limiting with regards to domestic prospects for developing a lignocellulosic biofuel production chain than the food versus fuel protests.

Chapter Eight's examination of energy crops and marginal land was particularly illuminating in this regard. Marginal land was argued to not be a universal category shared between policy mapping and on farm understandings of land creating significant disjuncture. Additionally, the dominant means of identifying marginal land in policy foregrounds knowledge pertaining to the characteristics that can be given cartographic form, ignoring the many ways in which land is valued and used. Land deemed marginal on a specialised arable farm might be considered quality grassland from the perspective of a dairy farmer. An extra consideration is that land marginal in a system of traditional agricultural management was often perceived as being marginal for energy crops as well. Steep or water logged land was still difficult to cultivate and at risk of returning poor crops. This mirrors earlier assessments of domestic UK biomass potential by the RCEP (2004) report *Biomass as a Renewable Energy Source,* which positioned marginal land as potentially limiting the yield and economic viability of energy crops.

Importantly, Chapter Eight highlighted how marginal land is constantly in the process of being made (and unmade), contingent on a number of interconnected factors. The core farm enterprise, the farm technologies and scale of equipment, and availability of alternative options (tourist, rental, equine, agri-environmental), are just some of the influences that surfaced in this research. As such there may be future opportunities as land is made marginal in the context of a specific farm. Although at present the majority of farmers rejected the use of their land for energy crops, the context is constantly evolving over time and in the future resistance to energy crops might diminish. However energy crops are just a single option amongst numerous alternatives, many of which are more versatile, lucrative, and less disruptive. At the time of interviewing, many farmers considered solar and wind technologies to be far more preferable.

Similarly, by focusing only on high level resistance to policy visions and state imaginaries, the means and mechanisms to overcome these forms of resistance are neglected. As was noted, land use confers symbolic value to the wider farming community (Burton, 2004; Burton, 2012). When energy crops are framed as being for marginal land their planting symbolises that a farmers land is marginal or second-rate. This creates considerable resistance from farmers who do not consider their land to be marginal *enough* for energy crops. But biofuel policy has not effectively engaged with the barriers these forms of resistance pose to the development of biomass production chains. Nevertheless despite overlooking these factors their presence has had a discernible impact on adoption of dedicated energy crops. Energy crop cultivation continues to fall well below even the more modest policy expectations and with limited signs that this is to change (Adams & Lindegaard, 2016).

This empirical case points to the power of these forms of resistance have in shaping the emergence of imagined socio-technical futures. Nevertheless it is not simply a case of highlighting more barriers, it also points to the prospects for how these frictions might be reduced. As Burton et al. (2011) argues in the context of agri-environmental schemes these cultural factors need to be accommodated in altered management practices creating more acceptable

aesthetics from the farmer's perspective. Such insights illuminate possible areas where change is possible to minimise cultural resistance to alternatives.

The consequence is that when something like marginal land as a concept is stripped of the context and practices through which it is used and valued the result is limited understanding of the prospects for energy crops that could use this land because it's use is entangled in context and practice. For this to be possible, the UK vision for energy crops needs to be situated in the broader context of land competition, farmer values, existing practices and alternatives for land use.

Furthermore, the empirical focus on supply chains highlights the risks that are presented if an imaginary does not engage with its raw infrastructure needs. In this instance the result has been a market preference for highly contested north-south biomass supply chain arrangements that have underpinned much of the controversy and backlash that has occurred against biofuels (Mol, 2007). This is partly due to the inertia of established UK agricultural systems which have resisted efforts to diversify into biomass production.

This analysis highlights the need to expand the language of resistance to include the barriers that emerge from everyday interactions. Doing so adds further nuance to the ways in which imaginaries are resisted and at what level. Equally, this contributes further to understanding how desired futures have not always materialised as planned due to the inertia of existing practices and infrastructures shaping what is possible moving forward.

9.2.3 Materiality

As was noted in Chapter Three the imaginaries literature has not engaged with materiality as a component of resistance. Indeed the work that does touch upon it situates it as a facilitative factor (see Storey, 2015 on mining in South Africa). This separates it from a wider body of literature that is more closely attentive to materiality, highlighting the effort required to accommodate materiality (see (Shove, et al., 2014; Rutherford & Coutard, 2014), how materials are shaped to meet our requirements (Otter, 2010), as well as more broadly forgrounding the materiality of human societies and bodies (Latour, 1991; Iovino & Oppermann,

2014; Iovino & Oppermann, 2012; Bennett & Joyce, 2010). In this thesis materiality is situated as being important for understanding several disjunctures between UK policy expectations produced through modelling, and on-farm material and market circumstances.

Government policy modelling constructs agricultural resources as readily fungible and homogenous. One plot of marginal land or one tonne of straw is the same as any other, and thus readily useable for energy purposes. Consequently much effort has gone into quantifying the amount of land and straw available nationally. Focusing on straw Copeland and Turley (2008) estimate roughly 4.9Mt of straw is potentially available for energy production. This translates into a sizable portion of the UK's renewable energy targets. If the marginal land identified by Turley et al. (2010) was put to energy crops then "up to 18% of the RES renewable transport fuel energy target (10% by energy) could be met ..." (p. 3). These estimates fold many very different materials into a category that allows them to be framed as comparable and interchangeable to meet the needs of national energy policy aims.

The thesis has highlighted the material and definitional heterogeneity that exists around straw and marginal land, respectively. The consequence is that assuming homogeneity masks both additional barriers and potential opportunities outside the scope of modelling. Chapter Seven in particular highlighted a number of possible opportunities that arise from considering the material heterogeneity of straw on the basis of type, quality and bale size. Once these are taken into consideration, some areas of the straw market appear more viable than others. For instance, the livestock industry is presented as a key consumer of straw, but livestock farmers preferred particular types of straw (wheat, oat, barley) of high quality (dry). In addition users have bale size preferences determined by their needs and handling infrastructure. Therefore, rather than asking how much straw is used by livestock markets and therefore how much is left when subtracted from the overall amount produced, addressing material heterogeneity creates space to ask what types, quality and bale sizes slip through the gaps.

In this case attention is then drawn towards considering the suitability of damp, poor quality straw, and oil seed rape straw. The former usually achieves a lower price and the latter is materially fragile and therefore difficult to harvest and handle under current practices. These potential market spaces might be attractive to lignocellulosic buyers assuming they can be utilised and harvested effectively by the biomass handling and processing technologies. Furthermore they present more concrete opportunities for exploration than overarching assumptions about the national availability of resources.

In short if brought into play materiality offers opportunities to consider the viability of certain imagined futures on the basis of resource availability, perhaps feeding back into the future making process. Indeed as the work here shows, if integrated into the socio-technical imaginaries concept, it provides space to evaluate potentially more robust and tangible opportunities for sourcing resources as highlighted here.

9.3 **Key Reflections: Rural Sociology**

This section is broken into three sub-sections. The first (sub-section 9.3.1) highlights the empirical contribution this thesis makes to the historical story around the emergence of the productivist agricultural regime in the UK. The second (sub-section 9.3.2) highlights the importance of engaging more fully with agricultural intermediaries in rural sociology. The third (sub-section 9.3.3) reflects on broader consideration of symbolism in the farming community.

9.3.1 Productivism

The rural sociology literature has largely engaged with productivism from the perspective of defining it in relation to what comes after, post-productivism, the system of empirical interest (see Lowe, et al., 1993; Ilbery & Bowler, 1998; Wilson, 2001; Walford, 2003). However, significantly less work has engaged with how it came to dominate agricultural systems of practice in the UK. This analysis has highlighted how productivist practices and institutional arrangements were the result of concerted government activity to secure an imagined good future of self-sufficiency. Analysis in section 5.2 for instance highlighted the sustained legislative program in the post war period which aimed to change the practices

of production, market arrangements and drove techno-scientific innovation and adoption, as a means of producing sufficient food to meet the needs of the poor and plug national security vulnerabilities. Failure on the part of the farmer could result in farms and land being confiscated. The relative rarity of farm confiscation suggests that in general the community was relatively willing (or sufficiently coerced) to adopt the new technologies and practices promoted by government initiatives. Productivism did not emerge 'naturally' but was rather the result of persistent government effort and considerable work over time to achieve a very particular set of quantitative outcomes imagined as desirable in the post-war environment. These efforts aimed and succeeded in moulding agriculture into a highly productive and efficient socio-technical system (Lowe, et al., 1993; Wilson, 2001; Walford, 2003; Burton, 2004). This thesis therefore contributes to understanding how productivism has become a particularly dominant and persistent system of agricultural production, highlighting the long time frame over which change was achieved and concerted government action to achieve what was imagined as positive change.

9.3.2 Intermediaries

The farmer is widely examined and assumed to be the crucial actor making decisions over land and undertaking management of land. This research does not wish to fundamentally challenge this. However, it does highlight the important role of merchants, advisors and contractors within the matrix of decision making and management. A small body of literature from a rural sociology perspective has engaged previously with agronomists as an important agricultural advisor influencing on farm practices (see Tsouvalis, et al., 2000; Ingram, 2008; Ingram & Morris, 2008).

The findings of this thesis once more highlight the importance of these actors in in introducing new technologies and practices but in the novel context of energy feedstock developments. Agronomists where shown to influence on-farm practices, which established wider trends in the sector, potentially causing disjuncture with the goals of biofuel policy. This was most notable in the straw market where agronomists routinely advise incorporation of straw as the best practice soil management option. Straw merchants remarked how this had

reduced baled straw availability over time. Whether this has consequences on the future availability of straw is difficult to tell, and will depend on how well entrenched incorporation is as a practice on particular farms and how open farmers are to negotiation about the sale of their straw (see Glithero, et al., 2013i; Glithero, et al., 2013ii). Likewise, in the context of energy crops, agronomists have not engaged with these crops in any significant way and were unsure of the economics and agronomics of cultivating the crops. The consequence is that agronomists are not involved in the soft sell of energy crops, or able to influence farmer decision making in this regard.

Chapter Six and Seven also engaged with merchants and contractors. These intermediaries have been given, at best, passing mention in the energy crop literature (see Sherrington, et al., 2008; Sherrington & Moran, 2010). No study has engaged with merchants and contractors as an important set of actors in their own right. In the context of the straw and energy crop supply chain, merchants and baling contractors provided important services to arable farmers and end users. The quality of their service and their relationship with arable farmers was key to influencing farmers' subsequent decisions about whether to bale straw. Ensuring a strong, professional, and capable set of intermediaries is therefore an important component in translating demand into bona fide supply. This was a major problem in the energy crop market. Contractors in the sector had repeatedly gone insolvent, leaving farmers with planted crops but no intermediaries with the specialist machinery to harvest them. Uncertainty around the continued presence of these key actors is unsurprisingly a barrier to adoption (Adams & Lindegaard, 2016). Furthermore, this raises question about the viability of the market; it seems spurious to claim the supposed prosperity of energy crops when the companies tasked with managing them on behalf of farmers are unable to remain in business.

At the other end of the supply chain, merchants had a role in opening up or closing down local biomass markets to new entrants. Existing bioenergy users relied heavily on straw merchants for the majority of their feedstock requirements. However, some merchants preferred to deal with long-standing clients and customers, over supplying new bioenergy entrants. In this latter case

local production of straw might translate poorly into availability for energy users, forcing a search further afield. Additionally, straw has a well-established if volatile international market, which can cause significant local disruption.

The inclusion of intermediaries within the analysis is vital to adding a significant layer of nuance with regards to the findings around the wider potential market for biomass products and on-farm decision making. This suggests that a considerable research gap is present within the current understanding of farmer decision making and land management practices within the rural sociology literature, particularly with regards to contractors and merchants to which this research highlights and contributes to addressing.

9.3.3 Symbolic Values: Energy Crops

Rural sociologists have been slow to capitalise on dedicated energy crops as a site to examine the symbolic value of particular types of land management, farm practices, farmer decision making and values in the context of liquid biofuels or bioenergy (see Convery, et al., 2012 as an exception). Chapter Eight and sub-section 9.2.3 of this chapter have already touched upon the symbolic disjuncture between energy crops and mainstream farmer values. So far the literature has been focused on agri-environmental schemes and their prescriptions (Burton, 2004; Burton, et al., 2008; Burton, et al., 2011). However, this thesis suggests that considering new technologies, in this instance a novel crop, offer a new avenue of research in this regard. Unfortunately Chapter Eight was only able to provide some tentative reflections, but nevertheless it highlights a potentially rich vein of future empirical research that is situated at the juncture of new technologies and symbolic farming cultures. Similarly, there is the prospect for future research examining how, and if, this changes amongst different subsets of the farming community, such as organic farmers.

9.4 **Key Reflections: Agricultural Economics**

This section is broken into two sub-sections. The first (sub-section 9.4.1) reflects on what is a rational decision if we suspend assumptions that rational is tied to economic gain. I also include consideration what is rational for intermediaries as a set of actors. The second (sub-section 9.4.3) reflects on the use of different

methods for producing empirical data about the farming communities and what implications this has for how we understand farmers' motives.

9.4.1 What is a rational decision?

An implicit assumption interrogated in this thesis is that rational decisions emerge from considering the economic advantages and disadvantages of an action. This is an important and enduring assumption, repeated across numerous models and in the wider literature engaging with biomass feedstocks. Furthermore, it serves to underpin several optimistic expectations about the adoption of practices relating to the cultivation of energy crops on marginal land and selling straw. I do not wish to challenge the importance of economic factors in farmer decision making. As reiterated by numerous farmers, a farm is still a business. Even those farmers who are reliant, partly or wholly, on the Basic Farm Payment regime to maintain profitability are not neglectful of the importance of getting the right price. Nevertheless, what is deemed rational from a policy perspective is not synonymous with what is rational on farm.

As noted by Edward-Jones (2006) even between farmers with similar crops or livestock enterprises "not all [the] farmers … grow the same crops in the same way, and not all dairy farmers … have the same feed rations and calving patterns" (p. 784). This seemingly self-evident observation points to an important argument made in this research. Each farm presents a unique interaction of farmer values, practices, knowledge, technologies, infrastructure, markets, inter-relationships with intermediaries, and personal desires that change over time. This farm heterogeneity impacts on the responses of individual farmers to state, market, public and community pressures to move towards new practices and technologies. Inevitably, what is rational will be constructed differently depending on how these factors come together, in a particular time and place.

In Chapter Seven straw was analysed as a resource with multiple uses with different economic and non-economic value being derived from these choices. Straw may be baled, in different ways to different sizes, and removed from the field, or chopped and incorporated. This signifies the two main ways in which

straw is valued by farmers. In policy the sale of straw is positioned as the 'rational choice' assuming the price is right. But, incorporation may equally present itself as the rational decision from the farmer perspective. Farmer and agronomist assessment of soil health was an important aspect of this. Furthermore, agricultural policy in the form of best practice guidance, positions incorporation of organic residues, such as straw, as important to continued soil health. If incorporation is perceived as crucial to the sustainability of the soil by the farmer (and hence the farm) then regardless of wider economic factors (fertiliser cost, market value of baled straw) incorporating remains constructed as the 'right' choice in that context.

That said, maintaining soil health is not the only occasion in which straw might be important to the sustainability of the farm. Chapter Seven also highlighted how in times of low grain or oilseed prices, straw sale may be crucial to balancing short term finances. At a time when grain and oilseed price were above £120 and £250 (Farmers Weekly, 2015) a tonne respectively, £30-50 a tonne for straw may not seem significant. In contrast when grain was £60 a tonne, as was the case in the early 2000s, straw priced at £30 a tonne becomes situated very differently.

Chapter Eight built upon the existing literature on energy crop adoption and highlighted a number of reasons beyond price why energy crops on marginal land were deemed unpopular. More broadly the economic prospects of the crops were seen as poor with contractor instability being particularly troubling, especially when the crop would last for 20 years and the contractor might last less than five. More local issues such as arson were also a fear. But most persistent was the sense that adoption of energy crops would be disruptive to the enterprise, perhaps causing redundancy of equipment, infrastructure, or labour.

In Chapter Eight, several dairy farmers were incredulous at the idea of switching grazing pasture to an energy crop that had no means of feeding into the main farm enterprise. Energy crops would have been marginal to the functioning of the core enterprise, disrupting existing land management patterns, and requiring

the farm to move towards more bought in feed or reduced animal numbers. Under these circumstances a decision to adopt energy crops is likely to be considered irrational regardless of the price of the crop because the work required to undertake cultivation is not balanced by the perceived benefit accrued to the farm, instead disrupting existing patterns of practice.

The two farmers who had most seriously considered energy crops (one having adopted them) were both elderly and had health complications that limited their ability to farm. As Potter & Lobley (1992) argue in the context of agri-environmental schemes, ageing brings with its change in actions, motivations, and outlook with potential consequences for large areas of UK land. Whether aging alone is a factor in energy crop interest was beyond the scope of this research. However, the adopting farmer was also confronted with ageing equipment and infrastructure in need of renewal, with land that was increasingly hard to cultivate commercially due to weed issues, and a farm ideally situated near an energy producer. Age and ill-health were just some of the factors involved, pointing to the broader convergence of factors that are involved in opening up the farm to energy crops as a viable choice. However, farmers are not the only actors involved in making decisions important to the function and configuration of agricultural supply chains.

Rather than revisit the arguments made in sub-section 9.3.2 about the need to include intermediaries as an important group when considering on farm practices and decision making, I consider here what is a rational decision from their perspective? For merchants it would be imagined to be the highest sale price.

Several straw merchants interviewed professed to rejecting very lucrative offers from short term entrants in favour of maintaining long term connections, and customers. Likewise, farmers also preferred to maintain long term relationships with trusted contractors and merchants over short term offers. Considerable effort went into building and maintaining these relationships and short term economic advantage did not compensate for the potential loss of long term relationships which ensure future access to straw and services. Therefore, in

questioning economic rational decision making the purpose is not to dismiss this as *un*important but to note that it masks the work that goes into maintaining existing on farm and supply chain configurations, and realising new ones. Decisions made with regards to potential biomass feedstocks are interpreted in different ways, with short and long term temporal dimensions, with consequences for the supply and availability of biomass for industrial use, energy or otherwise. Expanding consideration of rational decisions beyond the scope of economic factors to address the social and cultural implications of existing and new forms of practice is therefore an important area of analysis for assessing future prospects for on farm change. This aspect needs to be given greater consideration in the agricultural economics literature.

9.4.2 Methodological Choices

As was noted in Chapter Four the research drew upon several modes of interviewing: seated face-to-face interviews, phone interviews, and walking interviews. Existing studies on farmer decision making have utilised a range of methods from seated structured interviews (Glithero, et al., 2013i; Glithero, et al., 2013ii), seated semi-structured interviews (Convery, et al., 2012), focus groups (Sherrington, et al., 2008), and surveys (Mattison & Norris, 2007). What these methods have in common is that they take place at a remove from the farm and on farm contexts.

In this research seated and phone interview data was complemented through undertaking farm walk style interviews. As was previously noted, when undertaken, farm walks enhanced the richness and nuanced the data produced from the initial sit-down aspect of the interview.

An important instance that illuminated this was a farm walk in which during the opening seated interview the farmer was keen to assert the prominence of price in determining on farm decisions. In contrast the resulting farm walk revealed that the farmer had undertaken considerable environmental works, including building a large pond and planting numerous flower banks to encourage bees and birds outside of the scope of agri-environmental schemes. These decisions were rooted in a deep sense of loss with regards to the diminished diversity of

insects, birds and animals that were present on the farm. Such nuances to the understanding of the farmer's motivations and actions would likely have never been revealed if the interview had stayed confined to the kitchen table. This raises questions about the implications of where an interview is conducted on how we make farmers, their perspectives, values and norms, knowable. Equally it suggests that a seated face-to-face interview should not be taken as the default form of face-to-face interviewing. In the above instance it would have limited the scope and nuance of the data produced, significantly narrowing the frame of understanding with regards to the farmers decision making and on-farm practices.

9.5 Key Reflections: Biofuels and Bioenergy Literature

This section contributions to understanding the prospects for biofuels that are gained from considering agricultural actors as central to the story.

9.5.1 The Agricultural Connection

Chapter Two examined the conceptualisation of lignocellulosic biofuels as an energy technology, in particular highlighting the regulatory consequences of this framing and the focus of the literature on biofuels as a policy issue, requiring policy responses.

Chapter Two also highlighted how the framing of biofuels as a primarily low carbon energy technology resulted in a policy framework one remove from agriculture. Specifically the RTFO which created a market framework perceived to be sufficient to stimulate the development of biofuel production in the UK and the necessary innovations required for upscaling commercially viable lignocellulosic technologies. However, as was noted in Chapter One, biofuels as a socio-technical project straddles the agri-energy nexus, and thus this relatively minor change to the composition of liquid fuel market in the UK requires potentially significant changes to agricultural systems.

This thesis has examined at length the role of agriculture in facilitating and diminishing the prospects for a domestic lignocellulosic supply chain. Often this resistance emerges as a result of friction between the technologies and practices identified as supportive of lignocellulosic biofuels and entrenched agricultural

practices, technologies, values and decision making that create various barriers to adoption. In addition the failure of biofuels policy to proactively engage with agriculture as a site of intervention means that this resistance has continued to be unaddressed. One consequences has been the poor uptake of energy crops over time (Adams & Lindegaard, 2016). By considering agriculture as central to the prospects of biofuels this work adds further understanding to both how these spaces have not proven conducive to the development of large scale biofuel supply chains, whilst adding to the story of why controversial north-south trade networks have come to dominate.

Further to this it examines a wide range of actors' expectations about lignocellulosic biofuels and feedstocks and highlights once more that the UK is not a desirable space for these technologies. Industry representatives favoured energy crops and characterised straw as a high cost feedstock at the scale required to operate a lignocellulosic facility. In contrast farmers were ambivalent to the prospect of growing energy crops which were perceived to disrupt established systems. Therefore, there is an entrenched disjuncture between the availabity of the feedstock most likely to be available to prospective lignocellulosic producers, straw, and their preferred feedstock, dedicated energy crops. Whether intermediaries can navigate these tensions is unclear and would require a change to the regulatory and incentive landscape.

9.6 Limitations & Areas of Future Research

The process of doing any research introduces limitations. The fieldwork, its scope and duration are limited by available time and funds, access to participants, the accessibility of participants, the initial objectives of the research agreed by funding bodies (ESRC), and the broader limitations associated with qualitative research.

One limitation has been the dichotomy within the research between policy defined assumptions and expectations about farmer decision making, cultural identities, values and practices interrogated through comparison with commercially driven and intensive livestock and arable farmers, contractors, merchants and agronomists. Farmers practicing alternative forms of agriculture,

most obviously organic, were not present within the data. This was not a deliberate choice, nor did I undertake actions to exclude farmers engaged in such practices from the study. Further consideration of what opportunities and barriers are produced in the context of alternative systems of agricultural practice, farmer decision making and values is a potentially fruitful avenue of future research.

Furthermore, the research was unable to explore differences in form and scale of engagement with biofuels and bioenergy more specifically. On three occasions farmers were interviewed who were engaged in local community and on farm production and use of bioenergy which highlighted alternative scales of engaging with bioenergy production outside of large scale production envisioned in policy. Research into farmers' engagement and interest in small scale, farm based, or local community or co-operative forms of bioenergy and biofuel production could be an intriguing avenue of future questioning. Interrogating whether attitudes change when benefits and risks are distributed differently and what meaning the technology holds at these scales. Linking back to the previous point there is further options for research that examines whether at different scales different groups of farmers are more or less willing to engage with bioenergy and biofuels.

It may be that other technologies provide valuable examples to how this may play out. One aspect of lignocellulosic technologies is that they are currently expected to be commercially viable only at larger production scales. If this barrier can be overcome, anaerobic digestion perhaps offers an insightful example about the increased prospects for an on-farm biomass technology that can operate at small to medium scales. Assuming it benefits from a regulatory and incentive regime conducive to supporting those scales such as the Feed in Tariff. The current number of AD plants in the UK stands at 254 (Waste and Resources Action Programme, 2016) utilising a range material from farm wastes such as manures, dedicated crops such as maize and silage, and food waste from the food processing an catering industry.

Furthermore, this thesis has not undertaken a comparison with an alternative national context. Both the USA and Brazil where highlighted in Chapter Six as a more likely site for the initial deployment of lignocellulosic technologies than the UK. Even a very cursory examination of the agricultural context of Brazil highlights a very different system. Brazil is the largest producer of sugarcane in the world with 8.2 million hectares planted, however this is further concentrated into specific regions with over 60% of this production focused in the São Paulo region of Brazil (Goldemberg, et al., 2008). The production of sugarcane produces large amounts of biomass waste (bagasse) that is generated through the established practices of harvesting and processing sugarcane (Chandel, et al., 2012) not requiring new crops. Furthermore, land ownership (and thus decision making) is concentrated with large estates some of which also own sugarcane processing mills. In this context the barriers and opportunities for developing a lignocellulosic technologies are significantly changed from that of the UK.

In addition, all research offers a snapshot of a particular timeframe and this is no different. When the project started in 2011 lignocellulosic biofuels were still prominent in the UK policy agenda. The food versus fuel, and iLUC contestations were still being played out with varying degrees of prominence, press coverage was more substantial, and the BBSRC's BSBEC centre was just being established to develop research capacity to take forward the promises invested in lignocellulosic technologies. Since then the profile of biofuels and lignocellulosic biofuels has diminished considerably. Partly this is due to the fall in media attention as controversies faltered in their ability to continue to capture news attention. On the policy front the 2012 Bioenergy Strategy (DECC, et al., 2012) marked a line in the sand, ending what had been a period of almost continued engagement with biofuels and bioenergy as an area of ongoing UK policy formulation. With a change in government, energy policy has pivoted towards electricity and consumer price (DECC, 2014; DECC, 2015). Commercially viable lignocellulosic facilities of any significant scale have failed to materialise in the UK or elsewhere at the time of writing. What does this mean for the findings of this project and their relevance?

Firstly, although explicit mention of lignocellulosic technologies and biofuels has diminished, EU level policy and subsequently UK policy will maintain biofuel mandates and subsidies until 2020 (EU, 2009). Lignocellulosic technologies have continued to receive government support with the DfT announcing in December 2015 the award of £25 million to fund three demonstration plants for second generation biofuel technologies. Research and development of lignocellulosic biofuel capacity continues although with a much lower profile than previously was the case.

Secondly, bioenergy for heat and electricity remains an important renewable technology. Straw power stations have continued to expand in the UK, although the end of the RO regime may prohibit further expansion in the short term. In addition, long term visions for the bioeconomy and the hope invested in expanding the capacity of biotechnology to deliver bio-based products remain. Regardless of the end use, there will continue to be a persistent demand for agricultural biomass from crops, residues, wastes and dedicated lignocellulosic crops for non-food purposes. The findings of this thesis are therefore relevant to any expansion of these activities which will require embedding a production and supply infrastructure.

Thirdly, this study contributes to the qualitative literature on biofuels, bioenergy and agricultural systems. Rural sociologists have been slow to capitalise on biomass crops and residue production as a site to examine land management, farm practices, farmer decision making and values. As this thesis has highlighted, the adoption of new crops and practices relating to the production of biomass for energy is a fruitful avenue for qualitative rural research. There is scope for future work examining farmer identities, cultural values, practices and decision making in the context of agriculture/energy interfaces, perhaps linked to examining different configurations for bioenergy and biofuel production as highlighted above.

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Appendices

Appendix 1: Interview Guides

Producer Interview Guide

Opening Question

How has the company developed since your time here and what influenced the move into the area of biofuels and/or bioenergy?

Current/Past

What factors influenced the companies choice to produce 1st generation biofuels?

- What influenced the choice of feedstock? Existing experience amongst the business partners in managing wheat? Site placement in a wheat producing area?
- Why was it decided to structuring the feedstock supply around UK production infrastructure rather than importing feedstocks or vice versa?

Biofuels Future

Do you think the UK is in a position to develop further domestic production of liquid biofuels on a significant scale?

What do you see as the most significant future opportunities for British industry with regard to biofuels?

- What is the role of 2nd generation technologies in this?

What do you think is going to be the role of your company in the future commercialisation of these technologies?

- Do you feel your enterprise is going to benefit from 2nd generation technology in terms of adding to capacity and perhaps a 'whole' crop production stream or in competition to it?
- What is the role of farmers within this?

What are the most significant challenges as well as opportunities facing the viability of lignocellulosic biofuels processing plants in the UK?

Supply Chains

How have your worked to recruit farmers into supplying your biofuel production facility?

- How have you built your biomass supply chain?
- What sort of interactions do you have with the farmers that supply your facility?
- What commitment do you expect from the farmers you source from?
- How has the scope of your supply chain been limited by transport infrastructure?
- Given the emergence of a global market for biofuels what do you envision will be the main impact of that on the establishment of a UK-based biofuel industry/economy?

Sustainability

What does the production of sustainable biofuels or bioenergy mean for you?

- Does it require your farmers to work differently, or manage their land and crops in different ways compared to those for food and feed markets?
    - If so what is your role in governing that?
- How do you think 2nd generation technologies fit into the goals of achieving sustainability for biofuels?
    - In terms of more general efforts to achieve sustainable biofuels as well as within your business?

Farmer Interview Guide (Seated)

General Opening Questions

Can you just tell me a bit about the history of the farm and what you do currently?

- Have you diversified the farm at all? If so, into what new activities? Why did you choose to diversify in that way?
- Are you involved in any agri-environmental schemes? What are the main management activities you undertake as part of that?

- Do you rent any land and if so does your landlord place any restrictions on what you are able to do on it?
- Are you involved with or heard of organisations such as LEAF that promote sustainable food and farming production? If so, what is your involvement and what does this mean for your farm?

General Biofuel Questions

Is the production of crops or residues for use in producing biofuels something you have ever considered previously?

- If so what were the main factors that influenced your decision to grow or not grow crops for biofuel production?
- Have you ever been approached with regards to supplying a biofuel or bioenergy producer? Who approached you, a sales rep, agronomist etc?
- What do you think are the advantages and disadvantages of growing crops for the production of biofuels on your farm as well as more generally?
- When it comes to biofuels where have you previously seen the topic mentioned and get most of your information? From the farming press, discussions with other farmers, events such as Cereals Event?

Energy Crop Questions

Have you considered or already grow dedicated energy crops such as miscanthus or SRC willow on your farm?

- What did you consider to be the main advantages or disadvantages to growing energy crops on your farm? If any?
- Have you heard of the energy crops scheme? If so, what is your opinion of the support it offers? If not outline the scheme?
- What support would you require, if any, to make growing energy crops more attractive?
- If this support was linked to other schemes, such as ELS or HLS providing additional incentives within existing schemes would you be more or less interested in energy crop options?

- Do you perceive, or have had, any issues with storage and logistics, outside of normal operations, when growing energy crops?
- If you were to grow energy crops how large a proportion of your holding would you be interested in growing?

Comparison to other Renewable Technologies

Have you considered or do you currently utilise one of these alternative technologies on your farm? If so, what where the main factors that drew you to them in comparison to the alternatives, in particular biofuels?

- How do you think the opportunities of biofuel production compare to other possible ways for farmers to contribute to producing renewable energy, such as AD, wind, solar, on farm bioenergy, off-farm bioenergy?
- Do you think biofuels might compare more favourably if, rather than supplying a large scale facility, you were supplying a small or medium scale facility producing fuel for the use of the local community, or for use within a farmer co-operative for example?
- When/if you were thinking about diversifying your farm further what would be the main factors your would considered when making this decision?
- There is also interest in bringing non-commercially managed woodland into production for the purpose of bioenergy and biofuels. Do you have any woodland on your farm? How is it managed and for what purpose, either formally or informally?
- Would you be interested in managing this woodland for producing wood fuel? What are the main reasons that you would or would not manage the woodland for wood fuel purposes?
- If so, would you rather produce wood fuel for general sale or for supplying on farm heat and electric needs?

Is there anything else you would like to add?

Farm Walk Begins

Straw Merchant Interview Guide

Opening Question

Could you tell me a bit about the current business and how it operates?

- How and where do you buy and sell straw? Directly from and to farmers or at auctions or other ways?
- How does pickup and delivery of straw work? Is it at pre-determined times, on demand, as and when you are in the area with a load?
- Do you mainly buy and sell to and from longstanding customers or do things change on a year by year basis?
- When is your busiest time for hauling straw? Around harvest or is it spread over the year?

Straw Type and Use

What types of straw, Barley, Wheat and Oat for instance, do you deal with?

- Do different types of straw go for different uses?
- If so what type of uses?
- Does bale size change the use?
- If so in what way?

Straw Pricing

What is the farmgate price for straw before haulage is added?

- How has this changed, if at all, over the last 10 years?
- What is the difference in price between buying bales, straw in the swath or a standing crop?

Market Opportunities/Changes

Are you expecting any major changes to impact on the straw market going forward?

- What do you think are the biggest future opportunities for expanding the use of straw in the market?

Bioenergy Use

Do you deliver straw to customers that use it primarily for energy?

- If so how did you get involved in this arrangement?
- Was this a one off or regular supply arrangement?
- What is your perspective on the use of straw in this way?
- How do you think it will impact on future developments in the UK straw market?

Straw Availability

How do you perceive straw availability in the market at the moment?

- Is straw surplus to requirement or is the market tight?
- Do you think there is much opportunity to bring straw that is currently incorporated into the market?
- What do you think is the best way of trying to bring incorporated straw into the market?

Agronomist Interview Guide

General Business

Could you just tell me a bit about your business and the services you offer?

- What is the scope of advice you give farmers, variety selection, production, crop health, marketing?
- What are the common questions farmers ask you?

Interest in Bioenergy

Do you get many enquiries about opportunities to use biomass for energy?

- In these instances are farmers interested in on farm usage or sale into the market?
- What advice are you able to give farmers in this situation
- What do you think are the biggest opportunities for farmers with regards to use in energy?

Straw

How do you perceive farmer attitudes towards the production and use of straw?

- Do you think this is or might change as interest in the using of straw in energy increases/
- Are they primarily interested in growing short or tall varieties?
- Have you been asked to provide advice on how to maximise straw yield by a farmer?

Agronomist Networks

How do you access the latest information on crop science, variety options and land management practices?

- Do you attend specific events as part of this
- Are these big industry events, Cereals event for instance?
- Do you attend any workshops/
- How are these organised?
- How did you get involved in these activities?

Energy Crops

During any of these events have you been approached or provided with information on perennial crops such as miscanthus or SRC Willow?

- Has there been much interest from the farming community in these crops?
- What sort of questions do farmers ask with regards to these crops, if any?
- What do you perceive to be the main barriers for farmers adopting these crops?
- What do you think is required to increase farmer adoption of these crops?
- If farmers do ask you about them what sort of advice are you able to give?
- Do you know where to direct farmers with regards to getting more information, securing cuttings or root stock for planting?

Bioenergy/Biofuel Market

Do you advise farmers with regards to growing and marketing their crops specifically for liquid biofuel production?

- How do you perceive farmer interest in UK biofuel production?
- What are the main questions farmers ask you with regards to producing crops for biofuels?
- For these markets do farmers need to make any crop management changes?

Appendix 2: Participant Information Sheet

Richard Helliwell
Institute of Science and Society
School of Sociology and Social Policy
University of Nottingham

Introduction

I am Richard Helliwell I am doing research on biofuel supply chains. Biofuels, such as bioethanol and biodiesel produced from starch, sugar and oil crops have been proposed as an alternative transport fuel in the UK and EU. However, due to a range of controversies, in particular, food versus fuel, policy has proposed a shift to so called 2nd generation technologies that produce biofuels from the inedible parts of the plant. These new technologies require the adoption by farmers of new crops and potentially different management practices of traditional crops. Equally I am interested in how these 'new' supply chains are created and organised.

The purpose of this research is to investigate biofuel supply chains and in particular the role of the farmer within networks supplying biofuel and bioenergy production facilities. In addition to this, farmers who are outside of these supply chains are being approached to investigate their perceptions and intentions towards new energy crops such as miscanthus and willow short rotation coppice, possible advanced biofuel crops, and how they are viewed by farmers in relation to other renewable energy technologies such as wind, solar, AD and biomass boilers.

It is therefore with this purpose that I have invited you to take part in this research and why I am providing you with information contained in the Crop Information Sheets attached to this document. You do not have to decide today whether or not you will participate in the research [Delete if not relevant]. If you have any questions or queries either at this point or as we go through the form please ask me to stop. Equally if you have questions later, you can ask them of me or another researcher involved in this project. Contact information is provided at the bottom of this document.

Type of Research Method

The research will involve your participation in a farm walk style interview which will take around one hour and will involve me accompanying you around your farm while we discuss the topic.

Participant Selection

Your details were found by through publically available information contained within the yellow pages. It was through this information you were contacted. You have been invited to take part in this research because you are a member of the farming community who may and expressed interest in taking part in a interview for this research.

Voluntary Participation

Your participation in this research is entirely voluntary. It is your choice whether to participate. If you choose not to participate there will be no negative consequences. You may withdraw from the research at any time including after the interview has been conducted. If you make this choice your data will not be used in the research.

Procedures

If you do wish to take part in the research I you will be asked to participate in an interview with myself. During the interview we will walk around your farm. I will ask you questions about your current activities, your perception of biofuels, how you came to supply a biofuel/bioenergy facility [if applicable], what factors influenced this decision, why you feel they fit or may fit or may not into your farm business and, if you were to adopt energy crops how they may change or not change your current business. If you do not wish to answer any of the questions during the interview you may say so and I will move on to the next question. The information recorded is entirely confidential. No one except myself will have access the information documented during the interview. The entire interview will be voice recorded, this will then be transcribed at the earliest possible time and all names and places that may allow identification will be removed. No identifiable personal data will be published. After a full

transcription has been made the recording be secured against unauthorised access. The anonymous transcripts will be retained securely on the University of Nottingham premises for 7 years after publication after which they will be destroyed.

Duration

You will only be interviewed once with each interview lasting around one hour. You may be contacted at a later date if. Once the data has been analysed and findings published you will be invited to view the findings if you so wish.

Risks

By taking part in this research there are no risks.

Benefits

There will be no direct benefit to you for taking part in this research.

Reimbursements

You will not be provided with any incentive to take part in this research. However, I will cover any expenses that you had to bear (travel expenses) if applicable.

Confidentiality

All information gathered as part of this research is strictly confidential (one exception below). No information that could lead to the identification of any individual will be disclosed in any reports or publications resulting from the research, or to any other party. All transcriptions that result from interviews will be anonymised and only coded identifiers used in documents and computer files.

Please be aware that the researcher is required to report to the authorites any illegal activities that they become aware of during the course of the research and in doing so the principle of confidentiality will be violated.

Sharing the Results

What you tell me today will not be attributed to you by name. Before the knowledge gathered from this research is made widely available to the public through publication you will be invited to view a research findings summary that can either be emailed or posted to you, if you so wish. After this the results will be published as part of my PhD and will be available to the public.

Right to Refuse or Withdraw

You do not have to take part in this research if you so wish, and withdrawing at any stage prior, during or after the interview has been conducted will not affect you in any way. At the end of the interview I will ask if you wish to review your remarks and remove or modify anything you said.

Who to Contact

If you have any questions you can ask them now or later. Equally if you wish to withdraw you can do so now or later. If you wish to register a complaint about any part of the research process in which you have been involved and desire to register this complaint with someone other than myself please contact my Lead Supervisor of the Research Ethics Officer. Contact information for these individuals and myself is supplied below.

Principle Researcher	Lead Supervisor	Research Ethics Officer
Richard Helliwell Room A27 Law and Social Science Building University Park Nottingham NG7 2RD lqxrh2@nottingham.ac.uk	Sujatha Raman Room A15 Law and Social Sciences Building University Park Nottingham NG7 2RD 0115 846 7039 Sujatha.raman@nottingham.ac.uk	Christian Karner Room B36 Law and Social Sciences University Park Nottingham

Appendix 3: Works cited in Figure 5.1 & 5.2

Figure 5.1	
Primary	Agriculture Act, 1947. 10 & 11. Geo. 6: Ch. 48.
	Agricultural Marketing Act, 1949. 12 & 13. Geo. 6: Ch. 38.
	Agriculture (Misc. Prov.) Act, 1949. 12 & 13. Geo. 6: Ch. 37.
	Agriculture (Misc. Prov.) Act, 1950. 14. Geo. 6: Ch. 17
	Livestock Rearing Act, 1951. 14 & 15. Geo. 6: Ch. 18
	Agriculture (Fertilisers) Act, 1952. 15 & 16. Geo. 6. & 1 Eliz. 2: Ch. 15
	Agriculture (Ploughing Grants) Act, 1952. 15 & 16. Geo. 6. & 1 Eliz. 2: Ch. 35
	Agriculture (Misc. Prov.) Act, 1954. 2 & 3. Eliz. 2: Ch. 39
	Hill Farming Act, 1954. 2 & 3. Eliz. 2: Ch. 23.
	Pests Act, 1954. 2 & 3. Eliz. 2: Ch. 68
	Agriculture (Improvement of Roads) Act, 1955. 4 & 5. Eliz. 2: Ch. 20.
	Hill Farming Act, 1956. 4 & 5. Eliz. 2: Ch. 72.
	Agricultural Research Act, 1956. 4 & 5. Eliz. 2: Ch. 28.
	Agriculture (Silo Subsidies) Act, 1956. 5 & 6. Eliz. 2: Ch. 5
	Agriculture Act, 1957. 5 & 6. Eliz. 2: Ch. 57.
Secondary	Agriculture Wages Act, 1948. 11 & 12. Geo. 6: Ch. 47.
	Agriculture Holdings Act, 1948. 11 & 12. Geo. 6: Ch. 63.
	Agriculture (Poisonous Substances) Act, 1952. 15 & 16. Geo. 6. & 1 Eliz. 2: Ch. 60.
	Agricultural Land (Removal of Surface Soil) Act, 1953. 1 & 2. Eliz. 2: Ch. 10.
	Agricultural Mortgage Corporation Act, 1956. 4 & 5. Eliz. 2: Ch. 38.
	Agriculture (Safety, Health, and Welfare Prov.) Act, 1956. 4 & 5. Eliz. 2: Ch. 49

Figure 5.2	
EU	EU, 2003. Directive 2003/30/EC of the European Parliament and of

Biofuels Directive	the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport. Official Journal of the European Union. Brussels.
Fuel Quality Directive	EU, 2003. Directive 2003/17/EC of the European Parliament and of the Council of 3 March 2003 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels. Official Journal of the European Union. Brussels.
Energy Taxation Directive	EU, 2003. Directive 2003/96/EC of the European Parliament and of the Council of 27 October 2003 restructuring the Community framework for the taxation of energy productions and electricity. Official Journal of the European Union. Brussels.
Renewable Energy Directive	EU, 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Official Journal of the European Union. Brussels.
UK	Energy Act, 2004. Ch. 20
	Climate Change Act, 2008. Ch. 27
	HM Government, 2007. *Statutory Instruments - No. 3072 - The Renewable Transport Fuel Obligations Order,* London: The Stationary Office.
	HM Government, 2009. *Statutory Instruments - No. 843 - The Renewable Transport Fuel Obligations (Amendment) Order,* London: The Stationary Office.
	HM Government, 2011. *Statutory Instruments - No. 2937 - The Renewable Transport Fuel Obligations (Amendment) Order,* London: The Stationary Office.
	HM Government, 2013. *Statutory Instruments - No. 816 - The Renewable Transport Fuel Obligations (Amendment) Order,* London: The Stationary Office.
	HM Government, 2015. *Statutory Instruments - No. 534 - The Renewable Transport Fuel Obligations (Amendment) Order,* London:

	The Stationary Office

Appendix 4: Map of National Parks and Areas of Outstanding Natural Beauty

