Rethinking bioenergy from an agricultural perspective: Ethical issues raised by perennial energy crop and crop residue production for energy in the UK and Denmark

Orla Shortall, MSc.

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Abstract

The aim of this project is to explore the social and ethical dimensions of the agricultural production of perennial energy crop and crop residues for energy. Biomass – any living or recently living matter – is being promoted in industrialised countries as part of the transition from fossil fuels to an economy based on renewable energy. Various challenges face the use of bioenergy however. One particularly controversial and high profile example has been the use of food crop biofuels in transport which are seen to conflict with food production and to cause significant environmental damage. Suggested ways around these controversies is the production of perennial energy crops such as grasses and trees and crop residues such as straw, which are seen to require fewer inputs and less prime land.

Some have analysed the controversies raised by biofuels in terms of controversies around industrial agriculture more broadly: biofuels are perceived to be large scale, monocultural, environmentally damaging and pushed by agri-business and energy interests. This project asks what type of agriculture system perennial energy crops and crop residues are seen as developing within, if at all. This was considered worth exploring because the type of system will have a large bearing on how they are received in future. To this end a theoretical framework of different paradigms of agriculture ranging from industrial agriculture at one end to alternative agriculture at the other was developed and applied to the data. Interviews with key stakeholders and analysis of key documents in the UK and Denmark were carried out to address the question of how perennial energy crops and crop residues are seen as overcoming previous controversies raised by food crop biofuels, in terms of their place in agricultural systems.

The thesis argues that stakeholder's visions of perennial energy crops and crop residues can be understood in terms of four models of agriculture: two industrial and two alternative. These are called "*industrialism lite*" that involves producing perennial energy crops on marginal land; *life sciences integrated* agriculture including the biorefinery strategy; *multifunctional* perennial energy crop production on environmentally marginal land; and *ecologically integrated* multipurpose biomass production through agroforestry production. There is also an argument which cuts across the paradigms and maintains that regardless of the type of agricultural system used very little or no biomass should be produced for the energy sector because of the scale of resources it requires and the scale of society's energy use. These positions can be summarised as three different ways to overcome challenges raised by food crop biofuels: further industrialise agriculture; de-industrialise agriculture; and de-industrialise agriculture and reduce society's energy use, though biomass could still only be used to a very limited extent, if at all, in energy production.

List of published papers

Shortall, O.K. (2014). Agricultural Sciences and Ethical Controversies of Biofuels in Thompson, P. (ed.) *Encyclopaedia of Agriculture Ethics*, Springer, Dordrecht.

Shortall, O.K. (2013). "Marginal land" for energy crops: Exploring definitions and embedded assumptions. *Energy Policy*, 62, 19–27.

Gamborg, C., Millar, K., Shortall, O., & Sandøe, P. (2012). Bioenergy and Land Use: Framing the Ethical Debate. *Journal of Agricultural and Environmental Ethics*, *25*(6), 909–925.

Shortall, O.K. and Millar, K. (2012) The ethics of using agricultural land to produce biomass: Using energy like it grows on trees in (eds.) Potthast, T. and Meisch, S. *Climate change and sustainable development: Ethical perspectives on land use and food production* Wageningen Academic Press, Tubingen.

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Chapter 1 Introduction

1.1. Introduction

The research presented in this thesis focuses on the ethical and social issues raised by the production of non-food agricultural biomass, specifically perennial energy crops and crop residues for use in energy generation in the UK and Denmark. Biomass can be defined as "biological material from living, or recently living organisms. In the context of biomass for energy this is often used to mean plant based material, but biomass can equally apply to both animal and vegetable derived material." (Biomass Energy Centre, 2011). Before the industrial revolution people in the global North were largely dependent on biomass for their energy and material needs. This is still the case in much of the global South. Fossil fuels provided a more energy dense and bountiful supply which replaced biomass use in the global North. As the industrialised world tries to wean itself off fossil fuels the use of biomass in energy generation is again back on the agenda. Commentators in the media, non-governmental organisations (NGOs), industry, academia and the government among others have questioned where this biomass will come from, and what the environmental and social impacts of its use will be, in an energy hungry world where infrastructures have built up around the use of relatively cheap and more energy dense fossil fuels. The use of biofuels made from food crops has increased significantly in recent years: use increased by over 20 times in the EU between 2000 and 2011 (IEEP, 2014). This development is a case in point, as biofuels proved to be very controversial, as we will explore in more detail below.

One of the proposed ways forward for biomass is the use of non-food sources, such as perennial energy crops, mainly trees and grasses, and crop residues such as straw. The aim of this thesis is to explore why these feedstocks are seen by key stakeholders in the bioenergy sector as a way of overcoming, or not, previous controversies raised by food crop biofuels. Some, such as Thompson (2008a) have analysed biofuels controversies in terms of objections to industrial agriculture: food crop biofuels are produced under an intensive, industrial agricultural system that many see as problematic. In keeping with this industrial production system, food crop, or "first generation" biofuels production proved to cause substantial environmental impacts that were seen to significantly reduce their credentials as a "green" replacement for fossil fuels. To make matters worse food crop biofuels were seen to raise food prices and contribute to food shortages for the world's poorest people (FAO, 2008).

Thompson (2012a) argues that debates about agricultural technologies, such as biofuels, often get caught up in surrogate empirical arguments about the supposed merits or demerits of the technology when the real issues at stake are deeper and relate to people's views about what agriculture is and how it should progress Some people and institutions view agriculture as another sector of the industrial economy that should become more efficient through scientific and technological innovation, whereas others see agriculture as having a special significance beyond its material contribution which is threatened by the industrial vision and technologies which do not appreciate agriculture's wider significance for society (Thompson, 2012a).

This thesis starts with the assumption the agricultural system perennial energy crops and crop residues are developed within will have a bearing on whether or not they are as controversial as food crop biofuels. Are perennial energy crops and crop residues seen by key stakeholders in the bioenergy sector as developing within some version of industrial agriculture; within a different sort of alternative agriculture system with different values and methods; and/or do some maintain that these feedstocks should not be used in energy at all regardless of the system used?

As there has been little qualitative research on the agricultural dimension of perennial energy crop and crop residue production for energy, this thesis uses a framework of paradigms of agriculture which draws on philosophical work in this area: from industrial to alternative agriculture to explore key stakeholders' framing of these feedstocks. It does this by undertaking semi-structured interviews with key non-governmental organisation (NGO), academic, industry and government stakeholders; and analysis of key documents from these stakeholder groups in the UK and Denmark. The work conducted in this thesis is intended to add to the ongoing debate about bioenergy.

The remainder of this chapter provides a brief overview of controversies raised by food crop biofuels and how these were analysed in the literature in order to motivate the research aims and questions. It should be noted that this project is not focusing on feedstocks for transport biofuels specifically since perennial energy crops can be used in biofuels or stationary heat and power production. However, it is worth exploring the controversies around food crop biofuels because they provide the original motivation for the project and are illustrative of the issues raised by the production of agricultural biomass for energy. The thesis aims and research questions are then outlined and an overview of the thesis structure is provided.

1.2 Biofuels controversies

Food crop biofuels are made from either starch crops, which involve fermenting the sugar into bioethanol or oil crops which are used to make biodiesel. They were promoted in the 2000s in the name of climate change mitigation: they were seen as carbon neutral because the plants take carbon in from the atmosphere as they grow which is then released when they are burned

(Swinbank, 2009). They were suggested by governments, industry and academics as an energy secure alternative to fossil fuels as they can be produced in the country of use or imported from politically stable, friendly countries (European Commission, 2000). They were also promoted as beneficial for rural development because they give farmers an additional source of income (Lehrer, 2010). Biofuels policies were promoted in many countries, including EU countries where the 2003 Biofuels Directive (2003/30/EC) set non-mandatory targets for biofuels use in EU states. The EU Renewable Energy Directive (RED) 2009/28/EC then stipulated that 10% of Member States transport energy should come from renewable sources by 2020.

Despite their initial promise however biofuels policies proved to be very controversial in practice. Controversy began to break in the media and among NGOs around 2004 in relation to their environmental and social credentials (Mol, 2007; Monbiot, 2005). A series of scientific papers were published highlighting biofuels' negative environmental impacts, including the phenomena of direct and indirect land use change (DLUC and ILUC) (Fargione et al., 2008; Searchinger et al., 2008). Direct land use change means that land with high carbon stocks, such as forest land is destroyed to make way for biofuels production. Indirect land use changes happens when land that was used for food production is used for biofuels production, causing a shortfall in land use, which is then made up by a farmer in another part of the world clearing land with high carbon stocks or biodiversity for cultivation. The carbon debt this involves is traced back to biofuels. Since biofuels were made from intensively produced food crops they incurred the same environmental impacts as other intensive agriculture such as eutrophication, biodiversity loss, soil erosion, high greenhouse gas emissions from the use of fertilisers and other inputs (Doornbosch & Steenblik, 2008). What is more biofuels were seen to compete with food production, taking food from the food market and using it in the fuel market, and were partly blamed for food price increases in 2007/2008 (Timilsina, 2012). This gave rise to the "food versus fuel" controversy where the needs of the poorest for food was contrasted with the desire of the rich to fuel their cars. In October 2007 Jean Ziegler the UN special rapporteur on the Right to Food stated "It is a crime against humanity to divert arable land to the production of crops which are then burned for fuel" (BBC, 2007).

In response to these controversies there have been calls to develop so called "second generation" non-food based lignocellulosic biofuels, including the use of perennial energy crops and crop residues. Perennial energy crops are crops that stay in the ground for more than one growing season and include short rotation coppice trees such as willow, poplar and alder, grasses such as switchgrass and miscanthus. Crop residues include feedstocks such as straw and sugar cane bagasse. Many stated that the development of non-food biofuels, also called "second generation biofuels", can help to overcome some of the social and ethical controversies that have faced biofuels so far (Graham-Rowe, 2011; Sanderson, 2011; Tait, 2011). Perennial energy crops are presented as requiring fewer inputs than food based crops and less intensive management which would mean fewer environmental impacts and that they are better for biodiversity (Fairley, 2011). They are not food crops and it is also stated that they could be grown on “marginal land” which is not suitable for food production, thus reducing competition between food and fuel and helping to tackle ILUC (Nuffield Council on Bioethics, 2011).

There have been many studies exploring the social and ethical dimensions of the biofuels debate (Boucher, 2011; Boucher, 2012; Gomiero et al., 2009; Dürnberger et al., 2009; Gamborg et al., 2012a; Gamborg et al., 2012b). These will be explored in more depth in chapter 2. Of particular relevance to this study are articles which analysed the biofuels controversy by placing them in the context of objections to the global industrial agriculture system. This includes Thompson (2008a) who explores biofuels controversies in the US in terms of industrial and agrarian paradigms of agriculture[1]. Thompson (2012a) states that controversies around agricultural technologies such as biofuels, genetic modification and nanotechnology cannot be properly understood unless they are seen as part of a wider debate between different, competing philosophies of agriculture. Industrial agriculture views agriculture as a sector of the economy whose purpose is to produce commodities as efficiently as possible through high tech means, generally using large amounts of inputs and involving globalised agri-business players. Agrarian agriculture sees it as going beyond this role of providing food and fibre, as it plays an important role in forming the moral character of a society. The term “alternative agriculture” will be used in this project to designate the philosophy that is dissatisfied with the industrial conception and perceives agriculture as having a wider importance for society. This can be seen today in social movements that attempt to reconnect agriculture with people and with nature through shorter supply chains and smaller scale production in initiatives such as farmers markets, vegetable box schemes and methods such as organic production (Levidow, 2008). Thompson (2008a) maintains that a healthy dialectic between these two positions is needed to inform our views about what we want from agriculture. He states that the production of biofuels has thus far weighed too heavily on the industrial side and speculates about how an agrarian form of biofuels production could be developed. Thompson (2008b) makes a similar point, concluding that because biofuels feedstocks are produced within industrial agriculture systems even second generation technologies are likely to rouse controversy. He further links objections to biofuels to objections to the global interests that control agriculture: “However, many analysts interpret all of

[1] This is Thompson’s terminology. This project will use the terms “industrial” and “alternative” agriculture and will use the concept of agrarian agriculture in a narrower sense to how Thompson uses it, as a sub-section of alternative agriculture, as we will see in chapter 3.

the above themes as attaining significance as forms of resistance to the coalition of politically and economically powerful interests that currently control land use and food-system policy in the developed world." (p.152). More qualitative research that explores the agricultural dimensions of biofuels controversies and substantiates these claims is presented in the next chapter. The work in this research project builds on work exploring biofuels controversies from an agricultural philosophy perspective. The next section will outline the aims, questions and methods of this project.

1.3 Research aims, questions and methods

Research aims

The paradigm of agriculture perennial energy crops and crop residues are placed within will have a significant bearing on how they are viewed and potentially support in future. As Thompson (2012a) states: "The fate of agriculture and agricultural technology will be dramatically affected by society's general expectations for agriculture." (p.53). As we will see in chapter 3 all models of agriculture are faced with different criticisms. We can ask how these criticisms will have a bearing on the future of perennial energy crop and crop residue production for energy. The work within this project is motivated by the statement: "But the fuel-vs.-nature question is vexed because the agriculture-vs.-nature question is vexed." (Thompson 2008b, p.149) This suggests that a fruitful way to explore proposed biomass feedstocks is through paradigms of agriculture. Specifically, how can we understand the claims that perennial energy crop production and crop residues will, or will not, overcome controversies raised by food crop biofuels? Are the claims being made from within a model of industrial agriculture or are they proposing biomass production within an alternative model, or neither?

Therefore, the aim of the research presented here is not just to identify what paradigms of agriculture are at play: to label them "industrial" or "alternative" and leave it at that, but rather to identify and analyse the nuances involved in these assumptions, to better shed light on a contentious debate. Thompson (2012a) states "Understanding this fate [of emerging agricultural technologies] requires a general framework for articulating, interpreting and discussing assumptions about the nature and purpose of agriculture." (p.54). Work of this kind aims to dig deeper into arguments that use empirical evidence but which also have important differences in underlying theories and assumptions (Sarewitz, 2004). "A richer and more widely recognized understanding of this philosophical tension will help us achieve more creative and productive discussions of new agricultural technology." (Thompson, 2012a p.53). The aim is not to explore claims about perennial energy crops and crop residues in order to assess how "accurate" or feasible such claims are but rather to shed further light on their meaning by considering how these feedstocks are framed as fitting with agriculture and what assumptions underpin this.

Work from the social sciences and ethical analyses of bioenergy presented in the section above and analyses presented in chapter 2 mainly focus on the production of biofuels from food crops. There is a gap in the literature for analysing perennial energy crops and crop residues within an agricultural context. Most articles consider biomass production for liquid transport biofuels specifically, rather than biomass for all applications. Raman and Mohr (2014) point out that “biomass” or “biofuels” are often treated as though they were one homogeneous category whereas in fact there are many different types of feedstocks and energy production systems that raise different issues. Many of the articles also focus on the ethical issues raised by production of biomass in the global South, or biofuels *policy* in the global North, rather than *production* in the global North.

This project aims to make a contribution to addressing these gaps by analysing key stakeholders’ views of the production of perennial energy crops and crop residues in the UK and Denmark, within an agricultural context. The aim of the project is to combine research from the UK and Denmark, much in the same way that the project combines findings about perennial energy crops and crop residues. The aim is not to compare the findings from the UK and Denmark because the project does not aim to get a representative sample of views of perennial energy crops and crop residues from within the chosen stakeholder groups in the UK and Denmark. The aim is to access a range of views from the two countries, rather than to make generalisations from the data to those within a particular sector as a whole, such as industry to NGO. The UK and Denmark were chosen as case studies because they have interesting similarities in differences in their production and use of biomass for energy. Both countries are subject to the same EU legislation on renewable energy and renewable transport energy, meaning that the background context is similar. There are also similarities in their agricultural sectors in that they both have highly developed agricultural sectors with little room for expansion onto new land for new crops. Both also do not have a high proportion of their land in forestry cultivation, compared to other European countries, so a large proportion of indigenous biomass production is expected to come from agriculture (Booth et al., 2009). It is interesting to see how perennial energy crop production and crop residue use for energy are envisioned as taking place, if at all, within these systems. There are also some differences between the countries. For example Denmark has a larger and longer standing organic agriculture sector than the UK and already uses a far larger proportion of its crop residues in energy production than the UK (Booth et al., 2009).

Even though perennial energy crops are not widely grown in the UK or Denmark currently both governments have high hopes for their development. As the last UK Bioenergy strategy puts it:

> The greatest growth in domestic biomass supply is expected to come from agricultural residues and perennial energy crops. Our analysis suggests that existing domestic energy crops, such as miscanthus, short rotation coppice (SRC) and other grasses including reed canary grass and switchgrass, could see a significant increase in deployment from its very small current level. (DfT et al., 2012 p.33).

The Danish Ministry for Food, Agriculture and Fisheries states:

> […] plantation of fast growing trees like willow for energy purposes is likely to become increasingly important if we are to meet our target defined in the EU directive on promotion of the use of energy from renewable sources. (Ministry of Food Agriculture and Fisheries, 2010).

Crop residues are already an important source of energy in Denmark and are seen as a potential area of growth in both countries.

Research questions

The aim of this thesis is to explore the social and ethical dimensions of the agricultural production of perennial energy crop and crop residues for energy. The two overarching research questions are:

- How can claims that use of perennial energy crops and crop residues for energy will, or will not, help overcome the social and ethical controversies raised by first generation biofuels be understood?
- What assumptions and theories underpin these claims?

Here the “understanding” of claims, and the assumptions and theories in the second question, may refer to the different paradigms of agriculture used to conceptualise the production of these feedstocks. Are they envisioned within the industrial paradigm or alternative, particular subcategories of these, or neither for that matter? The work presented in this thesis of course does not wish to impose a theoretical structure on the data where it does not fit, so these concepts are used where appropriate and if it is not deemed appropriate then the “understanding” of these claims will refer to empirical and other assumptions. The understanding could also relate to whether difference between these feedstocks and food crop biofuels is seen as due to the characteristics of the feedstocks themselves, or the system they are being developed within. This distinction, though artificial, will be drawn on at times when it is helpful in shedding light on the interview and document data. The term "overcome controversies" means that perennial energy crops could be developed without facing the same environmental and social problems faced by biofuels, which were outlined above and are dealt with in more detail in the next chapter. The above research questions involve considering:

- If key stakeholders maintain perennial energy crops and crop residues should be produced.
- If so, how key stakeholders frame where production should take place.
- If so, how key stakeholders frame production methods of perennial energy crops and crop residues.

These considerations were used to design and analyse the research – focusing on particular aspects of feedstocks production. The focus of the research is on the production of these biomass feedstocks, rather than their use in the energy sector. The where consideration refers to land use issues: the location of production, the type of land used and the amount of land, among other factors. The last consideration refers to production methods: use of inputs and the approach taken to production.

Paradigms of agriculture

The framework used in this thesis is a conglomeration of different philosophies of agriculture taken from the literature. The term "philosophy of agriculture" is used in a similar sense to how Thompson (2012a) uses it:

> It expresses a general social vision for food and fiber production, distribution and consumption that helps us understand and anticipate how law, policy, market structures, consumer preferences and the political climate will converge to create the socio-political context in which agricultural producers will operate. (p.54).

The framework adopted is of two overarching paradigms of industrial and alternative agriculture with subcategories within those (Thompson, 2012a). Industrial agriculture is the view that agriculture is another sector of the industrial economy whose function is to meet market demands as efficiently as possible (Thompson, 2010). It is driven by technological innovation and is characterised by global supply chains, operated by large agri-businesses. The agriculture itself is resource intensive and results in environmental impacts that are widely seen as problematic (Pretty, 2002). Within this, "productionism" and "life sciences integrated" agriculture are put forward as subcategories of industrial agriculture. More details of these will be given in chapter 3. Alternative philosophies of agriculture maintain that agriculture has some significance to society beyond its material contribution; a description of agriculture as another industrial sector of the economy misses important aspects of it. What this significance consists of will differ according to different types of alternative agriculture. “Agrarian agriculture”, “ecologically integrated agriculture” and “multifunctional agriculture” will be outlined as subcategories of the alternative paradigm in chapter three. The overarching division into alternative and industrial agriculture will be referred to as paradigms, and within those the different subcategories will be called models. It should be emphasised that the paradigms of agriculture are theoretical constructs, and though a clear theoretical case can be made for the differences between industrial and alternative systems, there are also overlaps. Any discussion of paradigms of agriculture in this project is a matter of interpretation by the researcher, for which the researcher aims to provide a convincing rationale.

Research methods

Qualitative research methods were used to answer the research questions. Semi-structured interviews with key stakeholders in the bioenergy sector from academia, industry, government and non-government organisations were carried out as well as document analysis. Purposive sampling was used as the aim was not to get a representative sample of views from any particular sector in order to generalise about, for example, NGO views as a whole, but rather to access a wide range of views to inform a discussion of the bioenergy debate more broadly. Frame analysis was used to explore the data. A frame is taken to mean a lens through which we view reality, it is a way to organise reality that directs attention to some aspects and leave out others (Entman, 1993). Frames can be underpinned by assumptions and values: "Frames are cognitive structures that ‘organise central ideas defining a controversy to resonate with core values and assumptions.’" (Larson, 2011 p.16). This thesis involves combining qualitative research from the UK and Denmark, and involved looking at two feedstocks and two sources of interview and document data.

1.4 Thesis structure

The thesis will be structured as follows: chapter 2 will provide more background to the use of biomass in the UK and Denmark, the biofuels controversies outlined in this chapter, and how these have been analysed previously from within ethics and social sciences, including more analyses of the agricultural dimension of biomass production. This was considered necessary because the main research question relates to these controversies and how perennial energy crops and crop residues are seen as overcoming them, so a more thorough exposition of this area was appropriate to put the rest of the project in context.

Chapter 3 outlines the paradigms of agriculture that are used as the framework for the work. These are taken from different sources, including the fields of agricultural ethics, geography, science and technology studies (STS) and agri-food studies.

Chapter 4 sets out the methods used in the PhD. It gives an overview of disciplines the project is situated between: STS, bioethics and agricultural ethics in order to outline the theories and approaches that influenced the project aims and methods. The chapter then gives an exposition of qualitative methods in order to outline the project's methodological position. Frame analysis is described, as is way in which it will be used in the project. The approach the project takes to combining data from the UK and Denmark and the synthesis of document and interview analysis is also described. The chapter then outlines how the research was carried out, considering how interviewees and documents were selected and how analysis was conducted.

Chapters 5-8 are data chapters. Because the analysis was undertaken at different stages in the project and because of the inductive approach of the project, following interesting features of the data to see where it would lead, the analysis in the chapters differs somewhat. Some chapters seek to understand claims made about perennial energy crops and crop residues in terms of the paradigms of agriculture throughout the chapter, such as chapters 5 and 8, whereas other chapters focus on more a-theoretical assumptions and claims in the data, and connect the analysis to paradigms of agriculture at the end of the chapter, such as chapters 6 and 7.

Chapter 5 gives an overview of the findings and describes why certain themes and issues are taken forward and examined in more detail in the following chapters. It traces how perennial energy crops and crop residues are framed as being produced within the same productionist system that was seen to cause problems for food based biofuels and considers the solutions that are proposed to this within different forms of industrial and alternative agriculture.

Chapter 6 then focuses in more depth on the marginal land argument: perennial energy crops should be produced on low quality marginal land to help overcome previous land use controversies raised for food crop biofuels. It explores definitions of marginal land used in documents and interviews in some depth and draws out implicit assumptions and values within these definitions about why production on this type of land is desirable and what counts as appropriate trade-offs in the use of the land. It then explores this framing in terms of the paradigms of agriculture.

Chapter 7 focuses on the concept of environmentally marginal land, which appears to be an almost exclusively Danish characterisation of land. The use of this type of marginal land does not seek to address the global land use controversies caused by food based biofuels but rather seeks to use perennial energy crops to fulfil local environmental goals such as reducing nutrient leaching on environmentally sensitive land. The specifics and the history of this idea are explored as well as conflicting objectives for its use. The different aims for using the land, which perennial energy crop production may or may not be compatible with, are explored in more depth and the concept and controversies are then analysed in term of paradigms of agriculture.

Chapter 8 explores the idea of perennial energy crops and crop residues within multipurpose agriculture: producing biomass as well as other goods and services, which emerged as particularly prevalent in Denmark. Two different visions of the “multipurpose use of biomass” idea are outlined in the chapter that represent emerging strands of industrial and alternative agriculture paradigms. The specifics of these systems were explored, including the values and assumptions underlying them and any overlaps between them.

Chapter 9 introduces an important criticism which undercuts the four models of perennial energy crops and crop residue production presented in previous chapters. It maintains the view that little or no agricultural biomass should be used in energy production. This argument is explored and the counter arguments to the criticism from the two different paradigms of perennial energy crop and crop residue production are considered.

Chapter 10 concludes the thesis and answers the research questions of how we can understand claims that perennial energy crops and crop residues will, or will not, overcome previous controversies raised by food crop biofuels, and what assumptions and theories underpin these claims. It also outlines the limitations of the study and presents areas for future research as well as some notable points to take away from the thesis which might have a bearing on the debate in the future.

The next chapter will provide more background to biomass and biofuels in the UK and Denmark to motivate research aims of this project.

Chapter 2 Background.

2.1 Introduction

This chapter examines the background to the project, expanding on the outline given in the introduction. Because the research questions relate to previous controversies around food crop biofuels it was considered important to describe these in more detail. This chapter will introduce biomass in more detail: what it is, how it is used and current policies in the UK and Denmark. It will then focus on biofuels because they are a particularly controversial type of biomass and are illustrative of ethical issues raised by the use of biomass in energy; considering the controversies they raise and responses to these controversies. It will tell the story of biomass controversies and responses to these controversies chronologically from around 2000 to the present. It will outline the original rationale for biofuels development, and present a short history of the controversies they faced and responses to those controversies in terms of policy, certification schemes and new technologies. This will include the use of perennial energy crops and crop residues. It will then consider responses to these responses to the controversies, mainly from NGOs and academics, and objections to biofuels that have not received as much attention as the food versus fuel and environmental issues. The story is told chronologically rather than grouping exposition of policy or scientific innovation together because discussions of policy only makes sense when presented in relation to the controversies that have gone before. This furthers ground the study and provides the rationale for the research aims.

2.2 Bioenergy background

Introduction to bioenergy

The burning of biomass is one of the longest standing sources of energy for humans and made up the majority of energy supplies before the industrial revolution (Lewis, 1981). The vast majority of biomass used in heat and power production today still consists of “traditional” biomass: the burning of wood, charcoal and dung, often in a domestic setting in the global South (Bringezu et al., 2009). This thesis focuses on the “modern” use of biomass as renewable feedstock to replace the burning of fossil fuels in industrialised countries. “Modern” feedstocks include industrial or household waste, wood and agricultural produce such as crops and straw. These can be used to produce stationary heat or electricity or used as liquid or gaseous fuels in transport, what are generally referred to as biofuels.

Biofuels come in the form of bioethanol and biodiesel. Bioethanol is fermented from the sugars in plants and can be substituted for petrol in car engines, up to a blending wall of 10% for most engines

(Adams et al., 2011). Biodiesel is made from plant oils and can be used in diesel engines after the addition of lubricants, without the need to modify the engines (Bringezu et al., 2009). These are referred to as “first generation biofuels”. The definition of “second generation” biofuels is disputed (Levidow & Paul, 2008) but they generally refer to biofuels from non-food, lignocellulosic materials. Feedstocks can come from crop and forest residues such as straw, purpose grown crops like grasses and short rotation coppice such as willow and poplar, and from the organic components of municipal solid waste (Sims et al., 2010). Sugar in food crops can be easily fermented into ethanol whereas the sugar in non-food biomass is effectively locked in to plant cell walls in a hard resin called lignin that protects the plant and keeps it upright.

Biofuels also have a long though sporadic history in the energy sector. Some of the most high profile early examples include the diesel engine unveiled by Rudolf Diesel in 1900 which ran on peanut oil, and plans by Henry Ford to run the Ford Model T on biofuels (Lewis, 1981). Ethanol was also produced from woody crops as far back as the 1890s in Germany and the early 1900s in Sweden (Rødsrud et al., 2012). Biofuels also made up a certain proportion of petrol in cars until after World War II, but were overtaken by cheaper, more readily available fossil fuels. The 1973/74 oil crisis focused attention on fossil fuel dependence and created some renewed interest in biofuels. Brazil was one of the earliest countries to respond to this concern and established a national biofuels policy producing bioethanol from sugarcane in the 1970s (Bringezu et al., 2009).

Scientific research is currently under way on different stages of the production of biofuels from non-food biomass. Demonstration plants exist in different parts of the world but lignocellulosic biofuels are not yet widely in commercial production (Service, 2007). The most common way of producing electricity from biomass is to burn it in steam generators (FAO, 2008). The biomass heats water which turns into steam and causes blades to rotate and power a turbine. It can be used alongside fossil fuels in power stations without major adjustment to the infrastructure. The hot water produced in this process can also be piped to homes and businesses to be used in heating systems.

The most common reasons cited for the development of bioenergy are: energy security, climate change mitigation and rural development (Levidow & Papaioannou, 2013). Energy security involves ensuring that everyone in a country has access to a stable and affordable supply of energy (European Commission, 2000). Dependence on imported fossil fuel makes a country vulnerable to disruptions in supply and price increases caused by political instability abroad. Peak oil, which is a stage in production when the rate of extraction of oil reaches a maximum and less oil is produced per day causing supply to be constrained, also threatens supply and price. There is dispute about when it is likely to occur, some estimates suggest before 2030 (Sorrell et al., 2009). There is disagreement about what exactly “energy security” involves: whether a certain degree of energy self-sufficiency is necessary or an import based system can be considered secure (Winstone et al., 2007). The generation of renewable energy, such as bioenergy, is seen as a means of pursuing energy security, as renewable energy by definition will not be exhausted, can be generated by different means, ensuring a diverse supply, and can be produced in the country of use or from politically friendly and stable countries (Maegaard, n.d.).

Bioenergy is also seen as a way to reduce greenhouse gas emissions (Swinbank, 2009). Fossil fuels for energy production account for 70% of global greenhouse gas emissions (FAO, 2008). Unlike fossil fuels, bioenergy is intended to be carbon neutral as biomass stores carbon as it grows, which is then released when it is burned (Bringezu, 2009). The EU committed to joining the Kyoto Protocol for greenhouse gas emissions reductions under the Council Decision 2002/358/EC**.** It committed to collectively cutting emissions by 8% during the period 2008-2012 compared to 1990 levels and by 20% by 2020. The UK was committed to a 12.5% reduction during the first period 2008-2012 and 20% during the second period 2013-2020. Denmark had a 21% reduction target during the first period and a 20% reduction target during the second period (European Commission, 2013).

The possibility of supporting rural development was also a motivating factor in the promotion of bioenergy, particularly biofuels (Levidow & Papaioannou, 2013). Agricultural support systems in industrialised countries, such as the EU’s Common Agricultural Policy (CAP) have become unwieldy and expensive in recent decades (Garzon, 2006). Farmers were given large production subsidies under the EU’s Common Agricultural Policy (CAP) after World War II to modernise systems and encourage food self sufficiency. This led to over-production with agricultural surpluses being “dumped” on developing country markets, effectively dampening prices. They were also viewed as an inefficient use of money and promoted environmentally destructive intensive agriculture (Grant, 1997). The production of food crops for biofuels was seen as a more defensible way to maintain agricultural support in the US and Europe (Smith, 2010). Farmers in the EU could grow crops including wheat, sugar beet and rapeseed for biofuels on formerly set aside land, giving them another source of income. It was presented in the UK as a way to diversify agriculture (DTI & DEFRA, 2004).

Within the US corn based ethanol took off as a result of policies promoting biofuels production and the USA was the largest producer of biofuels globally during the decade 2000-2010 (IEA, 2011). Biofuels have become a global phenomenon in recent years with 64 countries legislating biofuels targets (Smith, 2010). Brazil is currently the second largest producer and has the highest use with

23% of transport fuel coming from soybean and sugarcane based biofuels (IEA, 2011). Other significant sources include palm oil from Indonesia and Malaysia. Globally biofuels made up 3% of all transport fuels in 2011 (IEA, 2011).

Renewable energy in Denmark

Denmark imported more than 90% of its energy during the oil crisis of 1973, motivating the country to diversify energy supply using renewable sources and decentralised energy production (Danish Energy Agency, 2010). As a result of this strategy and oil and gas reserves in the North Sea, Denmark is currently the only net energy exporter in the EU, and is likely to remain so until 2018 for oil and 2020 for gas (IEA, 2010). Legislation in the 1970s and 1980s stipulated that new power plants must supply heat and electricity rather than electricity alone, increasing their energy efficiency. This paved the way for the transformation of the energy sector: district heating plants now supply 50% of Denmark's heating demand and 12 of the 14 largest power plants distribute their heat to the heating network (IEA, 2010). These district heating plants were established and owned by consumer lead co-operatives and municipalities (Maegaard, n.d.).[2] The majority of these plants run on natural gas and some also have small biomass convertors. When the Liberal Party of Denmark were in power they lowered the ambitions of the renewable energy policy in 2002 (Maegaard, n.d.). This plan came to an end however in 2008 with the Agreement on Danish Energy Policy 2008-2011, a cross party agreement to make Denmark less dependent on fossil fuel through a combination of energy savings and increased renewable energy production. The 2009 Renewable Energy Act developed detailed feed-in-tariff support for renewable energy. Municipalities and energy companies receive a subsidy per tonne of biomass used in power stations and also a price supplement for the electricity produced. This act increased the grant support for electricity and heat generated from biomass (Larsen, 2009). The Energy Strategy 2050 was introduced in 2011 with the aim of making Denmark independent of fossil fuel by 2050 and included interim targets. The main focus will be on increased wind, biomass and biogas energy, as well as mandatory increases in energy efficiency within power plants. There will also be a tax on electricity and gas as well as tax increases on oil and coal. The 2011 report "Energy Strategy 2050" (Danish Government, 2011) states that biomass will play a bigger part in combined heat and power (CHP) production, and biofuels will be used for large vehicles that cannot be electrified. It states that plans will be established to convert district heating plants from gas to biomass and to relax regulations about type of feedstocks so that biogas can be used in these plants.

[2] This was partly changed by the Liberal government in 2004 when some of the plants were transferred to commercial ownership as part of a reorganisation of the energy sector.

Renewable energy in the UK

The UK was a net energy exporter before 2004, and placed less emphasis on generating energy from renewable sources than many other EU countries (Perry & Rosillo-Calle, 2009). Efforts to supply renewable energy did start after the oil crisis in the 1970s, initially emphasizing wave energy and hydro-electric power (Connor, 2003). In the late 1980s the energy sector was privatised and public funding for renewable energy was reduced as it was expected that private funding would develop the renewable sector, through the Non-Fossil Fuel Obligation (NFFO), expectations which were largely not met (Connor, 2003). This was replaced by the Renewable Obligations Order which came into effect in 2002 and mandates that energy suppliers source a proportion of their energy from renewable sources or pay a fine (Carbon Trust, 2011). Companies demonstrate their compliance with the policy through purchasing Renewable Obligation Certificates (ROC). The policy is intended to last 25 years. However this policy has been controversial as exemplified by Helm's (2002) criticisms that renewable energy policy in the UK was not far reaching enough. Connor (2003) similarly states that renewable energy policy in the UK had been less successful than in countries such as Denmark, Germany and Spain which he maintains have fewer natural resources and similar amounts of funding for renewable energy in the 1980s. He states that it consists of trying to establish renewable supply on the margin of a centralised, fossil fuel and nuclear based system, rather than changing the system into one based on small scale local supply which he argues is more fitting to renewable energy sources. He states that the privatisation of the energy sector has reduced suppliers' monopoly meaning that customers can change supplier at will, and energy companies are unsure if they will recoup investment in renewable energy infrastructure, making them more reluctant to invest. Renewable energy policy is also set out in the Energy White Paper of 2003 which promoted the use of biofuels. At the time there was a tax cut for biodiesel which was extended to all biofuels in 2005. Renewable energy was also promoted in the 2007 Energy White Paper and the Low Carbon Transition Plan of 2009.

Bioenergy policy

The first biofuels legislation in Europe was the 2003 Biofuels Directive (2003/30/EC) that set targets for biofuels use in EU countries. Targets for 2005 and 2010 were not mandatory for member states. The UK announced the implementation of this policy in 2005 through the Renewable Transport Fuels Obligation (RTFO) overseen by the Department of Transport, coming into effect in 2008. It obliges suppliers of hydrocarbon fuels for transport to include a certain proportion of biofuels in this fuel or to a pay a fine (Department of Transport, 2011). Denmark was somewhat more reluctant to implement biofuels policy, setting a target of 0%. Initially concerns related to economic and technical feasibility, and then to environmental sustainability and the cost effectiveness of carbon savings (Hansen, 2014). However, policy was put in place in response to pressure from the EU and a push from the biotechnology industry to make biofuels a part of the EU bioeconomy (Hansen, 2014). This was seen as an economic opportunity for Danish industry as they had two of Europe's largest enzyme companies Danisco and Novozymes. Denmark did not introduce biofuels policy until the introduction of the EU Renewable Energy Directive (RED) 2009/28/EC which stipulates that 20% of member states' total energy consumption should come from renewable sources by 2020, with individual targets for different member states, and 10% of all countries' transport energy should come from renewable sources by 2020, consisting of biofuels or renewably powered electric vehicles. The Fuel Quality Directive (2009/30/EC) stipulates a minimum of 35% greenhouse gas emissions savings from biofuels compared to fossil fuels, rising to 50% in January 2017 and 60% in January 2018. The biofuels component of the RED policy was implemented in the UK under the Transport Fuels Obligation (Amendment) Order, with an interim target of 5% of the UK's transport fuel to come from renewable sources by 2013. This was then lowered to 4.75% from 2014 onwards (DfT, 2014). In Denmark the previous EU target of 5.75% energy in the transport sector to come from renewable sources was phased in until 2012 under the 2009 Sustainable Biofuels Act which obliges fuel suppliers to include a certain proportion of biofuels in their fuel. Biofuels are also exempt from carbon taxes.

The UK has a target of 15% total energy consumption from renewable sources by 2020 (Perry & Rosillo-Calle, 2009) and Denmark a target of 30% total energy consumption from renewable sources by 2020 (Danish Energy Authority, 2008). Table 1 shows some key figures for UK and Danish energy supplies.

Table 1. UK and Denmark country statistics.

	UK	Denmark	Reference UK	Reference Denmark
Population	63 million	5.5 million	(CIA World Factbook, 2013)	(CIA World Factbook, 2013)
Area	244,000 sq km	43,000 sq km	(CIA World Factbook, 2013)	(CIA World Factbook, 2013)
Renewable energy target	15% of total energy consumption by 2020	30% of total energy consumption by 2020	(Perry & Rosillo-Calle, 2009)	(Danish Energy Authority, 2008)
Biofuels target	10% renewable energy in transport by 2020	10% renewable energy in transport by 2020	EU RED 2009/28/EC	EU RED 2009/28/EC
Energy from renewable sources	11%	25%	(Dagnall & Prime, 2012)	(Danish Energy Agency, 2012)
Percentage renewable energy from biomass	74%	61%	(Dagnall & Prime, 2012)	(Danish Energy Agency, 2012)
Main sources of biomass (descending order by power generated)	Landfill gas; energy crops and straw; waste; liquid biofuels	Wood pellets; waste; straw	(Dagnall & Prime, 2012)	(Danish Energy Agency, 2012)
Percentage of biomass imported	42% of solid biomass 75% biofuels	23% total biomass	(DECC, 2013)	(Danish Energy Agency, 2012)

Percentage biofuels in transport fuel	3%	2.7%	(DfT, 2014)	(Danish Energy Agency, 2011)

2.3 Biomass controversies

This section explores the controversies that surrounded bioenergy after it was initially promoted as producing win-win-win outcomes of contributing to greenhouse gas mitigation, energy security and rural development. The section will provide background for the project, highlighting controversies around food crop biofuels and why perennial energy crops and crop residues are suggested by some as a way forward for biomass production. It also forms part of the literature review, as academics played a significant part in highlighting the controversies. It will focus in particular on transport biofuels because these have proven to be the most controversial.

Environmental controversies

As highlighted in the introduction there was a change in views about biofuels from around 2004 onwards (Mol, 2007). A paper published by Fargione et al. (2008) explored the phenomenon of direct land use change (DLUC). They considered six different habitats and found that biofuels production resulted in significantly larger greenhouse gas emissions compared to fossil fuels if they were grown on this land. The phenomenon of "indirect land use change" (ILUC) was also highlighted by Searchinger et al. (2008) in an influential paper published in Science. They estimated global greenhouse gas emission from corn production for biofuels in the USA using a global land use model and found that land with high carbon stocks was converted in other countries to make up the shortfall of corn diverted to biofuels in the US. Once these indirect emissions were factored in, bioethanol doubled greenhouse gas emissions compared to petrol consumption over a thirty year period. Mellilo et al. (2009) carried out similar analysis for the proposed use of cellulosic feedstocks in biofuels, with similar findings. The methodology in these studies was controversial however and the findings are contested. Some question the existence of the ILUC phenomenon, as illustrated by a quotation from a BP representative taken from the report on the ethics of biofuels by the UK Nuffield Council on Bioethics (2011): "The scientific basis for indirect land use change is extremely weak…ILUC modelling and analysis is the wrong tool for assessing these issues. Rather, better land management is required…" (p.33). The causality chain is seen by some as too weak to make the link between biofuels and the land use change elsewhere (Wassenaar & Simon, 2008). It is fair to say however that the Fargione et al. (2008) paper and this concept have had a major impact on the debate and caused considerable controversy. Land use change has become a dominant frame through which to understand biofuels controversies. Palmer (2014) and Levidow (2013) maintain that ILUC has narrowed down the framing of the sustainability debate as it came to be viewed almost exclusively as a greenhouse gas emissions accounting error in EU policy, to the exclusion of other framings and ways of understanding it.

Researchers within academia, NGOs and other organisations have highlighted other environmental issues with biofuels. Crutzen et al. (2008) was one of the most influential papers examining the nitrous oxide emissions from fertiliser application to first generation biofuels. They found that these emissions alone, irrespective of emissions from land use change, made total greenhouse gas emissions from biofuels higher than those of fossil fuels. Others also highlighted that increased production of food crops for biofuels has led to the same environmental problems associated with food production from monocultural and intensive farming systems, such as loss of biodiversity, soil erosion and degradation, increased water use, eutrophication, species invasion and ozone depletion (Doornbosch & Steenblik, 2008). The policy in the EU to allow biofuels production on formerly set aside land was also controversial because of perceived conflicts with the promotion of biodiversity (RSPB, n.d.).

These environmental issues were part of the media and NGO storm that blew up around biofuels after this time. Numerous NGOs were particularly vocal about biofuels because of the perceived environmental hypocrisy: a policy which was intended to tackle climate change was now perceived to worsen the problem (Action Aid, 2010). In 2006 an NGO called Biofuelwatch was established to campaign against biofuels policy. Palmer (2010) maintains that because NGOs exercised influence over the policymaking process they were viewed as “brokers of public trust in the policy making community” (p.1005). Pilgrim & Harvey (2010) analyse the scale of the biofuels controversy in terms of NGO opportunism, as they saw biofuels as an area where they could influence government policy, rather than as part of a coherent strategy by the NGOs. NGOs and the media were also pivotal in the food versus fuel controversy.

Food versus fuel

The so-called “food versus fuel” controversy is seen to date from the production of biofuels in the 1970s and 1980s (Rathmann et al., 2010). Raman & Mohr (2014) state that this was not viewed as overly problematic from the outset because it was assumed that biofuels production and consumption would stay within national borders. As biofuels production increased and the biofuels market became a transnational phenomenon (Mol, 2007) the food versus fuel controversy became increasingly important. It came to the forefront during the 2007/2008 food price spikes. Price increases caused riots in many countries in the global South. Many commentators blamed this price spike partly or wholly on the diversion of staple food crops such as corn and wheat from the food market to the biofuels market, or the production of biofuels crops instead of other staple food crops (Mudge, 2008; Sodano, 2009; McMichael, 2010; Biofuelwatch et al., 2007). An influential report by the World Bank attributed as much as 75% of the increase in food prices to biofuels production (Mitchell, 2008). In October 2007 Jean Ziegler, the UN special rapporteur on the right to food, stated “It is a crime against humanity to divert arable land to the production of crops which are then burned for fuel” (BBC, 2007) and more recently reiterated this claim in an article published in the Guardian (2013a). Many NGOs made biofuels an important campaigning issue and linked up with food companies to press governments for the removal of biofuels targets. The issue became increasingly controversial with the rights of the poorest to food contrasted with the desire of the rich to drive their cars and biofuels generally framed as an unethical, unacceptable technology (Gomiero et al., 2009).

The role biofuels played in raising food prices has been disputed. For instance Ajanovic & Haas (2010) concluded that biofuels were one of the factors that contributed to steady food price increases from 2002 to 2008 but that they did not necessarily play a role in the 2007/2008 price spikes. Instead factors such as a rise in the price of oil, poor harvests, increased demand and reduced food stocks in developing countries were seen as responsible. Some maintain that the food versus fuel controversy oversimplifies the debate, contending that the food crisis had been building for decades, with vulnerable countries becoming net food importers (Wetzstein & Wetzstein, 2011). In addition the problem is not only one of supply and demand but also a political-economic problem of access to food (Thompson, 2008b). Thompson (2012b) provides ethical arguments that problematise the standard narrative, suggesting that biofuels production may *reflect* an underlying problem in world food markets that the allocation of resources is not directed to feeding the poor as a main priority, rather than biofuels *being* the underlying problem.

Social justice

Biofuels have also been cited as an opportunity for the rural poor in the global South. Some contend that the rural poor could earn money from producing biofuels for use in their own country or exporting them abroad (Gilbert 2011; Martin, 2011). EU biofuels targets cannot be met using land in the EU alone, as there is very little suitable land left for production (Jank et al., 2007) and many developing countries have a comparative advantage because of availability of land, tropical climate and low labour costs (Mol, 2010). FAO (2008) point out that while cash crops can have a bad name because they are seen as exploiting resources and diverting profits and benefits away from the country of origin, they can also provide much needed employment, improve transport infrastructure and provide access to markets that would not otherwise be available.

Previous studies have suggested however that much depends on how projects growing biofuels in the global South are undertaken (Gamborg et al., 2012a), as promised material benefits from certain biofuels feedstocks have sometimes failed to materialise due to lack of support from an investor or government or lack of a market for the produce (German et al. 2010; GTZ, 2009). The production of jatropha, a non-food crop that produces oil rich seeds that can be used to produce biodiesel grown in parts of Asia, Africa and South America is a case in point. It was hailed as a wonder crop because of its ability to grow on marginal land and use very little water, but it has failed to deliver the promised benefits so far (Van Eijck and Romijn, 2008). Poor harvests have been interpreted in terms of a need for better land, more water resources and more scientific investment into breeding the crops. Ewing & Msangi (2009) state that the major beneficiaries of bioenergy production have been large scale producers, with benefits by-passing smaller producers who make up the bulk of producers in Sub-Saharan Africa and Southeast Asia. They point out that examples of biofuels production benefiting small scale producers do exist however.

There is also evidence of the forced and violent eviction of indigenous people from their lands to make way for biofuels production, so-called “land grabbing” (Borras Jr & Franco, 2010; Ribeiro, 2013; Borras Jr., 2011). Even when land deals to grow biofuels are not forced there can be significant negative environmental impacts and effects on local food production as land is cleared or given over to biofuels production (Franco et al. 2010; Mortimer, 2011). Amigun et al. (2011) state that 136,000ha of land is being used for biofuels in Ghana by seven private companies, which has major implications in a food insecure country. Borras Jr. et al. (2010) frame the outsourcing of biofuels production as a new type of colonialism: production takes place in poorer, politically weaker countries and industrialised countries reap the benefits. There have also been reports of human rights abuses and slave like conditions in biofuels production (Nuffield Council on Bioethics, 2011).

The local use of home grown bioenergy feedstocks is also framed as an opportunity to improve energy security in the global South. Evidence is also mixed about the potential opportunities for and benefits from small scale bioenergy projects in local communities. Gilbert (2011) and Mangoyana and Smith (2011) state that they may not yield a return for investors and need contributions from government or NGOs.

Another aspect of the social justice around biofuels is determining who the main beneficiaries of the biofuels policies have been, as many see it as a short sighted policy driven by agri-industrial interests. McMichael (2009) states "The rush to agrofuels, under the guise of policies geared to alternative energy and reducing carbon emissions, opens up new profit frontiers for agribusiness, energy and biotechnology corporations." (p.825) Levidow and Paul (2008) also claim that the EU established a biofuels policy early on because of lobbying pressure from the agri-industrial complex. Smith (2011) states that farmer cooperatives and processors were initially the main players in the "biofuels assemblage" and today the main drivers of the policy are large agri-business such as Archer Daniels Midland and Cargill, as well as large oil companies and car manufacturers. He states that the power of these groups "begins to explain the extraordinary growth of biofuels in the face of such ordinary evidence about their emissions and efficacy." (p.76)

The cost effectiveness of biofuels policy and how those costs are allocated has also been questioned. The FAO (2008) highlight the fact that the EU pays the highest subsidies per litre of biofuels produced of any state subsidy scheme, spending $1 on every litre of bioethanol and $0.7 on every litre of biodiesel produced. Lehrer (2010) highlights the fact that the majority of subsidies in the US have been allocated to large companies. Bringezu et al. (2009) state that EU and US biofuels policy has been effective in supporting farmers but has not achieved either of its other stated aims. It is also highlighted that biofuels are an expensive way to mitigate CO2 emissions compared to other policies within the transport sector or elsewhere (Richardson, 2012).

2.4 Responses to the controversy

Because biofuels policies were supposed to fulfil many objectives there were always different versions of these objectives proposed and different visions of how these would be achieved (Thompson, 2012c; Levidow & Papaioannou, 2013; Boucher, 2012). Bioenergy policy did change in response to the above controversies (Boucher et al., 2014). Responses to the above controversies have focussed on two distinct aspects: more technologically advanced and purportedly more sustainable biofuels; and developing sustainability criteria to regulate biofuels (Levidow & Papaioannou, 2014; Hunsberger, 2014). It is therefore important to consider these two strategies.

Sustainability in biomass policy

These controversies shaped the policy response on biofuels that followed (Philip Boucher, 2012). Following on from the controversies the UK government commissioned the Renewable Fuels Agency[3] to carry out a report on the indirect effects of biofuels production. This was published in 2008 and was entitled the Gallagher Review (RFA, 2008). It concluded that the indirect effects of

[3] A non-departmental government body which was in charge of implementing biofuels policy and has since disbanded in 2011.

biofuels were significant and were difficult to measure and control. It recommended a more cautious approach to biofuels, recommending that the 5% target be met by 2013 instead of 2011.

The European Commission published a report in 2010 outlining the sustainability criteria for solid and gaseous biomass (European Commission, 2010). These criteria were not mandatory but the report outlines what member states should include in criteria they develop themselves. The UK published a report in 2011 setting out the biomass sustainability criteria that power stations larger than 1MW must report on under the Renewables Obligation (Ofgem, 2011). These sustainability criteria were originally supposed to be made compulsory in the UK by April 2013 but this was put back until 2015 for power plants generating over 1MW. If power plants do not comply with the criteria then they will lose their RO support (DECC, 2013). Denmark currently has no mandatory sustainability criteria for solid or gaseous biomass.

Some maintain that the policy response to concerns about biofuels' sustainability narrowed to focus on measurable environmental impacts like greenhouse gas emissions, to the exclusion of a more holistic approach (Boucher, 2012; Palmer, 2014). Under the 2008 RTFO suppliers were required to report on the origin and type of biofuels used as well as greenhouse gas emissions savings and other selected sustainability criteria. Wastes and residues only need to fulfil the minimum criteria. Article 17 of RED 2009/28/EC sets out the mandatory sustainability criteria for liquid biofuels. Article 17 states that in order to count towards renewable energy targets biofuels cannot be grown on land designated for nature protection purposes, forest land, highly biodiverse grassland, or land with high carbon stock including wetlands and peatland. This was transposed into UK law by the Renewables Obligation (Amendment) Order 2011. In addition the order states that "degraded" land which was not in agricultural use in January 2008 and is either severely degraded or contaminated will receive a carbon sequestration bonus. Order No 1403 of 15 December 2009 enforces these criteria for biofuels in Denmark. An EC proposal on biofuels stated that these measures may be changed because they may not be suitable in their current form and will need to be integrated into other measures to minimise emissions from land-use change (European Comission, 2012).

In response to the controversies discussed, a 2012 proposal from the European Commission suggests that the contribution of food based biofuels will be limited to 5% of EU transport energy, half of the target for transport energy from renewable sources set out in the RED. A later EU proposal has raised the limit of food based biofuels in meeting the target to 7%, some state in response to industry pressure (The Guardian, 2013b). Feedstocks originating from oil, cereal and sugar crops will be assigned specific ILUC factors and all other feedstocks, including perennial energy crops or "lignocellulosic feedstocks", will be assigned a factor of zero. Member states will also have to report on the ILUC factors of the feedstocks used. Second generation biofuels which do not compete with food production will also be weighted more heavily towards meeting the target than biofuels from food crops.

Mol (2010) states that because of the transnational nature of biofuels markets, different types of authorities are emerging in biofuels governance other than state actors, such as private market authorities and moral authorities such as NGOs. One of the ways these other actors operate is through the establishment or regulation of certification schemes or sustainability standards for bioenergy feedstocks, such as the Roundtable on Sustainable Biofuels (Roundtable on Sustainable Biofuels, 2010). In 2010 the European Commission (EC) established guidelines that voluntary certification schemes for biofuels must follow in order to be recognised by the EU. Thus far seven sustainability schemes have been recognized, of which Germany has registered the only national scheme (European Biofuels Technology Platform, 2011). Some see these as the best option for biofuels, whereas others raise questions about the legitimacy and efficacy of these certification schemes as there is not agreement on definitions of sustainability criteria and a large number of actors are involved (Partzsch, 2011; Kløcker Larsen et al., 2014).

New crops and technologies

Lignocellulosic biomass sources producing “second generation” biofuels have been presented as a way forward for biomass policy. These include short rotation coppice trees such as willow, poplar and alder, grasses such as switchgrass and miscanthus, and crop residues like straw and sugar cane bagasse. These can also be used in power stations, either co-fired with fossil fuels or burned on their own. Crop residues are seen as overcoming land and resource controversies because they do not require additional land but are a by-product of an already existing crop (Nuffield Council on Bioethics, 2011). Willow may be harvested after 3-4 years of cultivation, and every two years after this (Karp & Shield, 2008). Harvesting involves removing branches and foliage and requires special machinery. Once planted, land usually stays under cultivation for a period of 20-25 years, meaning that the land changes use for an extended period of time. These feedstocks can be burned directly in stationary power stations to produce heat and/or power as a replacement for fossil fuels. They can also be made into “second generation” ethanol biofuels. These biofuels are not yet in commercial production because the sugar in non-food biomass is not as accessible as it is in food biomass, making their conversion into ethanol more difficult to achieve. The sugar in non-food biomass is effectively locked in to plant cell walls in a hard resin called lignin that protects the plant and keeps it upright. Research within the biological and chemical sciences is currently under way on different stages of the production of biofuels from non-food biomass. Research on the pre-treatment phase concerns how feedstocks can be treated in order to make this sugar more readily available for fermentation, and the fermentation phase investigates the different strains of yeast needed to ferment the different types of sugar found in the biomass.

A number of academic commentators stated that the development of non-food biofuels can help to overcome some of the social and ethical controversies that have faced biofuels so far (Graham-Rowe, 2011; Tait, 2011). As Service (2007) puts it: “To get past the food versus fuel debate you’ve got to get into cellulose” (p.1489). Claire Wenner, the biofuels representative for the renewable industry body Renewable Energy Agency (REA) states in a newspaper article:

> Of course, if the biofuels industry were to endlessly expand there would be inevitable conflict between food and fuel. But what is vital to understand, and what is missing from the debate, is that biofuels are at an early stage in their technological learning curve. With the right framework, this technology will have moved on long before conflict need be inevitable, and agriculture will have become more sustainable and productive in the meantime. (Wenner, 2012).

The Nuffield Council on Bioethics (2011) define second generation biofuels in terms of sustainability: “The unifying principles of development of new approaches to biofuels centre on abundant feedstocks that: can be produced without harming the environment or local populations, are in minimal competition with food production, need minimal resources, such as water and land, can be processed efficiently to yield high-quality liquid biofuels and are deliverable in sufficient quantities.” (p.47).

Non-food biofuels are seen as resulting in greater GHG emissions savings than first generation because more of the biomass can be used and so they will provide a higher energy yield per hectare (Delshad et al., 2010). They are seen as less environmentally damaging to produce because they will require fewer inputs such as fertiliser and pesticides (Fairley, 2011). Trees are perennial and so lock more carbon into the soil than annuals, in some cases willow has been used to rehabilitate depleted soils (Sugrue, 2008). Booth et al. (2009) quote a number of studies showing that biodiversity levels on land under perennial energy crop cultivation are higher than on arable land, because it is not as intensively managed and it adds another habitat to the farm that allows more species to thrive. They also maintain that the cultivation of bioenergy crops is likely to have a beneficial effect on water quality as they do not require as much fertiliser and pesticides as other crops, meaning there is less nitrogen leaching. Perennial energy crops’ long roots and longer growing period also result in less nitrogen leaching than annual crops. Jørgensen et al. (2005) highlight the possibility of using sewage or wastewater as fertiliser for willow. Sewage and wastewater cannot currently be used as fertiliser for food production because of the risk of spreading disease. There are some examples in Denmark of the use of wastewater and sewage on willow cultivation. For instance, the company Nordic Biomass undertook a project in conjunction with Skagen municipality to use local sewage sludge and wastewater on their willow plantation. It is suggested that these feedstocks will not compete with food production and minimize land use change because they are not food crops and they could be grown on marginal land unfit for food production (Schubert et al., 2008).

Because crops such as willow are not currently widely used in energy production some scientists see this as an exciting and promising area for agricultural sciences. Karp and Shield (2008) state that there has been relatively little research into increasing the yield of willow for bioenergy. They state that research is needed into lengthening the growing season, increasing biomass harvests without depleting below ground nutrients and necessitating increased nutrient application, or increasing water use. Karp et al. (2011) are optimistic about the prospects for the use of knowledge of genetics in breeding.

Another, potentially complementary, way forward for biomass is the inclusion of bioenergy within the “greener” “bio-based economy”, or bioeconomy. The bioeconomy involves processing biomass into energy, chemicals and advanced materials from food and non-food crops for industries such as construction and manufacturing (FAO, 2012). This is done in a “biorefinery” similar to the use of oil in oil refineries. The policy concept of an EU Knowledge Based Bioeconomy (KBBE) was launched in 2005 as a combination of the Knowledge Based Economy – a vision of an economy build on communication and information services – and the bioeconomy (European Commission, 2005). The EU’s Strategy for Innovating for Sustainable Growth: A Bioeconomy for Europe calls for a bioeconomy as a way to ensure the sustainable use of resources (European Commission, 2012). It is proposed as a way to safeguard food and energy security whilst overcoming resource constraints, dependence on non-renewable resources and tackling climate change. Biofuels are promoted as a particularly important part of the bioeconomy strategy to decouple increased economic growth from increased pollution (Richardson, 2012). This is particularly true in the case of Denmark where biofuels policy got off to a later start than in the UK and was linked from the outset with the promotion of the bioeconomy and the biorefinery concept (Hansen, 2014). This theme will be dealt with in more detail in the analysis of multipurpose biomass in chapter 8.

There is currently relatively little perennial energy crop production in the UK and Denmark. Production began in the UK with the establishment of the ARBRE power station in Yorkshire in 1996, which was part funded by the EU. This stimulated some energy crops production in the surrounding area, though the power station was unsuccessful and was decommissioned shortly after establishment. The Energy Crop Scheme (ECS) was launched in 2000 funded by the Rural Development Programme for England (RDPE) and administered by Natural England offering farmers a fixed payment per hectare of perennial energy crops grown (Defra, 2011). The scheme finished in 2006 and was replaced in 2008 by a second phase which gave farmers 40%, rising to 50%, of establishment costs. Farmers were also permitted to grow energy crops on set aside land, a scheme which ended in 2008. The EU also offered the Energy Aid Payment Scheme between 2004 and 2009 which gave farmers a flat rate per hectare for planting perennial energy crops. The schemes encouraged a gradual increase in planting, with hubs emerging around Drax power station in Yorkshire and Eccleshall in Staffordshire. Planting slowed in recent years because of low returns and other establishment barriers. Sherrington et al., (2008) state that farmers are reluctant to plant perennial energy crops because they see them as potentially riskier and less profitable than arable crop production. They view the market as unstable and were concerned about the security and terms of contracts with large power companies. They also perceive them as less profitable than arable crops and less flexible because they stay in the ground for a longer period of time.

Estimates of perennial energy crop production in the UK vary. Booth et al. (2009) quote a figure of 15,500ha of short rotation coppice and miscanthus. DEFRA (2012) shows a figure of 11,000ha of perennial crops in England in 2012, the majority of which is miscanthus. NNFCC (2012) state that 10,000ha have been planted in the UK since 1996. This makes it one of the highest producers of energy crops in Europe, alongside Sweden (Rechberger & Lotjonen, 2009). This remains small however in comparison to the target for land under energy crop cultivation put forward in the 2007 Biomass Strategy (DTI, 2007) of 350,000ha of perennial energy crops by 2020.

Statistics on Danish perennial energy crops also vary. A realistic estimate puts the amount of perennial energy crops at around 9000ha in 2013, the majority of which is short rotation coppice willow and popular (Larsen, 2014 personal communication).[4] Political interest in the crops has increased, a report in 2008 by the Ministry of Food, Agriculture and Fisheries (MFAF) calls for 100,000ha of perennial energy crop production on economically marginal land by 2020 as part of a strategy to reduce greenhouse gas emissions from agriculture (Ministeriet for Fødervarer Landbrug og Fiskeri, 2008b). This figure is reiterated in a 2013 cross ministerial working group report on how to reduce greenhouse gas emissions in Denmark (Tværministeriel arbejdsgruppe, 2013). In 2009 the Greengrowth initiative was introduced to establish a long term environmental policy for the agricultural sector. It aims to reduce annual GHG emissions from the agricultural sector by 800,000

[4] Larsen, S.U. 2014. Senior consultant, Agrotech. Højbakkegård Alle 21, 2630 Taastrup. 10 June 2014.

tonnes a year. The policy promotes the production of perennial energy crops through tax deductions, a change in regulation to allow cultivation in water course buffer zones[5] and a grant scheme to cover up to 40% of farmers' establishment costs (Danish Government & Danish People's Party, 2009). The scheme was part of six environmental initiatives under what was called Article 68 and ran from 2010-2012. The regulation to allow cultivation of perennial energy crops in water buffer zones was removed after this period, because of objections to the restrictions it put on views of the landscape due to the height of the crops. The planting grant scheme was renewed in 2013 until 2015 under decree 78 with a fixed rate grant per hectare of perennial energy crops planted.

In 2011 6.5% of UK straw was used in power stations for energy production (Agriculture and Horticulture Development Board, 2014). This was used in a large straw burning power station in Ely in East Anglia, two other power stations in Lincolnshire and one in East Yorkshire. The Drax power station in East Yorkshire also burns a certain amount of straw alongside fossil fuels. The main uses of straw are incorporation into soil to maintain soil quality and its use in animal bedding and feed. Estimates state that there are around 12m tonnes of straw produced in the UK annually (Agriculture and Horticulture Development Board, 2014). Straw production is concentrated in the east of the country and a large quantity is transported west for use in animal production. (Copeland & Turley, 2008) estimate that there are 5.7m tonnes of surplus straw that could be used in energy production. Glithero et al. (2013) suggest a lower estimate but also consider the potential of using straw that is currently chopped and incorporated into the soil in energy production.

Rechberger and Lotjonen (2009) state that Denmark is currently the European leader for straw utilisation for energy. A total of 5.5m tonnes of straw were produced in Denmark from cereals and oilseeds in 2010, 1.6m tonnes of which was used in the energy sector (StatBank Denmark, 2011). This exceeds the target set by the Danish Biomass Agreement in 2002 for a total straw consumption in energy of 0.93m tonnes a year (Voytenko & Peck, 2011). Voytenko and Peck (2011) maintain that the Danish Straw Supply Association (DSSA) played an important part of the establishment of a straw use network by negotiating straw prices that farmers would receive from the large energy companies. They divide the straw burning biomass plants in Denmark into four categories: on-farm plants that produce heat for the farmer's consumption using straw produced on the farm. In 1997 there were 10,000 such plants. There are on-farm plants that produce extra heat that is distributed to the local community. In this case farmers own the heat distribution infrastructure. In both of these cases the nutrient fly ash from the plant is returned to the soil. There are medium sized district heating plants that are supplied by a number of farms owned by a private company or local

[5] As opposed to food crops, which cannot be produced in water course buffer zones because of susceptibility to nitrogen leaching.

authorities or consumers who also own the distribution network. Here the price of straw is often negotiated directly between farmer and plant owner and may not always be formalised in a contract. Fourthly there are large CHP plants that are owned by the two major energy companies, DONG and Vattenfal. Here straw prices are usually negotiated through sub-constractors or the DSSA. There is no regulation covering the return of fly ash to the soil and it is not usually covered in the contract, which Voytenko and Peck (2011) view as sub-optimal for maintaining good soil health.

The removal of straw can lead to negative impacts on soil fertility as the carbon in the straw helps maintain soil quality. Lal (2009) lists the benefits for soils of straw incorporation: “Directly, crop residues retained on the soil surface as mulch moderate water and energy balance, buffer against erosive forces of raindrops and wind, recycle plant nutrients, and serve as food and habitat for soil organisms. Indirectly, crop residues affect soil processes through alterations of microclimate, soil moisture and temperature regimes, water and solute transport and erosional processes.” (p.234). Removal of residues can lead to soil degradation and increased erosion. This is seen to be of particular concern in Denmark which has a relatively large and well established organic sector which makes use of crop residues instead of inorganic fertilisers (Jørgensen, 2007).

2.5 Responses to the responses to the controversies

This section will consider how the above responses to biofuels controversies in terms of sustainability within bioenergy policy and new bioenergy technologies have been analysed by academics and NGOs. Levidow & Papaioannou (2014) consider how future imaginaries of technologically advanced biofuels that are currently in development serve to placate concerns about the sustainability of present biofuels. These technologies may not be in commercial production in time to contribute to the EU 2020 target but they serve to manage tensions between different actors such as industry and NGOs in the bioenergy debate by making promises about future sustainability. They also conflate the public good with private interests through the rhetoric of competitiveness that paints a picture of a common interest in economic growth. These imaginaries tend to frame sustainability in terms of market environmentalism: the best way to tackle environmental problems is by allowing free markets to operate. This will not placate those who call for more systematic change. McMichael (2010) for instance analyses biofuels controversies in terms of the failures of market environmentalism and a deepening “metabolic rift” between people and the environment (p.827).

There has also been work carried out on the bioeconomy concept, considering how it frames biomass controversies and solutions in terms of a need for innovation, increased competitiveness, a need for increased efficiency through biotechnological innovation and agro-industrial production methods, and how it closes down other alternative imaginaries (Birch et al., 2010; Schmid et al., 2012; Levidow et al., 2013). We will explore this aspect in more depth in chapter 8.

Many have also questioned the idea of producing these non-food crops on so-called marginal land. The term “marginal land” is notoriously ambiguous and once it is specified in more detail many have pointed to problems with the idea of using it for biomass production. At a somewhat practical level, one type of disagreement concerns whether marginal lands can be reliably located (Bandaru et al., 2013). A related disagreement is whether land lying fallow today might be needed in the future for food production, to offset potential demands of the world’s growing population (Butterbach-Bahl & Kiese, 2013). Evidently, there is also a great deal of disagreement about the possible environmental impacts of using marginal lands identified as suitable for biofuel production (Gelfand et al., 2013). Such impacts include greenhouse gas balances (Don et al., 2012), the water and energy footprints of bioenergy crop production (Bhardwaj et al., 2011) implications on soil (Blanco-Canqui, 2010) and biodiversity (Pedroli et al., 2013). In general, effective assessment of marginal lands is not well addressed (Kang et al., 2013).

At another, more fundamental, level there is disagreement about what actually constitutes marginal land. The lack of clarity makes it difficult to assess the claim that marginal land can be used for sustainable biomass production. Current definitions generally focus on a single criterion, primarily agro-economic profitability (Gopalakrishnan et al., 2011). Work has considered the ambiguity and fluidity of the term and the functions this can play. Some, such as Biofuelwatch et al. claim the term can promote the normalisation of past land degradation, the downplaying of the social and environmental functions the land currently has, and exclusion of those who use it (Biofuelwatch et al., 2007). Work focusing on the concept of marginal land in the global South has pointed out implicit assumptions and values at play in categorisations of land as “marginal”, and how this affects different groups connected to the land, often disadvantaging people who use the land but have little political power to defend that use (Borras Jr. & Franco, 2010; Brara, 1992; Nalepa & Bauer, 2012). Richards et al., (2014) conducted a review of the definition of marginal land in 51 academic articles and found similar definitions. They call for authors to clarify how they are using the term to facilitate understanding. Chapters 6 and 7 examine the concept of marginal land and will draw on literature on this subject in more depth.

2.6 Other analyses

It is fair to say that biofuels controversy solidified around the issues outlined above of environmental issues, food versus fuel and social justice. Here we will consider issues that arguably have not made as big an impact in the bioenergy debate but which are relevant to this project.

Scale and efficiency

Commentators have questioned biomass' efficacy as part of the move towards more renewable energy. They highlight the land intensive nature of biomass production, the small scale of production that is possible and issues related to energy efficiency. The WBGU maintain that because of their resource intensive nature biofuels cannot account for a large percentage of the world's transport fuel (Schubert et al., 2008). The WBGU also state that electricity and heat bioenergy should be used as an interim measure before other renewable technologies such as solar power are economically and technologically viable. FAO(2008) for instance quote a figure that if 25% of world crop land were used for biofuels production this could supply 14% of transport fuel needs, and Smith (2011) points out that if 75% of Britain's land was used for biofuels production this would not supply fuel to all cars. The energy efficiency of biofuels has also been questioned: the production of biofuels is dependent on fossil fuels, often making the energy saving over fossil fuels minimal (FAO, 2008). Net energy *loss* from biofuels production has even been claimed (Gomiero et al., 2009). There are suggestions that other approaches as well as technological solutions are needed, as the UNEP state "Global resources do not allow simple shifting from fossil fuel to biomass with the same consumption patterns in place." (Bringezu et al., 2009 p.21). Many state that a more important issue to tackle is overconsumption of energy in transport and elsewhere, which some frame as the main problem causing global greenhouse gas emissions (Biofuelwatch et al., 2007; Friends of the Earth, 2007). The issue of scale will re-enter the analysis in chapter 9.

Agricultural production of biomass

Chapter 1 considered a limited number of analyses that explore biomass from an agricultural point of view, considering whether production took place within industrial or alternative systems. This can be seen as another way to understand the controversy: controversies raised by biofuels relate to controversies raised by industrial agriculture more broadly. They share the same environmental and social justice issues as industrial food production, but to add insult to injury they were promoted as an ineffective environmental solution and were seen to actively disrupt food production. Raman & Mohr (2014) state that the controversy need not be analysed in terms of food versus fuel or greenhouse gas emissions, but rather in terms of issues with global agricultural systems as a whole.

They quote an anti-biofuels website Journey to Forever stating "Objections to biofuels-as-agrofuels are really just objections to industrialised agriculture itself, along with 'free trade' (free of regulations) and all the other trappings of the global food system that help to make it so destructive". Potter (2009) sees the push for biofuels production as part of the resurgence of productionism that emphasises different uses of land as a way to tackle environmental sustainability, rather than a change in farming practices and more environmental stewardship. Kuchler & Linnér (2012) also position the biofuels discourse within the IPCC, IEA and FAO as positioning biofuels within industrial agriculture:

> The biofuel discourse pursued by the involved institutions becomes a key carrier of various policies, options, and strategies that support industrialized, market-oriented agriculture characterized by large-scale production, land ownership concentration, and various biotechnological enhancements, as well as the further ''fossilization'' and mechanization of rural practices. These particular trends are allowed to penetrate the agricultural sector where, in particular, they intensify and transform the essential food- and feed-production modes. (p.587).

Borras Jr. et al., (2010) published in a special issue of the Journal of Peasant Studies on biofuels also analyse biofuels in terms of the discontents of industrialised agriculture. They state that some see biofuels as within a "new agriculture" based on commercial investment and high tech production methods. Levidow and Paul (2008) examine and question the promises made about second generation biofuels and biotechnology in the energy system. They state that the technologies themselves are not the only problematic issue. They are promoted within agro-industrial systems and so foreclose the possibility of other alternative systems being used to solve problems in agriculture. They state:

> […] the focus on GM crops diverts attention away from political-economic drivers of the current conflicts. It also reinforces dominant agri-industrial assumptions: namely, that societal conflicts over bioenergy result from inadequate yield, that agri-industrial monocultures are the only path towards societal progress, and that alternatives are inherently unrealistic or marginal. (p.30).

These critical commentaries all maintain that an exploration of biomass controversies in terms of underlying conceptions about agriculture is worthwhile. This idea that there is a need to consider the values and assumptions about agriculture that underpin the agricultural production of biomass for energy is the starting point of this research project.

Some features of the way in which perennial energy crops and crop residues are promoted over previous feedstocks appears to frame them as some sort of alternative biomass production: they require fewer inputs, can be grown on less productive land, could provide win-win outcomes involving recycling waste water as fertiliser or mopping up some of the environmental impacts of industrial agriculture. How are we to understand these claims from the point of view of agricultural systems? With the above analysis in mind it is worth reiterating the point that this is an under-researched area of biomass production, particularly for perennial energy crops and crop residues.

2.6 Conclusion

This chapter considered the use of biomass in energy generation in more detail: how it is used in energy generation, and the rationale for its use in the energy system. The commonly cited story of its development for energy security, climate change mitigation and rural development, as well as other analyses that suggest it was promoted by lobbying from the agri-business, energy and car companies were outlined. Then subsequent controversies were described, particularly focusing on food based biofuels considering the core issues of environmental sustainability, food versus fuel and social justice. The main arguments against food based biofuels were presented, and theories that problematise the most common stories told, such as Thompson's 2012 analysis of the food versus fuel controversy. Reponses to these controversies were considered in terms of the incorporation of sustainability in bioenergy policy and other technologies, such as the use of perennial energy crops and crop residues in both stationary heat and power and biofuels. These were framed as overcoming many of the controversies of food based biofuels because of the types of crops they were: requiring fewer inputs and less prime land, or no extra land in the case of crop residues. This also fits with the narrative of the bioeconomy as the way forward for biomass use generally. Analyses of the responses to the controversy were explored, many of which see these developments as framing problems and solutions within agri-industrial terms and excluding other framings. The chapter then looked at some of the issues that were arguably less prominent in debates, such as the issue of scale and the agricultural dimensions of the controversy to again highlight the rationale for this project. This last point leads on to the exploration of the next chapter of different paradigms of industrial and alternative agriculture and the framework that will be used in the analysis.

Chapter 3 Paradigms of agriculture

3.1 Introduction

This chapter will present some of the current thinking within philosophy of agriculture in order to inform the analysis of perennial energy crop and crop residue production for energy in the following chapters. Specifically this chapter will present different paradigms of agriculture: industrial and alternative to inform the later analysis. Before discussing this philosophical work it is first helpful to clarify the way in which a number of terms are being used within this analysis. The word “paradigm” is used in the same way as it is used by Lang and Heasman (2004):

> […] a set of shared understandings, common rules and ways of conceiving of problems and solutions about food. A paradigm for us is an underlying, fundamental set of framing assumptions that shape the way a body of knowledge is thought of. (p.17).

Thus the word is not used in a strictly Kuhnian sense to mean incommensurable systems of knowledge (Kuhn, 1996). The term “model of agriculture” will be used to refer to subcategories within industrial and alternative paradigms, such as life sciences integrated agriculture and ecologically integrated agriculture as we will see below. A theory is taken to mean a set of ideas or general principles intended to explain something, so a theory about agricultural development seeks to provide principles explaining why it has developed the way it has. A paradigm can involve different theories. The “theorising” of agriculture will by necessity be somewhat uneven in the following section: the philosophical lineage of some paradigms will be explored and critiqued in more depth than others. This is because the literature review draws on sources from different disciplines which theorise the agricultural paradigms in different ways: Thompson (1995) conducts a thorough philosophical critique of productionism whereas work on agricultural multifunctionality does not approach agriculture from the same angle, with much of it coming from the discipline of geography. Smoothing out the peaks and troughs in the depth of analysis undertaken for each paradigm is beyond the scope of this thesis but this work is conducted to provide a description of the parameter of the paradigm and its real life application as well as some criticisms. Work from STS, agricultural ethics, environmental ethics and rural geography will be drawn on to help understand the sets of fundamental framing assumptions that underpin the paradigms.

Thompson (2008c) states that the theorising of agriculture has largely been ignored in social sciences and philosophy. Zwart (2009) similarly states "One could say that it took philosophers 25 centuries to acknowledge the pivotal importance of food production for human existence." (p.512). As we will see in chapter 4, agricultural ethics is not yet a flourishing area in its own right. Environmental ethics would seem like a suitable area in which to explore agriculture because it relates to the interaction between people and nature. Thompson (2008c) states however that a large strand of environmental ethics has focused on the value of wild nature and the relationship between humans and nature. Jamieson (2008) points out that some argue we are facing the end of nature: anthropogenic climate change will mean that nothing on the planet is outside of human influence. Rolston III (1997) maintains that we value nature's autonomy: we find it reassuring and comforting to go to natural or wild places and be reminded of the indifference of nature and the limits of human society. These arguments have been used within environmental ethics to justify calls for more wild nature and conservation areas (Strong, 1995). The challenge within some of these arguments is that if any human interference with nature is objectionable then all agriculture becomes problematic. As Thompson (2008b) states in relation to biofuels: "But the fuel-vs.-nature question is vexed because the agriculture-vs.-nature question is vexed." (p.149) Soby (2012) puts forward this view in a paper on the Green Revolution: "Agriculture and other related food cultivation practices (i.e., deforestation, aquaculture) are inherently destructive, and degradation of land and freshwater resources complicates the problem of sustainable food production (Buck 2011; Foley 2011; Myers 2003; Holdren 1974)." (p.5). Thompson (2008b) points out that this tack leaves us with no way of differentiating between types of agricultural production or expressing preferences.

Within the industrial paradigm the productionist and life sciences integrated models are introduced and the alternative paradigm will cover the agrarian, ecologically integrated and multifunctional models. There are other ways of conceptualising agriculture: Thompson and Otieno Ouko (2008) state that much debate about agriculture revolves around support of or opposition to capitalism, which is not explored in detail here. Many of the debates from the 1970s onwards focused on the success or otherwise of the Green Revolution in developing countries, in terms of the perceived increased social inequality that resulted from Green Revolution technologies (Buttel, 1994). Some see the technologies of the Green Revolution as inherently anti-poor as they favoured richer farmers with capital who could afford to invest in them (Griffin, 1974). The ethics of food distribution and famine relief, as well as animal ethics became important topics within ethical debates about agriculture (Thompson 2014). Later environmentalism became a bigger factor and in time became one of the dominant themes of discussion and a dividing line among philosophies (Buttel, 1994).

Most theories of agriculture could be said to fit into some form of "industrial" and "alternative" typology, though the details of both of these, additional categories and subcategories vary. Environmental impacts can be addressed and dealt with in both industrial and alternative paradigms, though in different ways as are discussed below. Other ways of categorising agriculture which are different to the typology in this chapter include Thompson's (1995) theorisation of agriculture in terms of productionism on one hand and a systems approach; the internalisation of externalities; and what he calls "sustainable agriculture" as different approaches to agriculture. Lang and Heasman (2004) theorise agriculture in terms of productionism, life sciences integrated and ecologically integrated agriculture. Wilson (2007) in terms of multifunctional agriculture on a spectrum from productivist to non-productivist. Marsden and Sonnino (2008) theorise multifunctional agriculture in terms of agri-industrial, post-productivism, and sustainable rural development. Levidow & Boschert (2008) in terms of agri-industrial, agri-diversity and agrarian based rural development. CREPE (2011) theorise agriculture in terms of life sciences and agro-ecology models and Schmid et al. (2012) in terms of industrial and public good perspectives, to name but a few.

The following categories were chosen as the end result of the iterative process of exploring what theoretical framework could be used most fruitfully to understand the empirical data. These paradigms shed light on different aspects of the bioenergy debate presented in the following chapters. It was also considered that they provided a sufficiently complete picture of past, present and future developments within agriculture for the purposes of this study, covering major changes, theoretical developments and different visions for the way forward for agriculture.

3.2 Industrial agriculture

Thompson (2010) describes industrial agriculture thus:

> According to this view, whatever might have been the case in the past, we should now see agriculture as just another sector in the industrial economy. This means that society is best served when farmers, ranchers, and other animal producers make their products available at the lowest possible cost. (p.30).

We will discuss two philosophies below which are classified here as sub-paradigms (models) of industrial agriculture: productionism and life sciences integrated agriculture. It should be noted that productionism as a philosophy is not limited to its inclusion in industrial agriculture, and the philosophy could be seen to predate what Thompson (2012) refers to as industrial agriculture, but as it is used here the term also refers to a moment in agriculture in industrialised countries after World War II when it was the implicit norm guiding agricultural development (Thompson, 1995).

Productionism

Productionism is a paradigm that takes production of goods as the sole norm for evaluating agriculture (Thompson, 1995). Here progress within agriculture can be understood as increased production, following from Jonathan Swift's dictum:

> And he gave it for his opinion, "that whoever could make two ears of corn, or two blades of grass, to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together.(Swift, 1962 p.160).

This paradigm has led to the industrialisation of agriculture. Thompson maintains that productionism has been the most pervasive model of agriculture to date, but when explored in more detail its underlying assumptions are problematic and it has lead to various negative environmental and social impacts. A brief outline of the history of productionism will now be provided.

Progress within agricultural is fundamentally bound up with science and technology. As Vanloqueren and Baret (2009) state: "Science and technology are at the core of agricultural change." (p.971) Agricultural technology remained relatively unchanged for millennia from the start of farming (Fuller et al., 1996). Agriculture became "scientised" from the time of the industrial revolution onwards when new technologies and practices were introduced, such as the seed drill and use of fertilisers shipped from across the world (Zwart, 2009). The Haber-Bosch process to make inorganic nitrogen fertiliser from nitrogen in the air was discovered during the First World War in Germany and removed previous limitations on the productivity of agricultural lands (Smil, 2001). Agricultural productivity escalated around the world after the Second World War thanks to "Green Revolution" technologies of improved seed varieties, pesticides and herbicides, fertilisers and increased mechanisation, generally in a monocultural system (Trewavas, 2001). In Europe, significant increases in production were also due to policies promoting self-sufficiency in food and increased productivity through production subsides in the Common Agricultural Policy (CAP) by the newly established European Economic Community, now the European Union (Garzon, 2006). Increased trade liberalisation led to increasingly globalised agricultural markets and agricultural holdings by and large became bigger and more efficient. Recent years have also seen the growing influence of large, multinational companies on different parts of the food chain. Lang & Heasman (2004) state that productionism has been and still is the dominant model in developed countries. Productionism did increase yields globally, Lang and Heasman (2004) state that it has been "wildly successful" by its own standards (p.36). They maintain however that it may be on the decline as the most pervasive philosophy of agriculture as the problems associated with productionism are mounting.

Policies of production subsidies became increasingly expensive within the EU, with vast amounts of money being spent incentivising produce that had no market in the global North and was “dumped” on markets in the global South, dampening prices. The acceleration in productivity and intensity of production also led to extensive environmental impacts. These were described in chapter 2 when discussing the environmental impacts of biofuels production, including eutrophication, greenhouse gas emissions, soil erosion etc. Reforms to the CAP began in 1992 with the McSharry reforms that sought to move towards other ways of supporting agriculture by incentivising diversification and environmental schemes, and supporting rural development; so-called “pillar two” initiatives (Wilson, 2007).

Thompson (1995) traces the development of the philosophy behind productionism in his book Spirit of the Soil. He points to religious views that influenced productionism, including the Christian ideas of virtue being tied to industriousness and the idea of God bequeathing the earth to man to use as he saw fit. He states that under this framework wilderness was seen as a chaotic, undesirable state of affairs that was civilised and tamed by the farmer who could work hard to advance his spiritual and earthly station. He shows how productionism was brought forward through a combination of positivist science and economic utilitarianism. Scientific and technological progress was seen as the way to achieve progress within agriculture, though science itself should be objective and value-free. Economic tools served to justify and accelerate the use of technology. Thompson states “Preference utilitatrianism allows the technocrat to understand all problems as situations in which existing technology impedes the satisfaction of personal preference.” (1995 p.65).

Despite environmental and other criticisms which we will explore below, productionism is defended by some as a viable option for the future of agriculture, with some adjustments to address the environmental and economic problems (Lang and Heasman, 2004). Krzywoszynska (2012) analyses the policy responses to productionist agriculture of seeking to manage its negative impacts in terms of risk:

> The public and policy reaction was not to question the premise of the agro-industrial system, but instead to recast agriculture itself as a ‘dirty business’ and a threat to the unspoiled nature of the countryside. From a site of nature, agriculture became a site of risk. The risk posed by agro-food materialities to both rural environments and the bodies of consumers was to be contained through an increase in state intervention into all aspects of agro-food production. In this bureaucratic-hygienic mode of agrofood production (Marsden, 2003), the spaces and material flows of agricultural production came under scrutiny by a plethora of quality, health and environmental protection bodies. (p.51).

As a result of industrialisation agriculture has come to be seen as a “dirty business” with polluting and risky characteristics. The response within productionism has been not to fundamentally change the model but to seek to micro-manage its impacts on nature.

Life sciences integrated agriculture

Lang and Heasman (2004) maintain that there are however currently two agricultural paradigms competing to replace the productionist paradigm: what they call life sciences integrated and ecologically integrated. This thesis will use their term “life sciences integrated” or “life sciences” model. The life sciences integrated paradigm is about producing more, to “feed the world”, an imperative to reduce world hunger and tackle the environmental and health problems caused by productionism through the use of high tech biological mechanisms. Lang and Heasman (2004) state:

> The life sciences integrated paradigm describes the rapidly emerging scientific framework that is heralding the application of new biological technologies to food production. We propose this paradigm as a way of capturing a body of thought that has as its core a mechanistic and fairly medicalised interpretation of human and environmental health. […] This highly sophisticated thinking about health and food is at the heart of the application of biotechnology to food production, and its application on an industrial scale is at the core of the life sciences integrated paradigm. (p.21).

It involves the view that biology will be the most important science for the future of agriculture, using techniques such as genetic modification and the use of enzymes in food and fuel production. Vanloqueren and Baret (2009) highlight the importance of these techniques to current agriculture: “Fundamental and applied research in biology, chemistry and genetics has resulted in a constant flow of innovations and technical changes that have greatly influenced agricultural systems.” (p.971) Inputs will not be increased to boost production as was done in productionism, but rather this new strategy sees yields increasing through “smart” and “eco-efficient” use of inputs and technology (Levidow et al., 2013). Eco-efficiency is about improving the ratio of production to environmental impacts (Zhang et al., 2008). Agricultural innovation is also framed as necessary to ensure European competitiveness on global markets delivered through new patents for novel crops and processing methods, often facilitated through public-private partnerships (CREPE, 2011). The life sciences integrated paradigm is also tied to the idea of the bioeconomy – all the products that are currently made from fossil fuels in oil refineries could be replaced by the use of biomass in biorefineries. In this narrative biomass is framed as an abundant, flexible resource whose potential can be unlocked through biological sciences (Hansen, 2014). Here limitations are framed in terms of environmental and regulatory restrictions rather than technological barriers (Levidow et al., 2013). This idea of the life sciences integrated bioeconomy concept will be discussed at greater length in chapter 8.

Within this paradigm plants are framed as technologies in themselves, with metaphors of plants as computers and factories (Levidow et al., 2013). This paves the way for the reductionist, scientific approach that aims to further fine tune and optimise these plant “technologies” using biotechnology. Although, it should be noted that because of its emphasis on the biological sciences and attempts to move away from the productionist paradigm, life sciences integrated agriculture also draws on a discourse of naturalness, and the positive associations of natural produce, which we will see below is an important theme for alternative agriculture. The biorefinery approach within life sciences integrated agriculture for instance makes much of the fact that fossil fuels are being replaced with “natural” biomass (Levidow et al., 2013). Here the definition of “natural” is expanded to include any product of biological processes (Levidow et al., 2013). The metaphors are mixed so that plants are framed as “natural” computers and cell factories.

It can be difficult to see how the life sciences paradigm is different from productionism. It often also involves monocultural production, it fits into the same structure of production through large scale agri-business operating at a global scale, it conceives of progress within agriculture as being scientific progress, often using economic instruments, and it involves a reductionist view of agricultural science’s interaction with nature in terms of more closely engineering and controlling agricultural processes. Some critics contend that it is just a high tech form of productionism (Lang and Heasman, 2004). De Lattre-Gasquet et al. (2010) see current agricultural research as being driven by the same principles Thompson (1995) saw underlying productionism: “Whether they like it or not, public research institutions are being propelled to the crossroads of science and markets as a result of unprecedented hybridisation of scientific and economic rationality which leads stalwartly into a knowledge economy.” (p.310). However, Lang and Heasman (2004) state that it can be seen as different because of the central position and significance given to biology within agriculture rather than agri-chemistry, and because part of the motivation behind the life sciences paradigm is to replace some productionist elements, including reducing agriculture’s reliance on inputs and energy use and provide a better way to “feed the world”. Since there are obvious similarities and linkages between productionism and the life sciences model, within this thesis they will be referred to collectively as “industrial agriculture”.

Criticisms of industrial agriculture

Thompson (1995) critiques positivist science and the utilitarian underpinnings of neoclassical economic theories which have driven productionism. Criticisms include that of the pervasive idea that technological progress will lead to progress in society, which of course is widely questioned by some communities including STS scholars (Winner, 2004). The relationship between technological progress and societal progress is more complicated and technologies often have unintended consequences which are often far reaching and difficult to manage (Scott, 2011). Agricultural progress framed in terms of scientific and technological progress promotes a particular framing of problems that narrows down the scope for solutions and favours a particular set of interests, often well capitalised farmers and agri-business, as was one of the criticisms of the Green Revolution (Levidow et al., 2013). Part of Thompson's (1995) criticism of positivist science criticises the idea that science is and should be objective and value neutral, another important theme of STS. We will see in chapter 4 that STS highlights how science and technology are shaped by the social context they develop within.

Another criticism of the positivist science perspective within productionism is made by White (1967) and holds that science does represent a progressive expansion of knowledge and power over the natural world, but because science views nature through a lens of instrumentalism and reductionism, this "Baconian creed" of power over nature is necessarily exploitative and immoral (p.4). This criticism can also be found in the romantic strand of Critical Theory, a Western Marxist philosophical tradition. Adorno and Horkheimer (1997) give an account of the human relationship with nature in their book "Dialectics of Enlightenment". They maintain that the Enlightenment project of progressive thought, of privileging reason over dogma or tradition, with the aim to "liberate men from fear and establish their sovereignty" (Vogel, 1996 p.51) has led to a radically different relationship with nature, what they call the "disenchantment of nature" (p.55). They state that we have moved from a mythical view of ourselves as part of nature and nature as sacred, to a view of ourselves as separate from a quasi-mechanical nature that we can control and manipulate to our own ends. Enlightenment creates new myths in its instrumental understanding of nature devoid of any meaning or teleology. Krimsky (1995) describes how the use of biotechnology in agriculture allows us to pursue the idea of progress in terms of freedom from the natural constraints agriculture has always faced: "One traditional measure of human progress is the degree to which we can control, accommodate to, or survive the forces of nature." (p.6). The idea of science and technology being used within agriculture to overcome the limits of nature, or "tame" nature will be dealt with further in the section on alternative agriculture.

Many of the same criticisms of productionism can be made against life sciences integrated agriculture because of their similarities. Criticisms are made by those who agree with criticisms of reductionist science listed above. Karafyllis (2003) states that genetic modification is objectionable to some because of the power it gives us over the environment and it undermines our understanding of plants as symbols of autonomous growth and renewal, and as further reducing the otherness and autonomy of nature. Many see this new approach to agriculture as exemplifying the same belief that progress in science and technology will lead to straightforward progress in agriculture and as entrenching the same powerful agri-business interests instead of seeking alternative solutions and attempting to address existing inequalities (Levidow & Paul, 2008). We will return to criticisms of the industrial paradigm in later chapters.

3.3 Alternative agriculture

There are many different versions of "alternative" agricultures that have different philosophical and historical roots, as theorised in academia and represented in social movements. They do however share many common features as we will see below. Alternative agriculture is still a marginal sector in terms of its ideological and economic influence, though it is carving out a niche (Renting et al., 2003). Productionist agriculture remains the main type of agriculture in industrialised countries and the life sciences integrated paradigm is proving more influential among policy makers and agri-business as an alternative, because it relies on the current, individualistic approach to food choices which fits the current market structure (Lang and Heasman, 2004).

The above section highlighted Thompson's (2008c) point that the focus of environmental ethics on the importance of wilderness means it has little to contribute to developing a coherent agricultural philosophy. Raffensperger et al. (1998) reinforce the separation between agricultural and environmental ethics, stating that environmentalism does use different literatures and has different theoretical roots to work on sustainable agriculture. Some of the prominent formative thinkers within sustainable agriculture include Rudolf Steiner who formulated the bio-dynamic system; the British botanist Sir Albert Howard whose work contributed to the development of organic agriculture and Wendell Berry, an American essayist and poet on agriculture in the USA. However, the concerns of alternative agriculture can be said to overlap with those of environmentalism in dealing with the environmental damage brought about by productionist agriculture. It can also be seen to overlap in relation to an emphasis on a systematic approach to managing the environmental and holistic thinking, which comes from the disciplines of ecology, which we will focus on in more detail below. Alternative agriculture perspectives were also boosted by the development of modern environmentalism, which many see as beginning with Rachel Carson's study of the far reaching effects of pesticide use in her 1962 book Silent Spring (Beus & Dunlap, 1990), and as mentioned earlier environmentalism became an increasingly important part of debates about agriculture. Below we will explore three different but overlapping approaches to alternative agriculture.

Agrarianism

Agrarianism is the view that agriculture has a special status beyond its material contribution to society (Mariola, 2005). Agricultural also plays a role in producing a functional society because it is claimed that farmers and farming communities make the best citizens (Thompson, 2010). Some trace this philosophy back to the Ancient Greek philosophers' belief that a farming system built around family farms ensured that citizens had an in interest in defending their land and this system established virtues such as courage and loyalty among citizen farmers (Thompson, 2012a). Agrarianism is a more prominent philosophy in the US than in Europe and also has roots in the American school of pragmatism as well as virtue ethics. It is traced back to Thomas Jefferson's linking of farms with the moral character of a society: good farming was needed to produce a good farmer and society (Thompson, 2008c). Aldo Leopold (1949) was an important influence on agrarianism, and argued that disconnection from the source of one's sustenance posed "spiritual dangers" to the populace. Agrarianism provides non-consequentialist based arguments against industrial agriculture, that do not just try to assess what agricultural system can produce most at the least economic and environmental cost. Thompson (2010) similarly states that aside from its environmental and social "impacts", farming practices shape an individual's and society's character, and as such, industrial agriculture is a culturally deadening force. It involves an ontological position that breaks down dualistic, Cartesian boundaries between mind and body, the human and natural world and sees one as influencing the other (Thompson, 2008c). Inge (1969) conducted an analysis of agrarian themes in US literature and came up with five classifications: "1. *Religion.* Farming reminds humanity of its finitude and dependence on God. 2. *Romance*. Technology corrupts; nature redeems. 3. *Moral Ontology*. Farming produces a sense of harmony and integration, while modern society is alienating and fragmenting. 4. *Politics*. Rural autochthony provides the backbone for democracy. 5. *Society.* Rural interdependencies and reciprocities provide a model for healthy community." (in Thompson, 2010 p.281). Thompson's work attempts to bring some of the core concepts of agrarianism forward to articulate a philosophy relevant to modern agriculture, using the concept of sustainability (Thompson, 2010). The sections below will focus on the development of alternative agriculture practices and theory which do not share agrarianism's roots in virtue ethics and political Republicanism.

Ecologically integrated agriculture

Beus and Dunlap (1990) state that some alternative agriculture approaches differ from agrarianism in that they include the modern environmentalist criticism of agriculture and aim to develop a type of agriculture based on ecological principles. Lang and Heasman (2004) call the newer manifestation of alternative agriculture that aims to compete with the life sciences integrated model to replace productionism “ecologically integrated” agriculture. Like the life sciences integrated paradigm, ecologically integrated agriculture emphasises the importance of biology to the future of agriculture (Lang and Heasman, 2004). It has however a different orientation in the biological sciences (Vanloqueren and Baret, 2009)**.** It does not seek to engineer agricultural processes but rather involves a systematic, holistic approach to production and aims to work with nature to increase productivity. This is in line with the alternative agriculture paradigm which many see as having a different scientific orientation to industrial agriculture (Beus and Dunlap, 1990). Some see alternative agriculture as moving away from a mechanical, reductionist, Newtonian view of nature towards an ecological view of nature that sees farms as agro-ecological systems (Callicott, 1990). Agriculture is not seen to be working against nature to civilise it but rather claims to see the “natural” as a positive thing and try to work in harmony with nature in a way that mimics natural processes, producing as little waste as possible.

Agri-food studies have also included a call for the reintroduction of nature into the field of study, as a focus and active agent in its own right. This fits with the ontological turn within STS that aims to reintroduce materiality into the field of study and consider its role in shaping outcomes (Latour, 2004). Murdoch et al. (2000) state that industrial agriculture views nature as something passive to be controlled and to some extent replaced by non-natural functions. Within industrial agriculture nature is looked at through a scientific lens with the purpose of gathering and using this knowledge is to “outflank nature”: to overcome its limits and push it to produce more (p.108). Goodman (1999) states that alternative agricultural movements such as organic production re-introduce nature as an active agent by bringing to light agro-food chains that are opaque in industrial agriculture:

> In organic agriculture the fetishized abstraction of food is intentionally unveiled, bringing the complex filaments of food provisioning explicitly into focus. That is, the organic agro-food network invites scrutiny of its constituent metabolic relations, an interrogation that follows from its organizational and ethical premises of connectivity, in contrast to the punctualization or black boxing characteristic of industrial agro-food networks. (p.34).

Scientific agricultural knowledge is also applied in a different way. There is less of an emphasis on elite scientific expertise and control of knowledge and technologies by large agri-business and more of an emphasis on integrating scientific knowledge with traditional and local knowledge (Levidow et al, 2013). Lang and Heasman (2004) state that this is not a "recipe" approach to agriculture but seeks to work within a specific context. These systems are also characterised by an emphasis on closed loop on-farm systems of nutrient use, reduction in dependence on fossil fuels and seeking to mimic natural eco-systems, where nothing goes to waste (Levidow, 2008). Agricultural systems within the ecologically integrated paradigm include organic agriculture, permaculture, agro-forestry, biodynamics and agro-ecology. Agro-ecological systems aim not to use external inputs, whether organic or otherwise, but instead harness synergies between crops to supply nutrients and protect from pests (Altieri & Toledo, 2011).

The alternative paradigm became more formalised after the Second World War in the global North, including the establishment of standards for organic agriculture for (Stanhill, 1990). Some see the development of the alternative paradigm within the global North as motivated by resistance to productionist agriculture. There has been public resistance to new technological innovations such as GM in agriculture, with protests in the 1990s halting the roll out of GM in Europe (CREPE, 2011). High profile food scares such as the BSE crisis, also dented consumers' trust in the food sector (Murdoch et al., 2000). There were moves within agricultural markets away from large scale, industrial production, towards what have been called "alternative agri-food networks" (AAFN; Sonnino & Marsden, 2006). AAFNs involve local, shorter supply chains in initiatives such as farmers' markets, and lower levels of intensification, in systems such as organic production (Levidow, 2008).

The move towards AAFNs has also been theorised from within agri-food studies as characterised by an emphasis on quality production, territorialisation of agriculture and added value at the farm level (Sonnino & Marsden 2006; Goodman 2004; Levidow 2008; Lang and Heasman 2004). Quality can mean different things in different contexts. In Northern European countries it can refer to environmental sustainability and animal welfare, whereas in Southern European countries it can relate to traditional production methods and location (Renting et al., 2003). Nygård & Storstad (1998) define quality in the Norwegian context as local and more "natural" alternatives to conventional agriculture which are seen by consumers as inherently safer and more trustworthy. Alternative agriculture is proposed as a way for developing countries to modernise and increase yields without going down the same route as developed countries.

Multifunctional agriculture

The idea of "multifunctional agriculture" is another approach to theorising agriculture that originally comes from within the field of geography in the UK, though it has been subsequently used in other countries (Wilson, 2007). In a way it is trivial to say that agriculture is multifunctional, as it has always produced different things (Winter & Lobley, 2009). The current conception of agricultural multifunctionality however emerged from a policy and academic context from the 1990s as a descriptive or normative concept that describes and/or promotes multifunctionality as a way to avoid the ills caused by industrial “monofunctional” agriculture (Lowe et al., 2009; Potter & Tilzey, 2005). There is limited literature on the philosophy of the concept but it has largely been used in a policy or economic context (Wilson, 2007). Multifunctionality involves a move from productionism towards what has been called “post-productionism”. Post-productionism is exemplified by extensification, on-farm diversification and environmental protection. In a policy context it meant the withdrawal of production subsidies within the EU CAP from the 1990s and a move towards different subsidy frameworks, such as the single farm payment that paid farmers irrespective of what and if they produced on their farm, cross compliance which made subsidies dependent on the retention of minimal environmental standards, and so called “pillar II” schemes that promoted environmental initiatives and diversification (Garzon, 2006).

Marsden and Sonnino (2008) use the term post-productionism with a more specific meaning, seeing post-productivism as a particular form of multifunctionality, which replaces a farm-based approach to agricultural management with a land-based approach. Here land is seen as a consumption space to be exploited by urban and ex-urban populations. It highlights the different ecological, production, landscape and social functions of land.

Multifunctionality is a widely debated concept, particularly in terms of what it involves, how it should be theorised, how it should be implemented, to what extent it is actually happening. Some see multifunctionality as including the move towards the AAFNs of local and quality production (van Huylenbroeck and Durand, 2003). It is also used sometimes synonymously with on-farm pluriactivity or diversification. Thus it can have a very wide meaning that is akin to how “alternative agriculture” is being used in this project. Wilson (2007) divides conceptions of agricultural multifunctionalism into holistic, economic and political. Economic views of multifunctionality frame problems associated with producitivism in terms of negative externalities. The environmental services provided by agriculture are public goods: they are non-excludable and non-rivalrous, thus they are not accounted for within agricultural markets. Multifunctional agriculture is seen as the challenge of monetising these externalities to create a market for them, which Thompson (1995) points to as one of the responses to the problems of productionist agriculture. It is also associated with the idea of pluriactivity and providing farmers with additional sources of income in addition to productivist agriculture. The policy approach sees multifunctionality as something which should be driven through top down policies to incentivise farmers to use the land in particular ways. The holistic understanding of multifunctionality highlights cultural, social and environmental aspects of agriculture. It is a "territorial concept based on a spectrum of tensions and competing values in the countryside." (p.188). Wilson (2007) questions the claim that post-productionism is happening in practice, stating that the facts on the ground do not bear it out and the reality is that most agriculture is still a very intensive, industrial process. Instead he places agriculture along a spectrum of weak to strong multifunctionality according to the degree to which it involves non-production based activities. The concepts of multifunctionality and post-productionism will be used in chapter 7 when examining Danish marginal land.

Criticism of alternative agriculture

This chapter has described different theories and movements involved in “alternative” agriculture. However, we can maintain that there is enough homogeneity to use a single term to refer to this sector of agriculture. Critics of agrarianism state that is a somewhat esoteric philosophy whose main points are only relevant to a small subsection of contemporary society because only a small number of people are involved in agriculture (Mårald, 2013). Some also question the idea that agrarian societies are paradigms of virtue: rural environments are also associated with repressive norms and stultifying conservatism (Mårald, 2013). Agrarian discourse has also been linked in the past, particularly in Europe, to nationalism and even fascism, though Thompson (2013a) states that this legacy of agrarianism need not affect the current use of the philosophy. There is uncertainty about whether the principles of alternative systems such as agro-ecology; of increasing productivity through harnessing natural processes and synergies actually work in practice (Lang and Heasman, 2004). It is seen by some as backward looking and esoteric, and many claim that it cannot deliver the productivity increases that are necessary to “feed the world” (Trewavas, 2001). Despite its claim to hold the moral high ground some see it as positively unethical because yields are lower, it would require more land, further endangering biodiversity (Trewavas, 2001). The sustainability claims of alternative agriculture are also questioned. Forssell and Lankoski (2014) conduct a review of the sustainability criteria of alternative agriculture and question some of the claims made, pointing out that local production is not necessarily more environmentally friendly, farmers may find it a financial and time burden rather than a benefit to take part in direct selling to consumers, and territory based quality labels can lead to homogenisation of products as well as differentiation. Thompson (2010) points out that the romanticism of agrarianism continues in debates about agriculture. “Anti-technological Romanticism is rampant in contemporary debates on food and agriculture.” (p.283). He states that in some quarters alternative agriculture is centred on an opposition to genetic modification and the idea that technology corrupts and nature redeems prevails. The idea of developing a less exploitative relationship with nature within agriculture is also criticised. The notion of working in harmony with nature and achieving balance with natural processes can be seen as a myth, as these ideas are human constructs and ecosystems are very dynamic, often unstable entities and so the idea of a being in harmony and balance with an ecosystem can be seen as unrealistic. We will return to depictions of “nature” and “the natural” in relation to marginal land use in Denmark in chapter 7.

3.4 Conclusion

In summary, agriculture in industrialised countries underwent significant transformation since the industrial revolution, with the end of what Zwart (2009) calls the “common human pattern” of a rural agricultural existence of self-sufficiency, dependence on and connection to the land. The increasing industrialisation of agriculture took place during the 20^{th} century, to what is widely recognised as an economically and environmentally unsustainable degree in Europe. Inefficient production subsidies were rolled back within the EU and replaced to some degree with support for environmental schemes and other on-farm activities. This lead to a certain amount of public distrust in agricultural systems due to high profile food scares and new technologies such as GM that are viewed with trepidation by some members of the public. Thompson (1995) theorises industrial agriculture as driven by positivist science and economic utilitarianism, and an idea of progress as increased productivity and control over natural processes. Some STS work reflects on this idea of progress and problematises the straightforward link between technological progress and progress in society. Environmental ethics appears to accord with the policy response to the problems raised by industrial agriculture in seeing it as an inherently polluting and destructive activity whose impacts on unspoiled nature should be minimised. A new “life sciences integrated” paradigm tries to take forward the structures of productionist agriculture using technological innovation from the biological sciences with the aim of both increasing production and reducing environmental impacts. Some see this as simply a modernisation of productionism, whereas proponents see it as different because of the centrality of biology and the rationale of overcoming the problems of productionism.

Agriculture has seen the emergence of pockets of “alternative” forms of agriculture in recent decades, generally characterised by local, more extensive production systems. Agrarianism focuses on the non-consequentialist value of agriculture in forming a society’s moral character and providing a connection with the land. Agrarianism was outlined in this chapter because it was considered to be an important philosophy of agriculture but it is not taken forward in the analysis because its virtue ethics and political republican based philosophy did not emerge as relevant to analysing the empirical data. Ecologically integrated agriculture is a newer form of alternative agriculture that encompasses systems such as agro-ecological and organic and attempts to use the biological sciences to take a holistic approach to agricultural development, emphasising closed loop nutrient cycles and reduction in inputs. Agri-food studies understand alternative agriculture systems as defined by an emphasis on quality, territoriality and added value at the farm level, as well as the reintroduction of nature as an active part in production processes. Multifunctional agriculture refers to the economic and policy attempts to distance agriculture from the productionist paradigm by widening the scope of agriculture to include other activities and the provision of environmental services. It has also been theorised more broadly to mean a move towards alternative agriculture. Proponents of both alternative and conventional agricultural paradigms claim that their model is the only one that can feed the world and solve environmental problems, and that the other model puts global agriculture at risk (Vanloqueren and Baret 2009).

In order to support the analysis set out in the following chapters it is valuable to provide a summary of the characteristics of productionist, life sciences integrated, ecologically integrated and multifunctional systems (table 1). These four models will be taken forward and applied to the analysis in the following chapters. They will be applied where it is deemed appropriate and developed to fit the cases of perennial energy crops and crop residues as appropriate. The next chapter deals with the project’s disciplinary positioning, methodological issues and methods.

Table 2. Characteristics of productionist, life sciences integrated, ecologically integrated and multifunctional agriculture.

Agriculture paradigm	**Industrial**		**Alternative**	
	Productionism	**Life sciences Integrated**	**Ecologically integrated**	**Multifunctionality**
Description	Agriculture is an industrial sector of the economy that should aim to increase production as efficiently as possible through the use of scientific innovation.	Agriculture is an industrial sector of the economy that should aim to increase productivity and tackle the environmental issues caused by productionist agriculture, through the use of scientific innovation, particularly from within the biological sciences.	Agriculture should be restructured to tackle the environmental impacts and inequality embedded in the industrial system. Yields should be increased through diversifying farming practices, while reducing inputs and implementing systems of closed nutrient management.	Agriculture in industrialised countries is a multifunctional activity that provides a range of commodity and non-commodity outputs, including environmental services. This multifunctionality should be better managed and encouraged to help agriculture become a more economically, socially and environmentally sound enterprise.
Features	• Intensive production involving heavy use of inputs like fertilisers and pesticides.	• "Sustainable intensification" involving precision use of inputs to increase production.	• Extensive production involving fewer or no artificial inputs.	• A variety of different production systems from intensive to extensive.

	• Large scale production to increase efficiency. • Long, often global supply chains. • Supply chains dominated by large agri-business. • Adding value to products off-farm. • Scientific focus on increasing productivity.	• Large scale production to increase efficiency. • Long often global supply chains. • Supply chains dominated by large, agri-business. • Adding value to products off-farm. • Scientific focus on genetic engineering to increase productivity without increasing environmental impacts and inputs.	• Smaller scale production. • Shorter, local supply chains. • Supply chains dominated by smaller, locally owned business. • Adding value to products on-farm and off-farm. • Scientific focus on increasing productivity while reducing environmental impacts through a systems approach.	• A variety of different production scales. • Supply chains at different scales. • A mixture of ownership structures. • A mixture of value adding strategies. • Scientific focus on strategies to reduce environmental impacts and develop diverse activities and products for agriculture. • Knowledge as top-down

	• Knowledge as top-down and expert led. • Sustainability in terms of managing the environmental impacts of intensive production through legislation and subsidy schemes. • Commoditisation of land. Land ≠ place. Products not connected to place. • “Naturalness” of production methods and products not important.	• Knowledge as top-down and expert led and driven by industry needs. • Sustainability in terms of eco-efficient production, smart farming and driven by scientific innovation. • Commoditisation of land. Land ≠ place. Products not connected to place. • “Naturalness” of production methods and products not important.	• Knowledge as top-down and bottom-up, expert led and produced by farmers. • Sustainability in terms of on-farm nutrient cycling and energy management in a holist approach. • Land connected to place. Localness and territoriality of produce important. • “Naturalness” seen as an important feature of production methods	and bottom-up, expert led and produced by farmers. • Sustainability in terms of ensuring the economic, social and environmental health of farms and rural communities. • Land connected to place in post-productionist multifunctional uses of land. • “Naturalness” seen as important in some multifunctional activities.

			and products. Harmony with nature fostered.	

Chapter 4 Methods

4.1 Introduction

This chapter will detail how the research project was designed and carried out. Section 4.2 will outline the disciplines this thesis draws on: science and technology studies (STS), bioethics and agricultural ethics. It is important to present this detail because the project was conducted using a cross disciplinary approach and draws on and was influenced by a number of the theories and approaches. Section 4.3 will give an exposition of where this work is positioned between STS, bioethics and agricultural ethics, and how it draws on these disciplines. Section 4.4 will provide important background information on qualitative research methods and detail the methodological position of the project, as well as issues such as representativeness and validity in qualitative research. Section 4.5 will outline the project methods; considering frame analysis, thematic analysis, and the combination of data from two countries, and two different sources. Section 4.6 will then describe how the document analysis and interviews were carried out and analysed; how documents and interviewees were chosen and what these processes involved, and how data was analysed. Section 4.7 will conclude.

4.2 A methodological approach that draws on STS, bioethics and agricultural ethics

This section gives an overview of the disciplines that this project draws on, namely STS, bioethics and agricultural ethics. As we will see they differ in their disciplinary backgrounds, aims, conceptual inheritance and theories used. It will consider criticisms of the disciplines and some responses to the criticisms. The next section will outline how these disciplines influenced and are applied in this project.

Science and technology studies (STS)

STS came from the discipline of sociology and has its roots in social constructionist schools of thought, that maintain knowledge is constructed through the collective process of creating meanings and understandings about the world (Edge, 1995). That is, things do not have an essence that exists independently of human judgment. STS is concerned with how meanings and values in the social sphere influence scientific research and technology and how science and technology in turn influence society (Jasanoff, 1999). STS is a heterogeneous field with disagreements over its intellectual boundaries and theoretical coherence, though it shares the common goal of studying science and technology empirically (Jasanoff, 1999). This section will mention a few approaches and theories within STS that have some bearing on this project.

Some of the early STS work sought to dispel the idea that science and technology are "neutral" and a-social, focusing on the role social factors play in the scientific process and design of technologies (Vinck, 2003; MacKenzie & Wajcman, 1999). Work also focuses on how technology in turn changes society. Objects themselves have politics, because they require, or are compatible with, a particular political structure and set of conditions (Winner, 1985).

STS problematizes the straightforward assumption often made by scientists and lay people that technological or scientific progress will lead to progress in society. This can be seen in the technological fixes argument that technology gives shortcuts to the resolution of social problems (Weinberg, 1967). Scott (2011) points out that while "technological fixes" neatly delineate problems and make them more manageable, they can have unintended and far reaching consequences and produce other problems. Some social problems lend themselves to technological fixes, but other, often more complex problems do not (Sarewitz & Nelson, 2008). Certain STS scholars do not see technologies' unintended consequences as mere "side effects" or "impacts", but rather technologies alter our world significantly in often unexpected and fundamental ways, to the extent that they can change notions of risk and responsibility (Borgmann, 2004; Winner, 2004). Beck (1999) uses the concept of a global risk society to describe the great difficulty of attributing responsibility for environmental damage. Jonas (2004) claims that the power and complexity of modern technologies challenge previously held conceptions of ethics and responsibility based on the idea that we were responsible for the consequences of our actions, which were easily known. Now great knowledge and insight is needed to understand these consequences, attribute responsibility and regulate our use of technologies. In theory, risks are controllable but there is a question whether or not they are in practice, because technologies are powerful and systems complicated and anarchic as described above (Perrow, 1999). The concept of "post-normal science" developed by Funtowicz and Ravetz (1993) describes a method of inquiry where facts are uncertain, values disputed and the stakes high.[6]

Another important concept in STS literature is that of co-production that seeks to avoid the reduction of the study of a science or technology merely to the study of "perspectives" on it, or to scientific determinism that sees the technology shaping society in a straightforward way (Jasanoff, 2004). Co-production views the direction of causation as two-way with science impacting on society and society impacting on science. Jasanoff (2004) states that the theory allows for rich description of a new scientific entity or scientific controversy in terms of social and scientific factors that seek to avoid the reduction of one to the other or tautology and theoretical holism. This can be seen within

[6] Though it should be noted that Perrow, Jonas and Beck may not consider themselves to be STS scholars, their work has a bearing on the area.

what Woolgar and Lezaun (2013) call the "ontological turn" in STS that focuses on the materiality of objects which are seen as enacted or co-created through this knowing.

Some STS work focuses on how people conceptualise emerging technologies and the expectations and fears that surround them. Expectations are performative, they "mobilise the future into the present" (Brown, 2003 p.5). They bring about change in the world through encouraging particular research agendas and funding opportunities and mobilising networks and relationships around a technology. Positive expectations about a technology create a protected space for the technology to develop without the need for immediate results (Geels & Raven, 2006). Hope and hype around a technology also have a corollary in disappointment, while hype about a technology may be necessary it may create expectations which then collapse when the technology does not deliver (Brown, 2003). STS does not evaluate these expectations in comparison to a "right answer" about what the value of a technology should be. Rather it takes the view that there is no neutral position from which to analyse the "real" value of a technology, but it is worthwhile to map the cycles of hope and disappointment around a technology and that expectations about the future tell us something interesting about the present.

There is also a body of literature within STS that deals with the development of scientific evidence and the role of evidence within political disputes. Sarewitz (2004) for example outlines why more evidence will not necessarily solve a dispute, but rather it is fruitful to turn towards political means and/or an exploration of the values embedded within the different arguments. He outlines some fundamental aspects of this literature:

> This literature is characterized, for example, by the understanding that scientific facts cannot overcome, and may reinforce, value disputes and competing interests, that scientific knowledge is not independent of political context but is co-produced by scientists and the society within which they are embedded, that different stakeholders in environmental problems possess different bodies of contextually validated knowledge and that the boundaries between science and policy or politics are constantly being renegotiated as part of the political process. (p.386).

There are some criticisms of the approach STS takes. Johnson and Wetmore (2008) state that STS scholars do not usually take moral stances, preferring to examine how arguments achieve legitimacy rather than argue for the legitimacy of their point of view. They state that STS scholars tend not to make recommendations for change and this can serve to obscure implicit normative aspects of their work. Jasanoff (1999) states that policy makers and scientists have tended to see STS as unnecessarily opaque, theoretically dense and removed from their experience of science. The constructionist orientation of STS is seen by some as a relativist threat that seeks to disempower science (Gross & Levitt, 1998). Edge (1995) states that there is a tension within STS between the relationship of facts and values, between the "is/ought" distinction, to what extent can description of science lead to prescriptive claims about how science should change?

There is some disagreement within the STS and sociology of scientific knowledge (SSK) communities on how normativity should be dealt with in research (Radder, 1998; Wynne, 1996; Singleton, 1998). The debate centres on the philosophical discussion of relativism and realism: if one deconstructs scientific claims then has one in any sense "disproven them"? Are the claims made by STS or SSK "more true"? Thus what significance do claims made by STS and SSK have? This comes back to the perennial problem faced by relativism, of how to assert the truth of their own claims within a relativist framework[7]. Wynne (1998) replies that one does not have to resolve the relativist/realist debate in order to make normative claims.

The debate also centres on the differences between normative and descriptive claims: what it would mean for STS to make a normative contribution to a debate. Would it have to make assertions about what people *should* do or could a normative contribution consist of contributing insights to the field in order to improve the quality of the debate and decision making (Radder, 1998)? Jasanoff (1999) states that the STS method of deconstructing scientific claims does not entail moral nihilism or epistemological relativism: not all facts are placed on the same footing and it is still possible to make moral judgments about claims and make prescriptive claims. Rather the deconstructionist methods of STS aim to shed light on, rather than reduce the complexity of the world, in order to understand how science and society came to be seen in the way they are.

We will not delve into this debate in more depth but for now it is enough to highlight the issues at play to understand important differences between the disciplines and to inform the methodology of this work. We will now move on to consider a different approach to analysing issues of controversy and science from within ethics, with more modernist underpinnings which struggles with the is/ought distinction in a different way.

Bioethics

Whereas STS emerged from the social sciences, bioethics is rooted in the discipline of philosophy, using theories from normative ethics. The discipline has its origins in considerations of ethics within

[7] That is not to say that many STS positions are relativistic, many such as Wynne (1996) are intended to be more nuanced, but that the issue comes back to the same argument.

medicine, such as those involved in the Nuremberg trials in 1946 (Jasanoff, 2005). The term "bioethics" was first proposed by the biochemist, van Rensselaer Potter in the 1970s. Potter felt that the biological sciences had significantly advanced in the late twentieth century, yet reflection about values and the ethical impacts of this new knowledge had not advanced at the same pace. The discipline of bioethics was suggested as a way to bridge the gap between humanities and science (Potter, 1971). Mepham (2008) defines bioethics as "the study of the moral and social implications of techniques resulting from advances in the biological sciences." (p.4). Like STS, it is a heterogeneous field with blurred boundaries that draws on different disciplines. Frey (2013) describes it as a part of applied ethics, which is often seen as synonymous with medical ethics, but more broadly can also be seen to deal with environmental and animal ethics.

Within bioethics ethical theories are used to better understand issues related to science and clinical practice. Examples of theories used include Aristotle's virtue ethics, John Stewart Mill's utilitarianism and Kant's deontology and more recent approaches such as John Rawls's theory of justice. As highlighted by Beauchamp and Childress "the purpose of a theory is to enhance clarity, systematic order, and precision of argument in our thinking […]" (Beauchamp and Childress, 1994 p.5). As such new theoretical approaches have been developed more recently such as a "principlist" approach, combining ethical theories through principles that are used to assess problems. Beauchamps and Childress developed prima facie principles that relate to doctors' responsibilities towards patients: non-maleficence, beneficence, autonomy and justice. The ethical matrix and ethical Delphi are examples of recent tools that have been developed and used as aids to ethical decision making (Kaiser et al., 2007; Dürnberger et al., 2009). The ethical matrix applies the principles of well-being, autonomy and fairness to explore the potential ethical concerns of different groups affected by ethical issues (Mepham, 2008).

Borry et al. (2004a) state that traditionally a strong distinction was maintained between bioethics and social sciences because of desire by bioethicists to keep the discipline free from cultural contextualism and cultural relativism. Levitt (2004) states that Beauchamp and Childress saw their principles as a-social and a-cultural. Borry et al. (2004a) see this as rooted in the meta-ethical distinction between the descriptive and the normative: between "is" and "ought", raised by the Enlightenment philosopher David Hume. One cannot logically speaking derive an "ought" from an "is" and so bioethicists preferred to let their ethical analysis be informed by facts, which were not themselves treated as social constructs, as STS treats them. Some social scientists see the bioethics preference for facts over perspectives as a naive and uncritical understanding of how scientific facts are generated (Levitt, 2004). As described above, the STS perspective maintains that scientific facts are not developed in a value and culture-free vacuum but rather are also products of their context of production, and this cultural context is worth investigating.

Bioethics has also been accused of being too abstract and not adequately empirically informed. It often deals with thought experiments, or has been criticised for analysing the most extreme, theoretically interesting case, while ignoring the mundane reality of most cases in the area (Borry et al., 2004b; Hedgecoe, 2004).

Bioethics has however involved more empirical work in recent years. Molewijk (2004) states that empirical research can be integrated into ethical analysis in a number of different ways that involve different methodological positions. As is the case for STS, there are debates about the place of description and normative claims within bioethics. The is/ought distinction can be retained with the researcher letting themselves be informed by what people do and say in practice, using ethical analysis to delineate the boundaries of the ethical issues, and without relinquishing normativity and the use of normative principles to analyse issues (van der Scheer & Widdershoven, 2004). Borry et al. (2004a) call this empirical ethics and others call it integrated empirical ethics (Molewijk, 2004). There is ongoing debate about the role of empirical research in bioethics, but it has been incorporated to a greater extent in recent years (Levitt, 2004; Molewijk et al., 2004).

The view of bioethics as involving top-down, abstracted pronouncements by ethical “experts” is questioned by many in the field. Walker (1993) states that there are two views of the ethicist, one is an expert in ethical theories and another is someone who creates a space for reflection and thought on difficult issues. She states that the role of the ethicist is increasingly shifting from the former to the latter. The role of ethics is to render authority more self-conscious and create a literal or figurative reflective space; ethicists are “architects of moral space”. They do not necessarily have to master “codelike theories or lawlike principles” (p.33) and their view does not necessarily carry more weight than other contributors in the debate. She links this change in role to the increasing focus on the actual action and language of those being researched – the greater inclusion of empirical research, as discussed above. Elliot (2009) describes his approach to environmental ethical issues thus: "Rather than attempting to develop controversial theoretical conclusions about debated environmental issues, scholarship of this sort elucidates ethically significant questions and promotes critical reflection, shared understanding, and informed decision making in response to them." (p.170).

We will now consider agricultural ethics, which can be seen as a sub-branch of bioethics, and shares the same roots in classical philosophy.

Agricultural ethics

It is unclear whether "agricultural ethics" exists independently as a discipline. It is often placed as a branch of bioethics, with the title "agricultural bioethics" (Thompson 2013b). Thompson (2013b) states "Agricultural ethics comprises normative analyses and debates on the production, processing, distribution, and consumption of cultivated and human-supervised biological products typically (but not exclusively) used as food." (p.1). In this way it can be seen to share the same classical philosophy rather than constructivist roots of STS. There is also substantial overlap with the field of food ethics. Food ethics is another sub-field of applied ethics. In the pre-modern era it was primarily concerned with the consumption of food but a progressive focus on the science of food and the social dimensions of food in the modern era mean that it now also focuses on the production and distribution of food, as well as food policy, which are areas of overlap with agricultural ethics (Zwart, 2000).

Thompson (2013b) states that ethical reflection on agricultural issues has a long history and can be traced back to the ancient Greeks through to John Locke's discussion of the Enclosure Act in Britain in the 18th century. In the 20th century agricultural ethics dealt with issues of global hunger and animal rights. Thompson sees a conference held at the University of Nottingham in 1994 called "Issues in Agricultural Bioethics" as an important event within agricultural ethics because it established a wider vision for the future of agricultural bioethics, focusing on different topics within agriculture, in particular biotechnology (Mepham et al., 1995). Thompson (2014) states: "Agricultural ethics was to be an integration of biological science and inquiry into the underlying values implicit in such key food system concepts as food safety, food security, profitable." (p.5).

However the wide range of topics discussed at the conference in 1994 has narrowed in the intervening time and agricultural ethics has failed to materialise as a distinct discipline (Thompson, 2013b). Zimdahl (2000) maintains agricultural ethics has not been successfully institutionalised within agriculture departments in the same way that medical bioethics has been institutionalised in medical departments due to factors including the failure to recognise the importance of agricultural ethics on the part of those who prioritise university funding; the belief by those involved in agriculture that agricultural research is a morally unproblematic endeavour because it deals with the ethically sound task of feeding the world; the felt need of agricultural scientists to defend themselves against what they might feel is an unjustified attack; and a reluctance to engage in reflection that might raise more questions than it could answer. Other disciplines such as sociology, economics, geography and anthropology have also stepped in to research issues within agriculture. Thompson also makes the point that agricultural and food ethics have taken off within various social movements that challenge industrial agriculture and raise objections to the many controversies that have dogged agriculture in recent years, as we saw in chapter 3.

Agricultural ethics currently has at least two academic journals: Agriculture and Human Values and Journal of Agricultural and Environmental Ethics. These deal with topics such as agricultural biotechnology (Zwart, 2009), animal ethics (Anthony, 2010), the ethics of meat eating and other consumption choices (Nordgren, 2011), energy production (Graffy, 2011) and the structure of agriculture (Hardeman & Jochemsen, 2011). We will deal with the positioning of this project within these disciplines in the next section.

Summary

STS and bioethics both study the social and ethical implications of science and technology. STS broadly comes from a constructionist tradition in the social sciences that began by focusing on how scientific knowledge was produced. One of its initial aims was to show how science and technology are not a-social and a-contextual but rather are co-produced by the policy and social context they emerge from. It has developed different theories and approaches to carry out this aim of exploring the co-production of science and society. Bioethics applies classical ethical theories and principles to the study of the biological sciences and technology. Within this discipline, agriculture ethics focuses on agricultural science and technology, though it has not taken off and created a niche for itself to the same extent that fields like medical ethics have. Nevertheless it is a growing area of research. Both disciplines struggle in different ways with the integration of empirical research and the business of making normative claims or influencing policy decision making. Both debates touch on the relativism/realism debate and how descriptive and normative claims should be dealt with. The position of this project within these disciplines is discussed below.

4.3 Disciplinary positioning

This project draws on the field of bioethics and theorising of agriculture as well as being influenced by certain STS theories. The project drew on an STS orientation to scientific controversies, in the way the subject matter of the project was considered, how research questions were drawn up and analysis carried out. The project adopted the idea that science and technologies are not neutral, a-social entities but are influenced by the setting they are produced within, and in turn change the social world they inhabit. Ideas that problematise the widely recognised link between scientific progress and progress in society were helpful in thinking about biomass in energy production. The previous controversies surrounding biofuels outlined in chapter 2 are an example of the unintended consequences of technological development and the negative impacts a “progressive” technology can have. Scott's (2011) critique of technological fixes that frame societal problems as technological problems was helpful in considering how the problems biofuels address are framed as technological problems and the issues this gave rise to. Ideas from Beck, Giddens (1999), Perrow and Funtowicz and Ravetz about the complexity of technological systems, their far reaching consequences and the difficulty of predicting and controlling such consequences, were also instructive for considering the food versus fuel issue and environmental controversies such as ILUC. Ideas about the social and political shaping of technologies lead to a better understanding of the fact that different types of biomass production were not value free technologies but were influenced by the political and social systems they were developed within, as would be the case for crop residues and perennial energy crops. Theories of expectations also contributed to the rationale for the project which focuses on feedstocks not widely in use in the UK and Denmark currently, with the exception of straw use in Denmark. Stakeholders' expectations will have a bearing on the future course of these technologies as expectations mobilise the future into the present, and were also worthwhile to study for their own sake to tell us something about current values and assumptions within the bioenergy sector. The theory of co-production was also very instructive for thinking about how systems of perennial energy crop and crop residue production and use would develop (Jasanoff 2004). They would be shaped both by the characteristics of feedstocks themselves and the structures they were used within.

Literature on the use of scientific evidence in disputes about science was also instructive for this project (Sarewitz, 2004). The idea that more information did not necessarily resolve problems contributed to the approach taken in chapters 6 and 7 exploring the meanings of "marginal land" for biomass production in the UK and Denmark. Here documents estimating the various amounts of marginal land and the views of stakeholders were analysed. Differences in the documents were traced to different assumptions and values related to marginal land use. This shows how the different estimates of the amount of "marginal land" available are not directly comparable, meaning it is important to reflect on how the information was produced rather than call for more information to be produced to resolve the apparent dispute. The idea of investigating the assumptions and values embedded within scientific language will be explicated in more detail below in the section on frame analysis.

The project was also influenced by the aims of bioethics with its explicitly normative orientation of helping shed light on thorny ethical problems and Walker's (1993) term "architects of moral space". The goal of this project was seen in this way and indeed, it was explained in these terms to interviewees, that the project aimed to create a figurative space for dialogue between different perspectives on a controversial issue. In this way the main aim of the project was to examine the framing of claims about perennial energy crops in order to deconstruct them in terms of their underlying assumptions and surrounding context. This deconstruction process, which is seen to be compatible with both the aims of STS and bioethics, does however automatically involve reconstruction, as the stories told about the claims and framings are retold in a different story that will hopefully shed more light on the area.

An exposition of agricultural ethics is important for this project as it focuses on the goals of agriculture and desired types of agricultural practices, which Thompson (2013b) states was the aim of agricultural ethics as it was seen in 1994. The project does not use classical ethical theories and principles to do this, but rather paradigms of agriculture which involve implicit and explicit normative assumptions which were highlighted in the previous chapter and will be scrutinised in the proceeding chapters in relation to biomass.

4.4 Qualitative research methodology

The analysis in this project is based on qualitative interview and document data. Before explaining how this data was collected and used this section will reflect on certain methodological issues within qualitative research.

Qualitative research refers to research practices that do not involve counting data. These include ethnography, interviews, focus groups and document analysis. Qualitative research emerged from the discipline of anthropology and gained greater popularity from the 1960s onwards due in part to a growing disillusionment about the scientific method and the perceived need for a different approach to studying the social world (Bryman, 1988). Many maintain that qualitative and quantitative research have different philosophical underpinnings. Hammersley (1992) sees quantitative analysis as being grounded in realism: the belief that there is an objective, independently existing shared world out there for people to experience and which can be accessed through research. Thus valid research findings could be said to be an accurate description of the external world. He states qualitative research is widely seen as being rooted in idealism: the belief that there is no one objective reality, but rather what exists is each person's own experience of the world. Valid research explores different people's subjective realities but cannot be said to come to objective knowledge about *the world.* Bryman (1988) states that the fundamental characteristic of qualitative research is a commitment to view events from the perspective of those being studied, and the context is included to get a holistic understanding.

The constructionist or idealist roots of qualitative research raise questions about the status of the data and findings, as they did for STS above. If one can only access a single perspective about the world then how can one make claims about the data? How can one assess the validity of the findings if one cannot compare to an externally existing world? Silverman (1997) calls this situation "methodological anarchy" and states that it offers "a clearly negative message to research-funding agencies; namely, don't fund qualitative research because even its proponents have given up claims to validity" (p.19). Dingwall (1997) divides responses to this issue into "externalist" and "internalist" accounts of the interview process. Externalists contend that interviews can be treated as accounts of some external reality, like the realist position. Silverman (1997) for instance states that qualitative research *does* attempt to be objective and find out knowledge about the world, and test hypotheses. Thus this view does not see quantitative and qualitative research as completely incompatible from a philosophical point of view, both can adopt realist positions and be used to answer different sorts of research questions. Internalists maintain that interviews do provide interesting data but that it is very much a product of the research encounter. Dingwall (1997) states "Put in simpler terms, some constructionists, like Miller and Glassner, are not sure whether interviews are purely local events or express underlying external realities." (p.111).

We will not delve into an in depth theoretical discussion of these different positions here, or seek to pin this project to a specific and complex metaphysical position. Suffice it to note that it will be asserted in this project that the findings can tell us something about an externally existing world.

We can now ask what kinds of questions this research project is attempting to answer and what is the status of the claims it will make? What would validity mean in the context of this project and to what extent would it seek to generalise findings? Payne and Williams state that to generalise "is to claim that what is the case in one place or time, will be so elsewhere or in another time." (2005 p.296). Some social scientists, such as Denzin & Lincoln (1998), contend that the findings of qualitative research cannot be generalised in the way that findings from quantitative research can because there is a fundamental difference between the two approaches. Because qualitative research is concerned with the meanings people bring to the world, and meanings cannot be investigated using the same causal framework as quantitative research, the findings of one qualitative research cannot be readily generalised to another place or time. Others, such as Murphy and Dingwall (2003) state that the issue of generalisation is a practical rather than a conceptual problem, and there is no reason why qualitative data cannot be generalised in the same way as quantitative. If "thick description" of the sending and receiving contexts is given then the generalisability of findings from one context to another can be assessed. Bryman (2001) states that interview sampling must be carried out with generalisation in mind.

This project seeks to explore the views of key stakeholders about ethical and social issues raised by biomass production for energy. The aim was not to get a representative sample[8] of views from a particular sector so that generalisations could be made from the views of one UK NGO employee to “NGO views” more generally, but to access a wide range of views, opinions and perspectives from within the debate. The data will not be analysed in terms of different categories of data: NGO, government etc, but rather in terms of the meaning and importance of different arguments made and concepts used by interviewees. The purpose of the project is to contribute to the debate about biomass controversies, and so it does aim to ensure that the documents and interviews analysed are relevant to the debate. This is done by choosing “important” documents and “key” stakeholders. More details of these ideas and the sampling process will be given below in the research process section. The research can be considered valid if it accurately describes and gives insights into the current debate in the UK and Denmark. Although this formulation appears by necessity somewhat ambiguous, as Silverman (1997) states “The quality of qualitative research, it is argued: ‘cannot be determined by following prescribed formulas. Rather quality lies in the power of its language to display a picture of the world in which we discover something about ourselves and our common humanity’ (Buchanan 1992: 133)”. (p.19). Williams (2000) uses the term *moderatum* generalisation which he states is an intermediate type of generalisation that takes a position between the views that generalisation in qualitative research must meet the same criteria as quantitative research and the idea that qualitative research by its nature cannot be generalised. Williams (2000) states that interpretative research which investigates the meanings people give to events cannot usually meet the criteria of statistical or theoretical generalisation.[9] According to Payne and Williams (2005) *moderatum* generalisations “resemble the modest, pragmatic generalizations drawn from personal experience which, by bringing a semblance of order and consistency to social interaction, make everyday life possible.” (p.2).

Qualitative interviews were chosen in this project because as Murphy and Dingwall (2003) state it is “an opportunity to explore how informants themselves define the experiences and practices that are the object of the research.” (p.82). The aim of the project was not to define the ethical issues to be

[8] Bryman (2001) defines a representative sample as “a sample that reflects the population accurately so that it is a microcosm of the population” (p.85).

[9] Theoretical generalisations make claims about the general based on the particular by assuming that there is a law underlying the observed phenomena. Unlike empirical generalisation it does not involve a generalisation to a finite, specified population, but rather to an indefinite number of instances (Seale 1999). Hammersley (1992) states that it is difficult to justify the theoretical underpinnings of this type of generalisation and is it not widely used in qualitative research.

investigated but rather to allow participants to define these. Semi-structured interviews were chosen. These involve a set list of questions with leeway to follow particular lines of investigation in the dialogue with the interviewee as the researcher sees fit. A practical concern relating to the status of interviews and the meaning of validity relates to the extent to which interview data can be seen as a "true" expression of interviewees' "beliefs". This project will adopt the perspective of Dingwall (1997) that interviews provide "accounts", that is interviewees seek to provide an account of themselves as rational, moral agents in the role that the interviewee puts them in. He states:

> The consequence is that the data produced by interviews are social constructs, created by the self-presentation of the respondent and whatever interactional cues have been given off by the interviewer about the acceptability or otherwise of the accounts being presented. (p.113).

The constructed nature of interviews, in the sense that interviewees seek to give accounts of themselves as moral agents, need not be considered a limitation in the context of this project however, because it is concerned with the frames interviewees use to paint their view of biomass production as legitimate and moral. As Dingwall states: "However, work like that of Baruch (1981), Moore (1974) and Voysey (1975) illustrates how interviews can be analysed for what they can say about the kind of accounts that are treated as legitimate in a particular setting." (1997, p.114). We will deal with the influence of the interview process on the interview data in the section below.

4.5 Methods

This section presents the type of analysis used in the project. Frame analysis was used to understand the data. This is seen as a way of approaching the data, within this thematic analysis was used during the data analysis, which will be discussed in the next section. To elucidate the terminology further: in this project themes are considered to be particular areas or subjects, such as marginal land or the bioeconomy, and frames are how these themes are represented, such as marginal land overcoming controversies. The chapters in the thesis are mainly organised thematically and within those the frames are examined.[10] The project also involves combining analysis from two national settings; UK and Denmark, and the use of two types of data; interviews and document analysis. The combination of these types of data will be discussed below, before exploring how the project was carried out.

Frame analysis

The term frame was first introduced into the study of communicative interaction in 1952 by Gregory Bateson (Oliver & Johnston, 2000). It was used to describe how interactions are understood by

[10] Chapter 5 involves many themes.

participants in dialogue with the help of interpretative frameworks. The term frame analysis was introduced into sociology by Goffman (1974) as an aid to understanding social reality. He uses the word frame to refer to the basic elements of experience. "My phrase frame analysis is a slogan to refer to the examination in these terms of the organization of experience." (p.11). Another influential exposition of frames was Entman (1993). In his view a frame is a lens through which we look at the world. Frames orient our attention to particular aspects of reality and leave out others. According to Entman frames diagnose a problem, suggest causal explanations, make moral judgements and suggest remedies. Frames are dynamic and the framing of a particular technology can change over time (Benford, 1997). As we saw in chapter 2, biofuels were originally widely framed as environmentally beneficial and later as environmentally damaging.

Frames are about power (Entman, 1993). Entman states: "The frame in a news text is really the imprint of power - it registers the identity of actors or interests that competed to dominate the text." (1993, p.55). If one does not use the dominant frame then one’s voice risks being marginalised and seen as lacking credibility (Entman 1993). Elliot (2009) highlights the importance of framing and the rationale for investigating the use of frames when he states:

> The choice of scientific categories and terms can have at least four ethically significant effects: influencing the future course of scientific research; altering public awareness or attention to environmental phenomena; affecting the attitudes or behaviour of key decision makers; and changing the burdens of proof required for taking action in response to environmental concerns. (p.157).

Larson (2011) links frames to underlying values and assumptions: "Frames are cognitive structures that ‘organise central ideas defining a controversy to resonate with core values and assumptions.’" (p.16). Thus the frames people use are generally in tune with their values and assumptions. Mariola (2005) describes a similar relationship between language and values, analysing the underlying ethical frameworks used in debates about agricultural preservation through the use of discourse.

There have been various criticisms of frame analysis. Firstly, some state that the term “frame” is sometimes not adequately explained and is used unreflexively (Benford, 1997). Some point to two different meanings of the term: it can mean a static grammatical term that conveys the relationship between two variables, or it can mean a malleable, emergent concept that applies to a particular context (Benford, 1997). In this study “frame” will be used in the latter sense of a malleable way of understanding a particular context. Benford (1997) states that most frame analysis is descriptive and seeks to take a static snapshot of a context rather than explore the dynamics of frames and how they emerge, evolve and gain prominence. This project will consist mainly of this type of static analysis, with analysis of the assumptions and theories underpinning frames, as described above, and at times it will consider how frames have changed over time. This approach is considered to be legitimate as exploring frame dynamics would be a different kind of project. Another shortcoming of frame analysis is the tendency of the researcher to reify frames. Benford (1997) states: "By reification, I refer to the process of talking about socially constructed ideas as though they are *real,* as though they exist independent of the collective interpretations and constructions of the actors involved." (p.147). This criticism is born in mind for the analysis that follows and efforts are made to make it clear that the exposition of frames in the data involves an act of interpretation on the part of the researcher to weave a story from the data in order to contribute to understanding the bioenergy debate, rather than the identification of independently existing frames “out there”. A final criticism comes from Oliver & Johnston (2000) on the use of the “frame” in the study of social movements. They state that the term has been used interchangeably with the term “ideology”, which is a different concept. They state that ideology is a wider concept that involves beliefs and so using “frame” to mean ideology takes away the potential to use the concept in addition to frame analysis. This analysis appears consistent with how “frame” is being used in this project. The values and assumptions underlying frames can be investigated, as described below in relation to Larson (2009) and Mariola (2005), but these are not synonymous with the frame itself.

Metaphor analysis is used to a limited extent in this project. It is similar to frame analysis in that it highlights how our experience is structured through language. Lakoff and Johnson (1980) conduct a thorough and far reaching analysis of how metaphors structure our everyday life. They state: “The essence of metaphor is experiencing one thing in terms of another.” (1980 p.5) They argue that metaphors not only structure the way we describe things, but actually underlie our conceptual system: we experience the world in terms of metaphors. They analyse different categories of metaphors, for example, spatial metaphors that structure how we describe, and they argue, even experience emotion. For instance, positive emotions are described in terms of the “up” direction and negative emotions in terms of “down”. As in the case of frame analysis more broadly, metaphors highlight certain aspects of a phenomenon and ignore others. For instance, if the metaphor of a battle is used to describe an argument this ignores the way in which arguments involve consensus seeking.

Previous examples of work exploring the framing of issues within the field of agriculture and the environment include Elliot (2009) who considers how values and assumptions are embedded in the choice of language in scientific research on environmental pollution. Braiser (2002) conducts a method called “depth hermeneutics” to consider how agricultural interest groups used linguistic strategies to advocate certain policy positions or bolster their own political position around the formation of the Federal Agricultural Improvement Reform Act 1996 in the USA. Larson (2011) considers scientific metaphors that are used to speak about the natural world. He explores their implications for sustainability and suggests that we could formulate metaphors for the natural world with values more rooted in sustainability. He states: "By framing our relationship to an abstract entity in a specific way, such a metaphor contributes to a particular way of being and acting in the world." (p.16). Cacciatore et al. (2012) demonstrate how the framing of issues surrounding biofuels can influence how the public perceive them: the public respond differently to questions about biofuels depending on whether they are called “ethanol” or “biofuels”. Krimsky (1995) considers the myths that frame agricultural biotechnology and the power struggles over images of modern biology. He defines a myth as “a cultural story that embodies hope, expectations, moral attitudes, fears or positive visions of modernity.” (p.3). He considers how nature has been mythologised as something to be overcome or rationalised within agriculture. MacMillan and Dowler (2012) explore the framing of “food security” in a UK policy context, considering the term’s rise to prominence and the changing priorities within it. Mariola (2005) considers discourses used in debates about farmland preservation in the USA and attempts to conceptualise the ethical frameworks underpinning both sides in the debate. He finds that discourses relating to economic utilitarianism are widely used by both sides at the expense of discourses of agrarian values. Jay (2007) considers how environmental sustainability is framed within the dairy sector in New Zealand. She shows how environmental management is framed in such a way as to make it compatible with internationally competitive, industrial agriculture and considers the possibility of incorporating non-material values into environmental management. Nerlich (2007) explores how metaphors were used in the media to describe the modelling of the foot and mouth epidemic. She traces the change in metaphors used, from having positive to negative connotations, as the epidemic progressed. These examples show how frame analysis can be used to shed light on environmental and agricultural issues.

In order to explore frames data was analysed using thematic analysis. Thematic analysis is the most commonly used form of qualitative research analysis (Roulston, 2001). It draws out common themes used in the data (Bryman, 2001). This was done in order to explore the way issues were framed, as described above. Metaphor analysis was used at specific points in the document analysis, where it was considered appropriate and important for the research outcomes.

This project will use frame analysis in a similar way to that described by Larson (2011): to explore how stakeholders structure issues within debates on bioenergy and the assumptions that underpin these. The method of frame analysis relates to the aims of the project to create a space for discussion of moral issues (Walker, 1993), and to shed light on scientific controversies by considering how different uses of language can be at cross purposes and muddy debates (Sarewitz, 2004). Elliot (2009) highlights how this can be done through frame analysis. "In other words, philosophers can highlight issues (such as linguistic judgments discussed in this paper) that merit deeper societal discussion and facilitate needed deliberation about them." (p.170). The job of the researcher, or philosopher as Elliot calls her, is to facilitate or start a discussion by bringing implicit or previously ignored aspects of a debate to light, through in-depth analysis.

Combining analysis from the UK and Denmark

The project involves two sets of data: interviews and document, two countries: the UK and Denmark and two feedstocks: perennial energy crops and crop residues. The aim is not to compare these different features but to combine them to help elucidate the framings and assumptions in the debate. The project did not aim to get a representative sample of documents or interviewees in the bioenergy sectors in both countries so making generalisations from the data to the views in the country as a whole is not entirely legitimate. Instead, the aim is to use the data in combination to tell us something new and interesting about the wider debate, as explicated above.

Combining interview and document analysis

The method of interview and document analysis raises questions about how the two sets of data will be dealt with. The initial rationale for using these two methods was that document analysis would involve an initial exploration of the ethical and social issues which interviews could build on. Interviews are more flexible than document analysis as particular people can be targeted for interviews, particular questions can be asked to elucidate uncertainties in the documents and to inquire about things not covered in documents. Some document authors were approached for interview with that purpose in mind.

The documents were analysed prior to the interviews and so at an earlier stage of the project. As a result, and because of different subject matter in both, some different themes and frames were identified in documents and interviews, though similar themes and frames were also identified. This raises questions about how to discuss the analysis: should document data and interview data be treated in a similar way and presented alongside each other? From a methodological point of view both data sets were approached in the same way: as a text representing an account put forward by an individual or group working within the bioenergy sector. While more constructionist positions within qualitative research point out that the interview is to a greater or lesser degree a product of that encounter, a similar point could be made about a document, which is a product of the institutional setting it was created within. Both were considered not just as self-referential entities but as texts that articulated the individual or organisations' position on bioenergy.

As in the case of the comparison of UK and Danish data, documents and interviews were analysed not with the main objective of looking for similarities and differences between them, but in order to better understand the framing of perennial energy crops and crop residues and the assumptions embedded within these. Thus at times, when it adds to the analysis, data from both will be presented together, and they may be treated separately when it is appropriate. An exhaustive analysis of where they are similar and different is not the main objective of the project as such and would not necessarily contribute to the actual project objectives.

4.6 Research process

Document analysis

The documents for this analysis were chosen over a period of a year and three months. Documents consisted of academic articles, government, NGO reports and grey literature. The aim of the selection process was to identify documents that may be considered influential and important in debates about land use for bioenergy production in the UK and Denmark. Industry documents were originally included in the search, from the main energy providers and suppliers, and organisations representing the biomass industry, but a difficulty in obtaining suitable and comparable documents between countries meant that these were not included in the final list of documents selected. Documents were chosen if they came from prominent organisations or individuals involved in the bioenergy sector, and/or were published in peer reviewed journals. In order to answer the research questions, documents that discuss land use and production methods for perennial energy crops and crop residues were chosen. Documents were identified through keyword searches in journal databases, through citations in other documents, through browsing websites and through references to documents obtained at conferences.

Academic and consultancy documents that estimate the potential biomass resource available from perennial energy crops and crop residues for energy production in the UK and Denmark were chosen. The focus of the documents was restricted to production in the UK and Denmark in order to limit the scope of the study and keep the research manageable, and because the aims of the project relate to domestic production and use of perennial energy crops and crop residues. Government documents that express aspects of each government's strategy on bioenergy and significant reports about bioenergy commissioned by the government were picked. Documents by influential campaigning NGOs in the UK who have been outspoken on the biofuels issue were sought and influential reports by groups such as the Centre for Alternative Technology (CAT), Nuffield Council on Bioethics and Royal Society.

In total 118 documents were originally amassed, which were searched for the terms "land" in English and "*jord**" or "*areal**" in Danish. The word land, and its Danish translation, was picked because this was a word that was used in connection with the production of perennial energy crops and crop residues, and so could be used to roughly gauge the relevance of the document to the focus of the project. The number of references to "land", and the Danish equivalent, in each document was recorded and the document was reviewed to see if the types of land that should be used for energy crop production and production methods were discussed in depth. Documents were also searched for the term "marginal land", and documents referring to this were also retained, because it became a significant focus of the project. Based on this selection process the documents were narrowed down to 35 UK documents and 24 Danish documents. These documents are listed in the appendixes 1 and 2.

Interviews

Interviewees were chosen from NGOs, government, academia and industry. Purposive sampling was used and the aim of interviewee selection was to speak to people from a variety of backgrounds that might hold differing views and were active and influential in the bioenergy sector.

Lists of people involved in the bioenergy sector were kept throughout the scoping and planning stages of the PhD and tables were drawn up with potential interviewees, their anticipated perspective on different issues related to bioenergy and the reason for interviewing them. In this way the initial list was narrowed down to a more manageable number of 23 interviewees: 11 in the UK and 12 in Denmark. The University of Nottingham's ethical procedure was followed and permission was sought from the relevant department prior to conducting interviews (from the Research Ethics Committee (NSSP-REC), July 2012). This involved consideration of such issues as ensuring interviewee anonymity and interview data storage, and any negative impacts the interview process could have on interviewees. Interviewees were sent an email with an outline of the research project and an invitation to take part. This was sent by the PhD researcher in the UK and by the lead supervisor in Denmark. Research questions were formulated to build on the document analysis, as described above. The majority of the interviews were carried out in person, involving a fieldwork trip to Denmark. Four of the UK interviews were conducted over Skype. It was anticipated that this might raise problems in terms of technical difficulties or difficulties building rapport compared to face to face interviews, but these problems were not encountered. All of the Danish interviews were conducted in English, as all Danish interviewees were fluent in English. No significant communication problems were encountered in these interviews. Interviews took approximately 1 hour.

In terms of interview dynamics, the main consideration prior to the interviews was that interviewees would be relaxed so that they would feel comfortable to discuss the topic openly, that they would understand that the researcher had no particular bias or goal of proving any particular points in the research, and that the role of the researcher was not to make “judgments” about the ethics of producing bioenergy, but rather to look at how these issues are framed. The research aims were generally explained terms of the above idea of moral architecture and creating a space for discussion of the difficult issues. Bondi (2003) discusses issues of positionality and power in interviews and states that empathy as “a process in which one person imaginatively enters into the experiential world of another" (p.72) is useful to help break down barriers between interviewee and interviewer and ensure that the interview is carried out in a way that does not damage either party. I was initially interested in this idea because as outlined in the background section this is a very controversial area and I would be interviewing people with diametrically opposed views and asking sensitive questions. One of my interview questions was about whether it is acceptable to use any land for perennial energy crop production. This was difficult to ask of interviewees who themselves *grow* perennial energy crops. During the interview process however I was in practice more wary of the idea of empathy as I did not want to openly empathise with interviewees to any significant extent in case I expressed this as agreement with their position, as I wanted to maintain a critical distance from what was being said and feel free to critique it in the analysis without feeling in any way “hypocritical”. I tried to remain neutral in my reactions to their views.

In the actual interview encounters I did not initially feel in a position of “power” as I was younger than all the interviewees, was less senior and the majority of interviewees were male. As the interview proceeded however I was sometimes surprised at the eagerness of some interviewees to paint themselves as rationale, morale agents, as described by Dingwall (1997) and the relative power this gives the interviewer as somebody whose role it is to reflect on the ethical dimension of the subject. I was also surprised at the strength of emotion revealed by some interviewees: frustration at current government policy by some working in government, a feeling of being victimised and misunderstood by some working in industry, feelings of disillusionment after the initial promises of bioenergy production revealed problems and controversies, and feelings of fear, anger and frustration at government and industry expressed by NGOs. Some interviewees expressed a feeling of relief or gratitude for having “gotten something off their chest” or confronted their own misgivings about an industry that pays their wages and in which they are deeply embedded, confirming Bondi's point (2003) that the interview process can have effects that interviewees experience as beneficial and therapeutic. There were no significant challenges or breakdowns of trust or rapport during interviews, with interviewees engaged and willing to talk to a greater or lesser degree.

Data analysis

As described above thematic and some metaphor analysis were used to analyse data. Metaphor analysis was only used where there was confidence about the accuracy of the Danish translation. The metaphors identified were widely used across UK and Danish documents, justifying the choice of the analysis.

Documents in Danish required translation into English. Documents in Danish were copied and pasted, one page a time, into Google translate. The English translation was then copied into a new document and these documents were then analysed. While this is not the ideal way to analyse the documents, it was considered better than leaving out any documents in Danish or getting the documents translated by a professional translator, which would be too costly. Google Translate is a machine translation (MT) programme that can translate different language pairs using a computer programme. It was chosen because of the ease of use and because of recommendations that it was one of the most accurate MT techniques available (Aiken et al., 2009). Previous online translation programmes used a rule based approach that effectively "taught" the computer programme the language. Google Translate on the other hand works through statistical modelling techniques of language (Google translate, 2013). Millions of texts previously translated by humans are inputted into Google Translate and based on these the computer programme finds patterns across translations and produces a statistical model of the language pairs that can be used to translate new texts (Aikens et al., 2009). Thus large amounts of text translated by Google translate can be of a high quality and can read as though they were translated by a human translator. Aiken & Balan (2011) conducted a study of the accuracy of Google Translate for over 2500 language pairs. They inputted six sentences into the programme and measured the accuracy of translations using a test called the Bilingual Language Understudy (BLEU) which is supposed to mimic human judgment of how understandable a text is. The score ranges from 0 – not understandable, to 100 – easy to understand. They then checked a sample of these translations and BLEU scores with human readers. The average of the Danish to English and English to Danish translation pairs ranked fourth out of 1275 translation pairs, with a score of 88.5. This suggests that translations are in general understandable. That resonates with the experience of using Google Translate in this project, where translations were in general understandable. There were occasions when the translation was difficult to understand, to a greater or lesser degree. In these cases the text in Danish was sent to supervisors in Denmark to obtain a more accurate translation. Work that involved analysis of documents originally in Danish, such as that in chapters 5 and 7 was undertaken working closely with Danish supervisors to ensure the accuracy of findings.

The documents were analysed using the table shown in appendix 3. The documents were read in detail and the questions in the column on the left hand side were answered and general comments about land use and agriculture were put in the columns to the right. One table was completed per document and the results were synthesized into a table for each group, such as UK government documents. The main themes that emerged from these were then expanded on. These form the basis of the findings in chapter 5.

The interview data was transcribed using Microsoft Word. Notes were made about the data during this process. The transcriptions were then uploaded into the qualitative data analysis software programme Nvivo. This was chosen because the interface is easy to use and it makes the coding process more manageable: one can easily switch between codes and transcripts and write notes about different codes. The data was coded into particular themes or "nodes" as they are called in Nvivo with levels of sub-themes within these. Detailed notes were written summarising the data from many of the nodes and some of these were taken forward and investigated in more detail to be written about in more detail in the thesis. There were concerns that use of data analysis software could fragment the data and decontextualise it. This was not found to be the case in practice however as one can easily view the section of coded data within the original transcript and consider the context in which it was said. The interviewees were assigned initials based on the country, sector they were in and a number. Industry employee were given the initial I, academic employees A, growers G and government employees Gov. For instance a UK NGO employee would be UKNGO1, and a Danish industry employee would be DI1.

4.7 Conclusion

Drawing on a number of disciplinary approaches and underlying theoretical frameworks, the project crystallised more around the subject matter, methods and aims rather than a particular theory or set of theories, whether STS or bioethics, that would be applied to the data. The aims were to examine the discussion of controversial ethical issues around biomass for energy and deconstruct the language used through frame analysis in order to clarify underlying assumptions. This analysis is then reconstructed into an alternative account of the controversy. The theoretical underpinnings of the project are that science and technology are not neutral and a-social, that more evidence does not necessarily help resolve debates because of incompatibilities between different sides of an argument. For this reason it is useful to look closely at how issues are framed to help elucidate underlying values and conflicts. It is worthwhile to consider the expectations about an emerging technology, irrespective of the “merits” or chances of success of that technology, because expectations can tell us something interesting about values and assumptions in the present. The discipline of agricultural ethics informs the project research questions which are framed around agricultural issues.

Qualitative methods of semi-structured interviews and document analysis were used because they were considered the most appropriate for answering the research questions. A somewhat realist position was taken that the data can tell us something about the outside world. The project does not aim to analyse a representative sample of views from the sector and generalise about views from a particular segment, such as NGO views. Rather it seeks to access a range of diverse views and consider the framing of issues in the debate more generally. The different countries, data sources and feedstocks will be drawn on in combination to explore the framings and underlying assumptions.

Chapter 5 Emerging themes

5.1 Introduction

The purpose of the chapter is to begin formulating an answer to the question: How can claims that perennial energy crops and crop residues will or will not overcome previous controversies raised by food crop biofuels be understood? The chapter will also provide the rationale for why certain themes are taken forward in later chapters. The chapter tells the story of perennial crop and crop residue production first as they were framed within an overall productionist agricultural system that created the controversies faced by food crop biofuels. This analysis elaborates on the controversies identified in chapter 2. The chapter will then present a preliminary analysis of how crop residues and perennial energy are framed as developing within the industrial agriculture paradigm and the alternative agriculture paradigm to overcome, or not overcome, these controversies. It will deal with perennial energy crops and crop residues separately because the feedstocks raised different issues and this was seen as the most intuitive way to present the analysis without repetition.

In terms of the preliminary analysis of how perennial energy crops and crop residues are seen as developing within different models of agriculture to overcome previous controversies, the chapter will consider how perennial energy crops are positioned within what will be called “industrialism lite”. Here they are placed at the margins of the industrial system through the use of marginal land and through a contrast with more industrial, intensive meat production. Then perennial energy crops will be analysed as being placed within the industrial life sciences integrated model and within alternative agriculture in the ecologically integrated model. The same will be done with crop residues: issues and challenges with their production will be presented before analysing their proposed place within industrialism lite, life sciences integrated and alternative agriculture. Some criticisms of these different industrial and alternative visions will then be presented. The chapter will alternate between drawing on documents and interviews and discussing the UK and Denmark, as is needed to present the arguments.

5.2 Biofuels problem diagnosis. Biofuels within productionist agriculture

In line with papers listed in the background section which analysed biofuels in terms of problems with industrial agriculture (Thompson, 2008a; Raman and Mohr, 2014), this research analysed perennial energy crops and crop residues as fitting within a pre-existing agricultural system which was organised along industrial and productionist lines.

Land as a physical object and land ≠ place.

In both UK and Danish documents from all sectors the terms "land" and "land use" were reified and the metaphor of land as a physical object that could undergo various transformations was used. This is what Lakoff and Johnson (1980) would call an "ontological metaphor" where something abstract is made into something physical. This can be seen as a useful way of conceptualising domestic and global "land systems" as a single thing. Land or land use are widely, almost universally framed as "under pressure" (Kilpatrick et al. 2008, p.60). Land under cultivation by certain crops can undergo "expansion": Haughton et al. discuss "land expansion under such crops" (2009 p.316). Slade et al. (2010) mention "how much land is released" by a particular development (p.16). This way of framing land use could be seen to distance "land" from its physical manifestation in a particular place. These framings can be understood as broadly within a productionist paradigm, as this involves the disconnection of land from place. In the alternative model land is seen as more situated in a particular place. Jay (2007) makes this link in her analysis of the New Zealand dairy industry. She states that under the industrial agriculture system:

> Land comes to be viewed as a commodity rather than a place of dwelling. Commodification of land as a medium of production means that it tends to be viewed and managed primarily for its commercial value as opposed to non-material values such as cultural or natural heritage, personal or group identity, recreation and enjoyment, or quality of life. (p.268).

This suggests that these documents analysing the amount of land available for perennial energy crop production see land use within an overall industrial agriculture paradigm.

The words "displace" and "displacement" were also widely used in relation to land, usually in the context of one use of land, such as food production, being replaced by another, such as fuel production. "Displace" carries the meaning of the original land use "going elsewhere" and so is often used to discuss indirect land use change, but in some contexts can become somewhat contradictory. This can also be seen in Lovett et al., (2009) when the word "land" stands in for a particular use of land – for food, fuel etc. "Most of the concerns revolve around direct competition with land for food production, the *indirect consequences of land displacement* and the failure of first generation biofuel chains to achieve positive carbon balances and significant GHG reductions." (p.18, my italics). The phrase "land displacement" is an interesting example of the disconnection of land from place, to the extent that when it is taken literally it no longer makes much sense: how can land itself be displaced? It can be seen to illustrate the abstract nature of talk about land and land use. The language of displacement is used to describe the phenomenon of ILUC and automatically assumes land in one part of the world is equivalent to land in any other part of the world. Palmer (2014) and Levidow (2013) come to the same conclusion in their analyses of the concept of ILUC within EU policy making. Palmer (2014) states that the emphasis has been placed almost exclusively on the

GHG emissions consequences of ILUC, where ILUC is seen as an accounting error in the life cycle analysis of biofuels. This framing in terms of ILUC is done to the exclusion of other framings and voices. Levidow (2013) states that the crystallisation of concerns about biofuels around the concept of ILUC in EU policy making ignores the other land use impacts that biofuels give rise to in different places such as terrible working conditions in sugar cane cultivation in Brazil and eutrophication from corn production in the US.

Land use and land use change are negative.

The phrases “land use” and especially “land use change” were seen to have negative connotations in both the UK and Danish documents and interviews. This could be as a result of the food versus fuel and environmental controversies, when land use for biofuels was framed as raising different ethical issues. A report on biofuels written in 2004 by the Royal Commission on Environmental Pollution (RCEP) prior to the height of the biofuels controversy does not frame land use as an ethical problem or mention direct or indirect land use change. Rather it states that “Change need not be undesirable” in reference to landscape change resulting from energy crop production (Royal Commission on Environmental Pollution, 2004 P.18). Documents written after this time generally frame land use as something to be avoided where possible: Christian Aid (2009) state “Land use should be minimised” (p.32). Land is sometimes framed as an environmental impact in its own right. The Renewable Fuels Agency (RFA) state that one of the benefits of second generation biofuels made from crop residues over first generation is that they avoid additional land use (RFA, 2008). Astrup et al., (2011) include a category of “land occupation” among the environmental impacts considered in their life cycle assessment (LCA) of biomass production. This is a measure of the hectares of land used per peta joule of biomass energy production. It is presented as a graph alongside other environmental impacts such as greenhouse gas emissions and eutrophication potential. The Centre for Alternative Technology (2010) have a similar measure of “land intensity” of different agricultural products placed alongside a measure of greenhouse gas emissions. They state that the product’s land intensity is a useful measure of its environmental impacts. The term “land use change” also has negative connotations, which is not surprising given its associations with greenhouse gas emissions and the food versus fuel controversies outlined previously. For instance the Gallagher Review uses the phrase “land use change risks” (RFA, 2008 p.49).

This framing of land use as an environmental impact can be understood in terms of the idea described in chapter 3 that agriculture is seen as an inherently destructive and risky business by those developing policies to tackle the impacts of industrial agriculture, and within environmental ethics (Krzywoszynska, 2012). This framing sees land use for agriculture as necessarily at odds with land use for natural purpose. This can be seen to be particularly true for biofuels, with the land use controversies discussed in chapter 2 in mind. The analysis of land as an environmental impact could help in thinking about claims that perennial energy crops and crop residues will overcome previous biofuels controversies. Even if the use of land for perennial energy crops is not in itself destructive, its knock-on effects on the agricultural system – causing the conversion of natural land for food production – implicate it in the damage caused by industrialised agriculture. This point calls to mind the quotation from Thompson (2008b) to the effect that further biofuels production will continue to suffer bad press: “the fuel-vs.-nature question is vexed because the agriculture-vs.-nature question is vexed” (p.149), and suggests that perennial energy crops are still being seen as within this framework. The analysis will now consider how perennial energy crops and crop residues are framed as overcoming these issues, first within the industrial paradigm and then within the alternative paradigm.

5.3 Perennial energy crops within the industrial paradigm.

5.3.1 Perennial energy crops within “industrialism lite”

This section will now present the analysis of the “industrialism lite strategy” where producing perennial energy crops at the margins of the industrial system is seen as a way to overcome previous controversies raised by food crop biofuels. The framing of land as a scarce resource and pockets of “available” and “suitable” land within this for biomass production paves the way for this strategy.

Land as a scarce resource, available and suitable land

Land was framed as a scarce resource globally and in both countries. Action Aid (2010) state: “But the recent rise in both food and fuel prices has turned land itself – a finite and increasingly pressured resource – into a valuable commodity which investors and speculators are keen to exploit.” (p.21). A Danish government document puts this view nicely that land has been seen in recent years as increasingly under pressure when stating that land is “no longer an inexhaustible resource” (Ministry of Food Agriculture and Fisheries, 2008). This can be seen as the economic view of land within the industrial model; it is a valuable commodity for speculators.

Within this general overarching frame of land scarcity and keeping land use to a minimum, pockets of “suitable” and “available” land for biomass production were identified. This strategy of dealing with the controversies raised by biofuels by targeting biomass production to particular types of land can be seen in a quote from the RFA (2008):

> It is also important that the crops are not supported independently of the land on which they are grown. This is because, outside of an appropriately designed and well enforced regulatory environment, there may be nothing to prevent biofuels producers cultivating such crops on high quality arable land. (p.37).

The Committee on Climate Change (2011) similarly advocate the use of “Land which minimises competition with food production” (2011, p.5).

The meaning of the terms “suitable” and “available” land for biomass production were ambiguous and changed from document to document. Slade et al. (2010) conducted an in depth analysis of the different meanings of these terms in UK documents. Types of land within these categories included idle, unused, free, spare, abandoned, under-used, set aside, degraded, fallow, additional, appropriate, under-utilised and marginal land. The terms were generally based on the physical characteristics of the land and its current or future use. The terms were used in some government, academic and NGO documents to estimate the amount of land that could be used for biomass production. It could mean land that is “free” now: fallow, set aside or otherwise “unused” agricultural land. Or it was negotiated as free in the future pending various market or technological developments that could increase yields and mean that less land was needed for current production. This framing of particular “types” of land for biomass production also appeared in the interviews, as we will see in chapters 6 and 7 on marginal land.

Here claims that perennial energy crops will overcome the controversies caused by biofuels production are based on the idea that they can be targeted to “lesser” or non-prime types of land which are not suitable or ideal for food production, and so will lessen conflicts. This positions perennial energy crops on the margins of the industrial system. Chapters 6 and 7 will interrogate this idea further. How can the claims about using perennial energy crops on marginal land be understood? Marginal land in particular was chosen because it is an especially popular category of land that is promoted for perennial energy crops and because choosing just one type of land allows for a more rigorous analysis. As chapter 6 will explain in more depth this strategy will be called “industrialism lite”. It recognises the ills of the productionist agricultural system and biomass’ place within that and so seeks to minimise biomass’ impacts on this system through land use strategies and production methods that are at the margins of conventional productionism. It is linked to the life sciences integrated perspective through the use of science and technology to make this type of production feasible.

Meat versus fuel

There were some interesting arguments made around the food versus fuel debate, especially in the interviews. It was stated in the chapter 2 that the production of feedstocks for biofuels were seen as conflicting with food production and some claimed perennial energy crops would not conflict with food production because they were non-food crops. This argument was made in documents, but was not the predominant argument made by interviewees. Rather, some interviewees attempted to reposition perennial energy crop production by comparing them to other, more industrial, more damaging types of agricultural production. The food versus fuel argument was reframed as “meat versus fuel”. This was also found in a number of documents such as the UK Centre for Alternative Technology (2010) Zero Carbon Britain report. Within this argument frames of “imports versus domestic production”, “necessity versus luxury” and “environmentally damaging versus environmentally benign production” were used. These arguments were more prevalent in Denmark than the UK. This argument was made by those who would promote either industrial or alternative types of biomass production, e.g. by an employee from an organisation representing conventional farming interests and by an employee from an organic agriculture organisation. The structure of the argument is the same for those in both camps, that perennial energy crops are defensible compared to more industrial types of agriculture, thus positioning them either as alternative agriculture or industrialism lite.

Many reframed the debate in terms of meat, or feed for meat production, versus fuel. There was a direct trade off made between land for meat production and land for energy production, as a Danish NGO employee states.

> DNGO2: […] if we reduce the number of pigs produced then there might be more space for growing energy crops.

Two Danish interviewees distinguished very clearly between food and fodder, stating that fodder for animal production was not “food” as such, thus there was no ethical dilemma if fodder production was displaced by energy production. A Danish NGO employee states:

> DNGO3: But you could say “well if the real production when we produce food is not food it’s fodder, for meat production” and you could say “should we have meat or should we have energy?”

A Danish grower also asked the rhetorical question whether fodder actually counted as “food”. In this context meat was also framed as a luxury and energy as a necessity, meaning that energy should be produced instead of meat. A Danish NGO employee states:

DNGO3: We have food and energy these basic needs for humans, but meat is not a basic need.

Meat is framed as something that we can cut down on easily. A UK grower states:

UKG1: I really think meat needs to be viewed as the luxury it was once it always was a luxury, meat, that's not something we expected twice a day […].

The important issue at stake was also framed as meat production *for export* against energy production for *domestic use,* particularly in Denmark*.* Here production for domestic use was seen as more worthwhile. A Danish grower states:

DG1: The thing is that we are the biggest producer of pig, of pork, of meat in the world. Tiny country of 5 million people. And then we should grow eh willow, if we should be not allowed to produce willow on some land because we're going to export some meat to Japan, forget it. In my eyes it's totally wrong.

The main priority for some Danish interviewees is seen as meeting domestic needs. Similarly some interviewees stated that a better solution to the global food problem would be promoting self sufficiency in developing countries. Some interviewees, particularly in Denmark framed the food crisis as a global problem which Denmark was not responsible for. They stated that Denmark was only a small player on this global market and could not have a large impact making it ethically entitled to look after its own energy and food needs. A Danish government employee states:

DGov1: We can make some contribution to it and there is the ethical but that question goes on a more global scale not a national scale.

The issue was also reframed in environmental terms: the environmental damage caused by feed and meat production was contrasted with environmentally benign or even environmentally beneficial perennial energy crop production by a UK grower. These arguments were especially prevalent in the Danish context where there is a very large pig sector, the majority of which is produced for export, at considerable environmental cost. A Danish agriculture industry employee highlighted the negative press received by the pig industry because of animal welfare issues and pollution.

DI1: Because we have a general idea in the society that production of meat and especially pigs is huge a problem for the environment, it's a problem for the neighbours and so on and so on so I think it would be more and more difficult to get the acceptance of producing more than we do today because people they just every day talk about we're producing 25 million pigs, we're only 5 million persons in Denmark or almost 6, and they're dying, I can't remember the

> figures but there's dying a lot of small piglets every day and they take this numbers and say "there's dying, 10,000 of piglets every day" […].

Meat production was also framed as a very inefficient way to produce food in terms of the energy input and energy output by a UK grower and UK government employee. Here claims that perennial energy crops will help to overcome controversies raised by biofuels production can be understood in terms of a reframing of the debate that attempts to position fuel production as a less industrial use of land than meat production. In comparison with meat production it is seen to have characteristics closer to the alternative model of production: it is for self-sufficiency or local use, it is less environmentally damaging and does not entail the welfare problems of the meat industry, and is a necessity rather than a luxury. This positions energy crop production within "industrialism lite": at the margins of the industrial system for those who support an otherwise industrial paradigm. Or those who promote otherwise alternative systems use the argument to paint biomass as fitting easily within this alternative model and benign compared to industrial meat production.

Some questioned the reasoning behind this meat versus fuel framing however and whether a trade-off would work in practice. A UK NGO employee stated that the logic behind the argument was spurious. The biofuels market is an artificial one driven by government targets and subsidies and this could be easily influenced by the government, whereas the government currently has little or no control over the market for animal products, and it would be very difficult to establish an influence. She reframes the argument, not as the substitution of one product for another but as a spurious argument about the "overconsumption" of meat being used to "justify" biofuels production.

> UKNGO1: So what we're really concerned about is when, y'know when overconsumption of meat is being used as a reason to justify bioenergy expansion.

Thus this repositioning of biomass production outside of the industrial system, or to the margins of the industrial system, is problematised by some.

5.3.2 Perennial energy crops within the life sciences integrated model

Perennial energy crops were also framed as being produced within a life sciences integrated model of agriculture, which as outlined in chapter 3 is seen by many as the way forward for industrial agriculture. It involves tackling the resource scarcity problems and the environmental impacts of industrial agriculture through targeted rather than increased use of inputs and innovation within the biological sciences. It is used in different ways in relation to perennial energy crops as will be seen below.

Increased productivity frees up land.

A very common frame across the UK and Danish documents and interviews was the idea that increased productivity on existing agricultural land could free up land for biomass production. Total land used and land productivity were seen as interchangeable. In economic terms, productivity means the output per unit of a particular input, in this case land (Coelli et al., 2005). So increased land productivity effectively means increased output per unit of land. This would either be through yield increases of annual crops, meaning that they required less land and leaving that land free for perennials, or through yield increases of perennial crops so that they would require less land or could be grown in harsher, less fertile conditions. Booth et al. (2009) state that increased yields "will reduce the area of land required to produce the same quantity of food." (p.29) Lovett et al. (2009) state "anticipated gains in maize yield over the next 10 years could arguably meet the world's growing demand for food, feed, fibre and fuel, with minimal or no expansion of the land area under maize cultivation." (p.18). The Committee on Climate Change (2011) also assume that past yield increases will continue, leading to lower land use, and factor this into their land use modelling. Different though not mutually exclusive ways of increasing productivity were identified within a life sciences integrated model of agriculture. Increasing productivity was also promoted within the alternative agriculture paradigm as we will see below, but was seen as happening in a different way.

The strategies for increasing productivity were placed within the life sciences integrated model rather than productionism because most of them involved increases in productivity through scientific advances, generally from biotechnology, and some are explicitly distanced from the productionism that went before. As noted in chapter 3 the idea of increasing productivity to "feed the world" is an area of overlap between productionism and life sciences integrated agriculture, but the methods for doing this differ somewhat. It should be stressed that there is a significant amount of overlap between the different methods of increasing productivity identified below.

Increased productivity through increased intensification

The method for increasing productivity was often promoted as further intensification of agriculture, within what can be identified as the life sciences integrated model of agriculture, because of the emphasis on yield increases through biological innovation. This method for increasing productivity involves intensification that is largely seen as different to the productionist system that went before because it will not encounter the same environmental problems and will not involve increased use of inputs. Thompson and Otieno Ouko (2008) define intensification as using technology and a different labour structure to produce more in agriculture.

Kilpatrick et al., (2008) state that grassland use should be intensified to free up land and describe extensively used land as "under-utilised". CEESA (2011) advocate agricultural intensification in a paragraph about increased demand on global resources: "Agricultural intensification, i.e. mechanisation, improved nutrient management, improved seed sources and better plant protection, can increase crop as well as residue production of these six crops." (p.38). The RFA (2008) advocate the use of "appropriate intensification" to boost production. (p.39). Interviewees were asked about their view of the concept "sustainable intensification" and several interviewees endorsed the term and framed it in terms of increased productivity, stating that even highly agriculturally developed countries like Denmark and the UK have not reached the limits of their productivity or efficiency.

For some interviewees this could be achieved through better use of technology and targeted rather than increased use of inputs, in line with the life sciences integrated paradigm. As Kilpatrick et al. (2008) state: "Increased biomass productivity for food and fuel will therefore need to be achieved through new technology, improved agronomy, advances in plant breeding and increased utilisation of new crop species such as high yielding perennial non-food crops." (p.14). A UK grower stated that lack of access to GM was holding back yields, efficiency and environmental gains.

> UKG2: […] if we allowed GM crops into Europe we'd be able to grow food a lot more efficiently a lot higher yields, we'd be able to supply a more affordable food and a better quality because it hasn't had the pesticides application due to being GM breeding.

The view was also expressed that the technological optimization of energy crops could make perennial energy crop production profitable and feasible on different types of land (eg. Kilpatrick et al., 2008). Thus the promise of technology was used to negotiate what types of land were "available" and "suitable" for perennial energy crop production. This idea will be revisited in chapter 6 on marginal land. This vision resonates with the description by Levidow et al. (2013) of the life sciences integrated paradigm as "Sustainable intensification via smart inputs from lab knowledge: enhancing external inputs, engineering their compositional qualities and increasing land productivity." (p.98).

Increased productivity through increased efficiency

Efficiency of production is also widely promoted as a means to help overcome resource conflicts. Technical efficiency in production economics refers to the ratio of inputs to outputs in any particular production system given a particular type of technology (Coelli et al., 2005). But the term "efficiency" is often used to refer to a reduction in the ratio of inputs to outputs more generally. Efficiency is linked positively with intensification in the industrial model of agriculture. Turley et al. (2010) see extensive production as inefficient. "However, an examination of stocking rates over time indicates how efficiently livestock is using the available grass resource. Using the same methodology proposed by Kilpatrick et al., (2008), as stock rearing becomes more extensive as animal numbers decline, the grass resource is utilised less efficiently." (p.24).

A Danish industry employee advocates increases in efficiency through technology use and frames it as a natural progression in the development of production.

> DI3: I don't think we have, within almost all technologies and all production we have shown that we can become more and more efficient and we can become… so I think that's only the natural development and will continue […].

These findings accord with the findings of CREPE et al. (2011) and Levidow et al. (2013) that industrial conceptions of agriculture define problems encountered as caused by inefficiency, with the remedy being increased efficiency. Within this framework, problems within agriculture are seen to be caused by: "Inefficient production methods disadvantaging European agro-industry, which falls behind in global market competition for techno-scientific advance." (p.98). This view can be seen in a quote from the Nuffield Council on Bioethics (2011) which sees inefficiency as one of the main causes of the controversies around biofuels:

> At the heart of concerns about some biofuels are claims about their inefficiency and lack of convincing greenhouse gas (GHG) emissions savings, environmental degradation through deforestation, high-input cultivation using large amounts of fertiliser and taking up significant amounts of land, and competition with food production. (p.46).

It is worth noting that efficiency is also promoted by alternative agriculture groups through the concept of eco-efficiency (CREPE, 2011; Levidow et al, 2013). The different meaning of efficiency in the life sciences integrated and alternative agriculture models will be explored in more depth in chapter 8 on multipurpose use of biomass.

Increased productivity through restructuring agriculture

Some interviewees advocated increased production but not through intensification because of environmental regulation, particularly in Denmark.[11] Gylling et al. (2012) state: "There is therefore within the existing framework conditions, relatively few opportunities to increase biomass

[11] Although these different views on the appropriateness of increasing productivity through intensification may not represent actual disagreements about agriculture but rather different interpretations of what intensification is. Those within the life sciences integration model who oppose intensification may see it as within the old productionist model, whereas those who promote intensification within the life sciences integrated model would not.

production by intensifying the current production the increased use of input factors as fertilizers and pesticides." (p.10).[12] Rather they advocate a restructuring of agriculture: "However, there is considerable scope for an increased production of biomass through a restructuring of production systems, choice of crop and variety, and a differentiated land use."[13] They stated that this could lead to a doubling of yields through "smarter farming" methods (p.12). It should be noted that in some cases there may not be a substantial difference between increasing production through intensification and through restructuring agriculture, but rather it may be a question of what terminology is used. And many of the ideas expressed in relation to the restructuring of agriculture have not yet been put into practice and remain theoretical.

As can be seen in the quotation from the above paragraph, part of the restructuring plan involves increasing yields. Restructuring also involves greater efficiency, they state: "[…] there is a high potential for more efficient storage of solar energy into biomass." (p.12).[14] They describe changing the times that plants are grown in order to take greater advantage of the growing season. They state that plants are in the field maturing during July and August and so do not make optimal use of the sunlight. "If the whole of the growing season radiation was used for biomass production it would be theoretically possible to producing more than 30 tonnes of dry matter hectares in Denmark." (p.12)[15]. They also discuss making greater use of C4 plants such as maize and miscanthus that are said to be more efficient in their use of sunlight in photosynthesis than C3 plants. These suggestions are reiterated by several academic interviewees.

> DA2: We have to use as much as possible of the growing season for production. And we don't do that today because the main crops in Denmark are grain crops. Wheat is the largest area, the largest crop in Denmark. And those crops use at least two months of the best season, August and September on doing nothing. They're just there standing ripening on the field getting harvested, getting sown and all that time there's no production. Good radiation from the sun, good temperatures for production. So we have to change that into a crop that grows all the season.

[12] Original text: "Der er derfor indenfor de eksisterende rammevilkår kun relativt få muligheder for at øge biomasseproduktionen gennem en intensivering af den nuværende produktion ved øget anvendelse af indsatsfaktorer som gødning og pesticider."
[13] Orginal text: "Der er derimod betragtelige muligheder for en øget produktion af biomasse gennem en omlægning af produktionssystemerne, valg af afgrøde og sort samt en differentieret arealanvendelse."
[14] Original text: "[…] der er et stort potentiale for mere effektiv lagring af solens energi i biomasse."
[15] Original text: "Hvis hele vækstsæsonens indstråling udnyttes til biomasseproduktion, vil det teoretisk være muligt at producere over 30 tons tørstof pr. hektar I Danmark."

The restructuring of agriculture also involves the production of grass and perennial energy crops for use in energy and to provide environmental services within agriculture, among other measures. Plants are painted as entities that should be further exploited and made to “work harder”; as it is they spend two of the best months “doing nothing”. The discussion of more efficient plants recalls Levidow et al. (2013) describing the problem diagnosis within agriculture from the life sciences model. “More efficient plant-cell factories as biomass sources for diverse industrial products, thus substituting for fossil fuels and expanding available resources.” (p.98) Here efficiency means that plants can use fertiliser, nutrients and water more “efficiently” in growing, and produce more of the desired output per unit of input (Levidow et al., 2013). Levidow et al. (2013) state that in EU bioeconomy documents technological metaphors are used to describe plants, comparing them to computers and cell factories to further naturalise their adaptation for and inclusion in the bioeconomy. This idea of restructuring agriculture, and the inclusion of more “efficient” plants is discussed further in chapter 8 on the multipurpose use of biomass in biorefineries.

Mariola (2005) found a similar narrative in debates about farmland preservation in the US that less land would be needed for agricultural production in future because intensification would free up land. He states: “As is typical of an outlook grounded in neoclassical notions of progress, there is the firm belief in the ability of technology to mitigate the difficulties imposed upon us by natural scarcity.” (p.213). This is similar to arguments about technology made in chapters 3 and 4 that view technological progress as leading to progress in society. It also comes back to the goal of productivist agriculture as being that of producing more food from the same piece of land, as expressed by Jonathan Swift (1962). There were also overlaps at the philosophical level between productionism and the life sciences integrated model. Thompson (1998) states:

> Agricultural producers and those who support them with technology may have been seduced into thinking that, so long as they increased food availability, they were exempt from the constant process of politically negotiating and renegotiating the moral bargain that is at the foundations of the modern democratic state. (p.13).

Increasing productivity to free up land is also a way around confronting the “moral bargain” involved in producing fuel from the land, where moral bargain means the acceptability of using land to produce fuel, undertaken in different ways depending on the feedstock.[16] Under this framing

[16] Thompson uses the term moral bargain to refer to contractual Enlightenment morality which, as he sees it, has at its heart agreement over exposure to risks and consent: “John Locke’s portrayal of the social contract (which serves as the basis for civil authority) stresses the individual’s incentives for relinquishing natural freedoms in exchange for an assurance that one’s life, liberty, and property will not constantly be at risk of usurpation. The social contract is a balance of risk and consent. To the extent that contractual thinking exemplifies Enlightenment morality, the failure to secure consent for the imposition of risk goes against the deepest grain of the modern age.” (p.12).

technology renders biomass production from the land less problematic. That is not to say that strategy is illegitimate, indeed Mariola (2005) states that it is empirically true in the United States: less land has been needed in recent decades for production because of technological improvements. Rather it is worth pointing out that biomass production is framed in these terms, and it is worth considering in more detail what it involves because it can help to understand the kind of agricultural system that perennial energy crops are being positioned within. The dominant way proposed for increasing productivity to free up land was through what can be identified as the life sciences integrated model.

Perennial energy crops within life sciences integrated multipurpose biomass production systems

Multipurpose biomass use was also framed as a way to overcome resource scarcity within the life sciences integrated model. This was proposed at the level of biomass processing by using biomass in a biorefinery for different products such as plastics, chemicals, etc. in the same way that oil is used in oil refineries, which was considered briefly in chapter 2 (Taylor, 2008). This idea can be seen as very much within the life sciences integrated model of biomass use because it is seen as part of the new biotechnology revolution (Lang and Heasman, 2004). This idea is becoming increasingly important, linking biomass use to the concept of the bioeconomy which aims to replace the production of multiple products from fossil fuels in oil refineries with the production of multiple products from biomass in biorefineries. As a Danish industry employee states using biomass in a biorefinery is far preferable to simply burning it:

> DI1: […] the way we're using it [biomass] today because today we're just burning it, it's a very destructive way of using the biomass we need to go more and that's what we are working for in this house we are we will see that the use of biomass will be more intelligent eh it would be more the biorefineries that will find ways of using the biomass for more than one thing.

This promises to be an important area for the future of biomass use and emerged as a significant topic in the data. Thus it will be dealt with at greater length in terms of different paradigms of agriculture in chapter 8 on multipurpose biomass.

5.4 Perennial energy crops within the alternative paradigm

5.4.1 Perennial energy crops within alternative multipurpose biomass systems

There was another model for circumventing the scarcity of land and increasing productivity found in the documents and interviews within the alternative paradigm of agriculture. This is multipurpose land use that involves the production of biomass for energy – instead of growing one crop, animals and crops are produced from the same piece of land, as well as other environmental services. While multipurpose biomass use in the industrial vision above generally involves producing multiple products during the processing stage, this vision involves multiple production at the level of *land use*, though some who support this view may also promote processing into multiple products in a biorefinery. This vision involved many of the features of alternative agriculture discussed in the literature review such as reduced inputs through nutrient cycling, environmental synergies between crops and production of several products on the same piece of land. As the Organic Research Centre (ORC, 2010) state: “This ‘food–fuel–biodiversity’ conflict calls for multifunctional land use which can simultaneously meet the various demands of food and fuel production, environmental and biodiversity protection, in addition to providing the capacity for adaptation or resilience to climate change.” (p.7). Some state that these systems can actually be more productive than intensive agriculture, described above, because they produce more products per piece of land allowing the products to capture more resources than a monoculture (ORC, 2010). This system can involve perennial energy crops and/or crop residues for energy as important elements and so is a different way of understanding claims that they will overcome the previous controversies raised by biofuels than the claims analysed above. The multipurpose use of land and how it resonates with the alternative agriculture model will be discussed at greater length in chapter 8.

5.5 Crop residues

The use of crop residues in energy production was framed as a way to overcome land use controversies as straw and other residues were framed as not requiring the cultivation of additional land in both the UK and Denmark (Lovett et al., 2009; WWF, 2008; CAT, 2010; RFA, 2008). For this reason some advocated the use of residues before other sources of biomass. This was particularly the case in Denmark. A Danish government document states: “The use of land for energy crops should not, however, take place before the possibilities of using residual products for energy purposes have been exhausted.” (Ministry of Environment and Energy, 1996 p.20). Again, the problems with productionism are recognised and crop residues are seen as a desirable energy source because they entail fewer impacts than other types of biomass production, as a UK government employee states:

> UKGov2: […] there’s either this idea that using wood is basically deforestation or food versus fuel, and there’s very little that doesn’t, basically the only stuff that leaves you with then is wastes and maybe residues. I think wastes and residues are pretty safe […].

In this framing crop residues are promoted because they involve the fewest negative impacts and knock-on effects on the land system.

5.5.1 Challenges raised by crop residue use in energy production

This section will outline some of the issues that were commonly framed as challenges for the use of crop residues in energy production, before presenting the proposed ways to address these problems from within the life sciences integrated and ecologically integrated models.

One common challenge presented was competition from different sectors over the use of straw. Crop residues were seen as having competing uses in the animal sector and incorporation into soil to maintain fertility in the documents and interviews (Committee on Climate Change, 2011; Forestry Commission Scotland, 2007). The removal of crop residues was framed as causing negative environmental impacts, on soil health, biodiversity and even human health, if removal led to fewer nutrients in the soil and subsequently fewer nutrients in food (Biofuelwatch et al., 2007).

Some interviewees saw potential conflicts between the agriculture sector and energy sector over the use of straw. In Denmark crop residue use in energy was framed by some as opposed to organic agriculture (Jørgensen et al., 2005). Denmark has a substantial and well established organic sector (Jørgensen, 2007) which makes greater use of crop residues for maintaining soil quality than conventional agriculture because it does not use inorganic fertilisers. One document framed these competing objectives as difficult to reconcile within organic agriculture: “The production of bioenergy from local biological resources and the maintenance of soil fertility seem to have been opposing aims in organic agriculture.” (ICROFS, n.d. p.1). Gylling et al. (2001) similarly see organic agriculture and the bioenergy agenda as opposed to one another, as they assume in their modelling methodology that an increase in area under organic cultivation will lead to a decrease in straw available for the bioenergy sector. One of the aims of the organic sector is to make agriculture self-sufficient in nutrients and energy (Jørgensen, 2007) which results in the greater emphasis on biomass use for on-farm self-sufficiency in Danish documents than the UK (ICROFS, n.d. etc.).

Some interviewees highlighted other difficulties in incorporating straw, an agricultural product, into the energy sector, and the “cultural differences” this would give rise to. Two interviewees highlighted concerns from the industry point of view, stating that straw prices were volatile and supply was not always secure.

> DI2: Well for straw a challenge is the supply reliability we just had we just had a year with a low straw output from the agriculture and some of the decentralised power plants had to look

for other feedstocks to meet the heat, meet the heat demands in particular. So coming back to the investor point of view if you every I dunno three, four, five have a straw production that's suddenly goes to two thirds or less then that's a problem for your fuel or feedstock reliability.

A UK academic framed this same problem from the farmers' point of view, the consistency and longer term contracts required by the energy sector could be detrimental for soil quality:

> UKA1: I can see for a lot of farmers if you probably wouldn't necessarily want to be able to plough in your straw every single year but if you sort of give yourself the opportunity to plough it in some years and sell it others you're probably actually maximising the longer term potential of your land in a better way. So I think you'd be quite a brave person if you said I'm going to sign up to a ten year contract to deliver so many tonnes of straw to the power station every year regardless.

Thus the agricultural sector needs and delivers variation in straw supply each year, which is not entirely compatible with the needs of the energy industry, which requires consistency.

The next section will consider how these challenges are addressed from within life sciences integrated agriculture and ecologically integrated agriculture.

5.5.2 Crop residues industrial within life sciences integrated agriculture

Many within the life sciences integrated model are optimistic about the prospects for overcoming scarcity around biomass using scientific and technological innovation. Within the biorefinery perspective biomass is painted as an abundant and flexible resource that can replace all the functions of fossil fuels in the new bioeconomy, as outlined above. The same is true of crop residue use in the energy sector. This accords with Hansen's (2014) division of perspectives on biofuels in Denmark into "optimistic biorefinery" and "holistic bioscarcity" views, which were introduced in chapter 2. The views of some of those promoting the life sciences integrated model can be seen to overlap with Hansen's category of biorefinery optimists, as they are optimistic for the prospects of using crops residues in energy production, endorse the idea of the biorefinery and promote innovation within the biological sciences to achieve bioenergy goals. A Danish academic states that Denmark has "abundant straw". Another Danish academic maintains that there is potential for using straw from land where soil quality was currently not problematic.

> DA2: But that we allow as much as, that we allow that 85% is used in the rest of the country. Because there soil quality is no problem.

A Danish industry representative states that the restructuring of agriculture as described above can lead to more straw production, helping to overcome the food versus fuel controversy.

> DI3 […] see if we can change that, can we grow different kinds of straw, change the way that we organise our agriculture so that we can actually get more waste, if you say, to use. And also more food. But also waste which can be used through, to energy.

Ideas from within the industrial model of agriculture are also proposed as solutions to other issues with straw. An industry representative suggests crop breeding in order to overcome current technical problems with burning straw.

> DI1: So it's a place where we can eh improve eh the straw quality if we can find new varieties of wheat with lower content of salt.

This resonates with how Levidow et al. (2013) describe agri-energy linkages in the industrial model. "Redesigning plants and processing methods for more efficiently converting biomass into energy and other industrial products." (p.98). The use of crop residues in biorefineries will be explored in chapter 8 on multipurpose biomass use.

5.5.3 Crop residues within alternative ecologically integrated agriculture

This idea of potential conflict between residue use on farms, including crop residue use for soil conditioning within the organic sector, and in power stations resonates with the findings of Krzywoszynska (2012) that farmers' preference for using bio-wastes for on farm nutrient management or energy production can conflict with regulation around waste disposal and institutional structures that favour waste use in high tech, large scale applications in the wine industry in Italy. However an employee of an organic agriculture organisation in Denmark stated that their position had changed and that they were now in favour of straw use under certain conditions.

> DNGO3: I think my organisation originally was against that straw should be burned because straw benefits to soil carbon and soil fertility but it might not be realistic scenario that you can prevent straw from being burned. So what I have tried to say is that we must look at the situation in each field.

He appears to take a pragmatic position; they cannot be against the use of straw in energy in general but instead must look at the specific context.

In relation to competition over the use of crop residues, Hansen's (2014) distinction between the biorefinery optimistic perspective on biofuels in Denmark and the holistic bioscarcity perspective is again relevant. The holistic bioscarcity perspective has much in common with the alternative agriculture view and within this framework competition over crop residues use is framed as a significant problem, regardless of future science and technological innovation. Lang and Heasman (2004) state that the ecologically integrated paradigm involves an emphasis on the finitude of natural resources. Many interviewees were also more pessimistic about the prospects for crop residue use in energy. One interviewee stated that there are already serious soil carbon problems in some parts of Denmark because of removal of straw for the energy sector, and the removal of other nutrients is also problematic.

> DGov1: Because that's [phosphorus] also a limited resource that will run out in a hundred years or so […]. In some areas we are now starting to see carbon deficiencies in fields because it's too much is removed.

For some these conflicts are seen as a reason not to use crop residues in energy (NOAH (Friends of the Earth Denmark), 2010). A UK academic states:

> UKA2: I don't think we should be using crop residues for bioenergy largely because we need them to put back into the soil.

The possibility of removing straw from farms without significant environmental damage was framed as context dependent. The context included the type of crops that were being grown, the type of land, the weather, and other soil management practices. The area was framed as one that involved a lot of uncertainty that was difficult to make generalisations about, or even decisions, because of the degree of this context dependence. A Danish academic frames this area as one subject to a great deal of uncertainty and that should prompt caution in straw use in the energy sector:

> DA1: Yeah the straw it's not known how much straw in fact is needed for the soil to be healthy, for the building the soil fertility. So removing all the straw that seems not to be a good idea.

Some saw the solution to soil fertility problems as being a holistic or systematic approach over a long time period, what could be seen as an alternative view of agriculture. A Danish academic discusses the possibility of perennial energy crops for a period to mitigate the soil carbon impacts of straw removal.

> DA3: […] maybe we should think in centuries instead and therefore with the straws maybe that is not sustainable for centuries but then you could plant something else for 20 years and maybe it could, you should think in very very long term sustainability, not only in rotations or years but in decades.

Other suggest that there is a natural "balance" involved in straw removal and it is a question of finding that balance, a concept which also comes from the alternative paradigm.

> DA1: Yeah the straw it's not known how much straw in fact is needed for the soil to be healthy, for the building the soil fertility. So removing all the straw that seems not to be a good idea. That would be- so one should find a balance there.

In relation to incompatibilities between the energy and agriculture sectors, several Danish interviewees stated that farmers are at a power disadvantage when it comes to the straw market in Denmark because they do not control straw prices and are not adequately compensated and were not organised into cooperatives in their interaction with the energy sector, unlike the food market. A Danish government employee suggests that this may have knock on effects on the environment.

> DGov1: I think it will have the environmental repercussions because the interests for the company will be in a different way. You'll just pass on whatever pressure they have.

One UK interviewee pointed to similar problems for pig farmers in UK. She pointed to government subsidies for biomass use as a contributing factor to industry's relatively greater power.

> UKNGO1: I mean a power station just shores up the supplies and gets all the supply agreements. And they can pay more money because they get the subsidies. Then they really, they actually are really concerned for their livelihoods so there are - I mean in this area certainly they are really concerned about the economic side as well.

This chimes with the alternative view that sees the industrialisation of agriculture as the progressive inclusion of more corporate interests in agriculture, which serves to disenfranchise farmers (Thompson, 1995). Under this view the meeting of the agricultural and energy sectors could further disempower farmers financially and also in terms of the management of their land. As long as the meeting of the energy and agriculture sectors involves contact between farmers and the more powerful energy industry then it will follow the path of the further industrialisation of agriculture. For now the focus will remain on the methods of production of the feedstocks but chapter 9 will return to this theme of the meeting of the energy and agricultural sectors.

5.6 Criticisms of biomass production within the industrial and alternative paradigms

Some question the industrial narrative that increased productivity through intensification will free up land for perennial energy crop production. There was a large amount of anti-industrial, intensive, monocultural agriculture sentiments expressed in the documents by NGOs who campaign for environmental and social issues. Many NGOs also point to the environmental impacts of intensive production. Biofuelwatch et al. (2007) state: "both agricultural intensification and expansion could trigger large-scale, irreversible ecosystem changes and possible collapse, causing irreversible climate feedbacks." (p.9). Action Aid (2010) state that further intensification isn't possible: "The idea that we can increasingly intensify agriculture – ie to get greater biofuel yields from a hectare of land – is continually untenable." (p.37). Biofuelwatch et al. (2007) state that yields are unlikely to increase further because of climate change. As chapter 3 pointed out, the environmental critique of industrial agriculture is one of the important aspects of alternative agriculture (Raffernsperger, 1998).

A UK NGO employee directly questioned the reasoning behind the industrial, productionist approach. The above arguments see increased productivity through industrial means as the optimal use of land. UKNGO2 highlighted the assumptions underlying this view and questioned whether this was the best way to use land, in terms of its long term health.

> UKNGO2: I think underused is sometimes emm a product of the eye of the beholder, the person sees emm a piece of land that they think "well if you put more fertilisers in and you grew more crops and you had more machinery and all the rest of it you can make it, we could stop it being under-used." But it may not be that simple so. It's a complex issue […] you see rotation for example involves fallow periods doesn't it. And some people, some industrial agriculture proponents feel that fallow periods are a waste but actually fallow periods can be essential for regeneration, they need to be part of the crop cycle. […] somebody said they'd been to a big agricultural estate and they had sampled the land at 200 points and they found no earth worms anywhere in that land. So that land is obviously at the very least unwell. It needs care, it needs something, it doesn't just need fertilisers it needs a different method of cultivation in order to recover the health of it. So underused, underused or marginal land requires quite a lot of TLC really to bring it back.

These viewpoints echo criticisms highlighted in the literature review of industrial agriculture. UKNGO2's attitude towards caring for the land rather than seeking to maximise production harks back to Leopold's land ethic (1949) which was one of the cornerstones of alternative agriculture philosophy. Leopold (1949) states "The land ethic simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land." (p.200). UKNGO2's idea that the land can be "unwell" and needs care to recover chimes with the attitude which Leopold sees as necessary for a land ethic: "It is inconceivable to me that an ethical relation to land can exist without love, respect, and admiration for land, and a high regard for its value." (p.223). Leopold's land ethic also involves the idea of limits to what people can do to the land as part of its cultivation. This resonates with UKNGO2's idea that land needs fallow periods to rest and recuperate. Leopold stated that "An ethic ecologically is a limitation on freedom of action in the struggle for existence." (1949 p.200). UKNGO2's statement that land needs more than just fertilisers to recover also recalls the systematic, holistic approach of the ecologically integrated model to land management, which as stated in chapter 3, is an important part of the contemporary alternative agriculture paradigm. There is a contrast between this view and that voiced by DA2 above to the effect that leaving crops "idle" in the field for two months during the summer was wasteful. Under the industrial paradigm crops were represented with technological metaphors that framed them as needing further optimisation. Here fallow periods are painted as essential for regeneration rather than a waste of time and motivated by some sort of respect and care for the land.

Some interviewees reiterated this idea of sustainable intensification ultimately resulting in more pressure on land. A Danish NGO employee expresses a worry that the land is being used to produce too much at the moment with too many inputs and outputs. A Danish government employee states that even with increased inputs the increased output ultimately comes from the land, which is already under pressure:

> DGov1: You cannot have a crop that takes up more eh or has a higher yield, that yield has to come from somewhere, that somewhere is out of the soil.

Here yield increases are framed as not only coming from technology and intelligent use of inputs, but from the soil itself, which is an exhaustible resource.

The point was also made from within the alternative paradigm that the inferior energy density of biomass compared to fossil fuels and the vast scale of resources needed to produce any significant quantity of biomass means that it is not a realistic substitute for fossil fuels in energy systems in industrialised countries. As a UK NGO employee states:

> UKNGO1: That basically, the underlying con- the underlying background is the fact that the land footprint, the land footprint of bioenergy is inherently incredibly high if you compare it types of energy that we would see as genuinely renewable. And that's basically because photosynthesis only converts a minute amount of sunlight to new energy so if you use that that mechanism to generate any significant amount of energy then the land footprint is inevitably enormous.

This criticism will be called the "cross cutting criticism" because it effectively criticises ambitious plans for bioenergy from any paradigm of agriculture and will be dealt with in more detail in chapter 9.

The idea of more extensive production is also criticised from within industrial agriculture as irresponsible. The reverse of the narrative of increased production freeing up land was also presented: further extensification of agriculture was seen to involve more land use. One document went so far as to state that extensification of agriculture was *unethical* because it would lead to an increase in the amount of land under cultivation (Kilpatrick et al., 2008):

> "High productivity per unit area will minimise the area of grassland and forest lost to agriculture, keep food affordable and allow a mix of crops for both food and for energy production. Considering the growing world population it could be argued that *extensive, low yielding agricultural systems are unsustainable and possibly even unethical."* (p.14 my italics).

The same argument is made in reference to technologies that are seen to increase yields. A UK industry employee states:

> UKI1: After all the same people who say that there isn't enough land in the world is the problem are also absolutely hell bent on opposing GM. And in general strongly in favour of organic farming, which whatever else is to be said for it is a less efficient way on a per hectare basis of producing food.

This is in line with arguments within the life sciences integrated model highlighted by Lang and Heasman (2004) that denounce alternative agriculture.

5.7 Conclusion

This chapter has begun to answer the question of how one can understand claims that perennial energy crops and crop residues will overcome previous controversies raised by food crop biofuels. It first considered how problems related to biomass within the agricultural system were framed. It suggested that feedstocks are widely framed as being produced within a productionist agricultural system, which is unsurprising given that this is the dominant type of agriculture in industrialised countries. The chapter then considered how perennial energy crops and crop residues are framed as developing within industrial agriculture or alternative agriculture to overcome previous controversies.

Within productionist agriculture land for biomass production is conceptualised in terms of a physical object that undergoes various transformations depending on global land dynamics. This disassociates land from place and sees it in abstracted economic terms. Land use and land use change are generally seen in a negative light, to be minimised, because of the association of agriculture with pollution and environmental destruction, as well as the knock-on effects on food production.

Within this overall narrative there are pockets of land, such as marginal land, which are seen as suitable for biomass production, generally because of their current use or biophysical characteristics. This idea of “pockets” of suitable land was called “industrialism lite” because it proposes a way that biomass can be produced to minimise impacts within the productionist system, without fundamentally changing the structures that it is produced within. This idea is an important one and will be investigated further in chapters 6 and 7 on marginal land in Denmark and the UK to explore the framing in more detail and unpick some of the assumptions underlying it. The idea of industrialism lite was also visible in the positioning of biomass production in relation to meat production in the food versus fuel debate. Here biomass is reframed as a less industrial and more acceptable product than meat, because it is less environmentally damaging, more efficient, is a necessity and is produced for domestic use.

In terms of how production should take place, the idea that increased productivity frees up land was very widely promoted. There were different ways that productivity could increase within a life sciences integrated model of agriculture: through intensification and/or improved efficiency and/or restructuring agriculture. This diagnosed current problems as being caused by inefficiency and saw the way forward as precision rather than increased use of inputs, innovation from within the biological sciences and in general the further industrialisation of agriculture. The multipurpose use of biomass in the industrial biorefinery was also proposed as a way forward. This framing will be taken forward in chapter 8 as it can be seen as a very influential view on the future use of biomass that is gaining momentum as well as being a rich source of assumptions that exemplify the life sciences integrated perspective.

The industrial multipurpose biorefinery vision can be contrasted with a different sort of multipurpose biomass production that is advocated within the alternative system. This is a vision for increasing land productivity and overcoming scarcity which involved perennial energy crop production within multipurpose agro-forestry systems. This will be taken forward and contrasted with the life science integrated conception of multipurpose biomass use in chapter 8.

Crop residue use within the energy system was promoted because they are seen as overcoming land use issues raised by food based biofuels as they do not require additional land. Challenges to crop residue use raised by stakeholders included competition between different sectors and difficulties that might arise in the interaction of the agriculture and energy sectors that could put farmers at an economic disadvantage. Farmers require flexibility in access to their straw whereas energy companies require consistency of supply. This was framed as potentially continuing the effects of the "technological treadmill" as farmers would not be able to take proper care of the land's health because their hand is forced by outside corporate interest, in this case contracts to sell straw that they might prefer to incorporate into the soil during a given year. Different answers were proposed to these challenges from within industrial life sciences integrated and alternative agriculture. Within the life sciences integrated model competition over crop residues and issues with integrating them into the energy sector were framed as manageable through the restructuring of agricultural systems to produce more straw and by the optimisation of straw to suit power stations. There was also an alternative, holistic, systematic approach to crop residues use that would overcome competition and soil quality problems. Within the alternative perspective some criticisms of the intensification of agriculture were also made, and a different, care focused, way of viewing the land was put forward by one interviewee. On the other hand alternative agriculture was criticised as being unethical because it leads to lower yields and is a step away from the goal of "feeding the world".

This sketch of the findings has introduced concepts and themes that will be taken forward in later chapters. These include the idea of marginal land within the industrialism lite model, the life sciences integrated multipurpose biomass production model, and the alternative agriculture multipurpose biomass production model. The next chapter will deal with the idea of using marginal land for perennial energy crop production in order to overcome global land use controversies and the industrialism lite strategy this involves.

Chapter 6 Marginal land use within industrialism lite

6.2 Introduction

This chapter focuses on the use of marginal land in the UK and Denmark to help tackle the global land controversies raised by food crop biofuels. The idea of producing perennial energy crops on marginal land to overcome land scarcity was introduced in chapter 1 and considered further in chapters 2 and 5. Chapter 5 suggested that in some of the documents analysed, the global land system was framed in a top down way that disconnected land from place and equated land in one part of the world with land in another. This land "displacement" and the view of land use and land use change were seen to be within an industrial conception of agriculture. Within this pockets of suitable and available land for perennial energy crops were proposed, such as marginal land. It was suggested in the last chapter that this framing attempted to place perennial energy crops at the margins of the industrial system, within what the analysis calls "industrialism lite". Part of the answer to how perennial energy crops are seen to overcome previous controversies raised by food crop biofuels is that if they are grown on marginal land their impact on the industrial agricultural system, and subsequently their impact on nature, will be minimised.

Using marginal land is seen to involve less competition with food production and so reduce food versus fuel concerns and lead to less indirect land use change. The concept of marginal land is notoriously ambiguous however, as was outlined in chapter 2, with previous analysis of its use in journal articles finding multiple definitions (Richards et al., 2014). This chapter will explore the concept of marginal land, assumptions embedded in the concept and challenges to these assumptions to help answer the question of how perennial energy crops and crop residues are seen as overcoming, or not, controversies raised by food crop biofuels. There will then be an exploration of how the marginal land concept fits within paradigms of agriculture at the end of the chapter. The focus of the chapter will be marginal land in the UK and Denmark for perennial energy crops, but it will draw on research on marginal land in the Global South in order to make relevant comparisons.

6.3 Background

Before considering the definitions it is worth noting that before the land use controversies and criticisms of biofuels outlined in the introduction became widespread, marginal land was not widely promoted in the UK as somewhere suitable for energy crop production. In fact, quite the opposite: in one instance unproductive land is framed as marginally useful for energy crops. An academic document in 2005 estimating the amount of land available for perennial energy crops production in Scotland states that ideally crops should not be planted on "marginally suitable land" because yields would not be significant and production was unlikely to be profitable (Andersen et al. 2005). The term refers to “land with low yield potential and/or severe harvesting conditions.” (p.74). This definition is echoed in a report written by the Royal Commission on Environmental Pollution (RCEP) in 2004. The report led to the establishment of the Biomass Task Force and the publication of the UK Biomass Strategy in 2007.[17] The report contains no references to the problems of direct and indirect land use change and only refers to “marginality” in the following context: “Farmers currently see willow as a marginal crop and will make use of subsidies by planting on set-aside land. The land chosen for set-aside is often the lowest quality land and this could also result in reduced yields.” (p.11). Here the term “marginal” is used to signify that farmers do not regard willow as an important crop and as such it risks being put on the least productive land resulting in the lowest yields. The potential association of biomass production with “marginal land” or as a “marginal crop” is seen as a hindrance to its development in the UK. This can be seen to change after the height of the controversies in 2007 and 2008 when marginal land is promoted as land where energy production should take place.

6.4 Analysis of marginal land concept

6.4.1 Definition 1: Land unsuitable for food production.

The first definition classifies marginal land as land where food production cannot take place because the land is not productive enough. This definition appears in two of the UK documents. Appendix 4 shows the documents that use each definition. None of the UK interviewees appear to use this definition of marginal land. This strong, categorical definition was not identified in any of the Danish documents or interviews. The fact that it wasn’t widely used among interviewees could point to the evolution of the term and possibly that it is being less widely promoted over time. The interviews were conducted after the documents were chosen and analysed and none of the interviewees appeared to endorse the use of marginal land in an unequivocal way, as some of the documents do. This idea will be reconsidered later in the chapter.

The Gallagher Review, commissioned by the UK government in response to controversies raised by biofuels in order to explore their indirect effects, defines marginal land as: “• Land unsuited for food production, e.g. with poor soils or harsh weather environments; and • Areas that have been degraded, e.g. through deforestation.” (RFA, 2008 p.33). A similar definition can be found in the report on the ethics of biofuels by the Nuffield Council on Bioethics (2011) “[…] there is no agreed definition for marginal land; however, it has been commonly used to refer either to land that is

[17] This was superseded by the UK Bioenergy Strategy in 2012.

unsuitable for food agriculture or land that has a low carbon stock." (p.172). This definition exemplifies the original logic behind the idea of using marginal land for biofuels: it will help overcome controversies around the use of land for biofuels, including ILUC. There are several assumptions embedded within this definition and the use it is put to.

Assumption 1. Significant amounts of marginal land exist.

The first assumption is a practical assumption that sufficient quantities of this land exist in the UK and/or abroad to produce a substantial amount of biofuels crops. Several people have questioned this assumption in the UK context. Booth et al. (2009) – in a report funded by the Department of Energy and Climate Change and managed by the National Non-Food Crop Centre – state:

> The basic premise recommended by Gallagher, 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. Unlike the situation in Brazil or Southern Africa there is very little underutilised agriculturally productive land in the UK. (p.113).

However, the assumption made by Booth et al. (2009) that marginal land exists in the context of the global south has also been questioned by NGOs and academics. Young (1999) states that certain estimates of spare land that could be used to address hunger in developing countries are unrealistic and unhelpful as they significantly overestimate the amount of cultivatable land, underestimate current cultivation of land and do not take sufficient account of other uses of that land. Franco et al. (2010) and Borras Jr. & Franco (2010) point out that even when it is not farmed, marginal land is often used for another purpose, such as gathering firewood, and the people who use it often lack the political power to defend this use. Similarly, Brara (1992) points to the dissonance between local people and the government on the question of degraded pasture land in India. The local people still use the land for grazing whereas it is classed as wasteland according to the government's scientific definition. Christian Aid reiterate this point stating "One person's marginal land is another's vital grazing territory." (2009 p.26). Franco et al. (2010) and Borras Jr. & Franco (2010) also question the normative assumptions embedded in the definitions stating that the terms "marginal" or "degraded" land can be used to implicitly normalise past degradation of land, and to represent the land and its current uses as less important than those of "prime land". Action Aid (2010) also state that communities would often dispute the existence of marginal land and risk being displaced.

Others have highlighted the important environmental functions of that land, in addition to the social functions, and question the acceptability of displacing these. In the context of the global South the RSPB (n.d.) point out that "marginal land" could provide important habitats for wildlife. The Gaia

Foundation et al. (2008) make the same point about EU countries stating that policies to use previously set aside land and marginal land for biofuels production have had negative impacts on biodiversity, soils and water quality through increased intensification. A UK government employee outlines the different uses of “marginal land” in a UK context:

> UKGov1: […] but marginal land for agricultural production could give you the best benefits for other land use such as biodiversity or amenity or ‘cause if you think about all the upland areas in the country will be grade 4 and 5 they're thin soils, high up, stony, they provide a lot of other benefits, most of our drinking water will come from upland areas people like going to them, big income from tourism there […].

While the above quotation refers to marginal land in the UK, it is fair to say that many of the NGO documents above may refer to the production of arable food crops for biofuels production rather than perennial energy production on marginal land. It is stated that leaving land fallow has greater biodiversity benefits than growing arable crops, but the situation appears more complicated for perennial energy crops (Sage et al., 2006). It was stated in chapter 2 that perennial energy crops are widely promoted as being better for biodiversity than arable crops, supporting more flora and fauna. The question of how the biodiversity impacts of perennial energy crop production on marginal land in the UK and Denmark are framed will be considered in more detail in section 6.4.2 below.

Assumption 2. Production is possible on marginal land.

The notion of marginal land as land unsuitable for food production also contains technical and economic assumptions that production will be possible and economically feasible on this land. This is presented as a cautionary footnote within the Gallagher Review itself: **“**The potential for use of marginal land should not be overstated since whilst crops can grow in difficult conditions, the yield performance may be poor.” (RFA 2008 p.37). Doubts of this kind have been raised about the potential to grow perennial energy crops on this land in the UK, as some have pointed out that small yields have been obtained on less productive land (Sherrington et al., 2008; SEERAD, 2006). A UK grower states about marginal land:

> UKG2: From an academic’s point of view it makes a lot of sense, from a practical point of view from somebody who’s on the ground it doesn’t work because you need high- for willow to work you need high yield because you’ve got a lot of cost in harvest, a lot of cost in establishing the crops and the trouble is the more marginal the field the more likely it is for that crop not to be sustainable economically.

A UK government employee expressed the point that yields could be low requiring the intensification of production which would undo some of the benefits:

> UKGov2: And I suppose my concern is that because people say “oh they won’t go on grade A agricultural land it’ll grow on marginal land” and you think well you’re going to get fairly crap yields then aren’t you? Unless you start putting fertilisers on you start putting artificial fertilisers on and you take away most of the benefits, the carbon benefits of having the damn crops in the first place.

As was pointed out in chapter 5, many have highlighted the potential of advanced plant breeding techniques, such as genetic modification, to improve yields of perennial energy crops on marginal lands by making crops resistant to pests and disease and decreasing their nutrient and water requirements (Karp et al., 2009; Karp et al., 2011). Others claim that such technological promises are problematic and are a way of raising expectations about two as yet largely unproven technologies: genetic modification and second generation biofuels (Levidow & Paul, 2008). The role of technology and promises of technological innovation will be briefly revisited in the next section and the conclusion.

Assumption 3. Production can be targeted to marginal land.

This definition also contains market and/or policy assumptions that production can be targeted to this type of land alone, in the UK, Denmark or the global South, provided it exists and if production is feasible on it. If there is no policy framework to ensure this land is used then the term arguably has little impact and there is nothing to stop companies using better land to obtain higher yields (Nalepa and Bauer, 2012). The Gallagher Review again highlights the difficulties involved in developing such a policy: “A framework to prevent biofuels causing land-use change has been proposed but is challenging and will take time to develop.” (RFA 2008 p.14). At present there are instruments in the UK which regulate the change in agricultural land use. A farmer wishing to grow willow above a certain threshold of land area on agricultural land may need to undergo an environmental impact assessment (EIA) (Natural England, 2009). As mentioned in chapter 2 there are land use restrictions within the RED. If this definition of marginal land is taken forward, will suppliers of biofuels be required to assess whether the land was used for food production in the past? The practical feasibility as well as the will to implement such constraints, in addition to the ones already in place, remains to be seen.

6.4.2 Definition 2: Ambiguous lower quality land.

The second definition identified in the data is that of lower quality agricultural land. This can be seen as a weaker version of the first definition: it is not land that is necessarily *unsuitable* for food production but where food production is less productive. This is another normatively motivated definition: this land *should* be used to overcome land controversies. Since this use of the term "marginal land" is vague and ambiguous it may not be correct to call it a "definition" as such, but more of a loose category of terms. This version of marginal land appears in 7 of the UK documents, although it should be noted that the 3 NGO documents do not advocate the use of this land, but rather comment on the idea of using it. Seven of the UK interviewees define marginal land in this way, though several of them defined marginal land in more than one way.[18] None of them appear to unequivocally support the use of marginal land for perennial energy crops with some being more or less in favour of the idea but all of them pointing out caveats and issues with its use. Two of the Danish documents use this definition, though one of them uses it in reference to the other document. One Danish interviewee uses the term in this way and endorses its use to help overcome global land controversies.

A report by the Danish Ministry for Food and Agriculture (MFAF) investigating ways of reducing greenhouse gas emissions from agriculture also endorses this definition, in somewhat vague terms, and as we will see later, their use of the term "marginal land" primarily refers to economically marginal land (Ministeriet for Fødervarer Landbrug og Fiskeri, 2008b). They state: "The study focuses primarily on the exploitation of resources that do not compete significantly with food production and the inclusion of marginal land for biomass production." (p.12)[19].

A report on biofuels by the Royal Society uses the term in a similar way. It states that plant breeding could enhance the suitability of dedicated energy crops for processing into biofuels, reduce their environmental impacts and enable "the plant species to be cultivated on marginal land of low agricultural or biodiversity value [...]" (2008 p.8). On page 46 they state that this would reduce the amount of productive land diverted away from food production. Bauen et al. (2010) similarly define marginal land as grade 5 arable land in the UK: lower quality agricultural land where food production

[18] Interviewees were asked how they would define marginal land. Some of them declined to give a definition so interviewees are only "counted" as using a particular definition if they clearly define it in that way. Other interviewees may subscribe to a similar view of marginal land but did not define it this way. It is considered more important to clearly distinguish which documents use which definition than in the case of interviews because more of the documents endorse the use of marginal land and the arguments around these claims are examined in depth, and there tended to be less equivocation in documents than interviews.

[19] Original text: "Undersøgelsen fokuserer derfor primært på udnyttelsen af ressourcer, som ikke konkurrerer væsentligt med fødevareproduktionen og på inddragelse af marginale arealer til biomasseproduktion."

may currently be taking place. SEERAD (2006) discusses the production of perennial energy crops on "[…] marginal agricultural lands, where other arable crops are less successful." (p.18). They state there is a potential to use this land but yields may be lower. A UK industry employee uses this definition:

> UKI2: To me that is just land which is not as good for growing agricultural crops […].

Use of this type of land is promoted as reducing impacts on food production, as expressed by a UK academic.

> UKA2: […] the advantage of doing so is that you minimise the competition with food crops so you're not displacing much of the food production.

Assumptions. As above: marginal land exists, production is possible and can be targeted to marginal land.

This definition can be seen to involve many the same assumptions as the previous definition: that this type of land exists in the quantities estimated; that biofuels production is possible on it; that production can be targeted to this type of land alone; and that use of this type of land will lead to less significant and therefore acceptable impacts on food production and sustainability than the use of prime land. These assumptions can all be challenged as they were for the other definition.

Here we can return to the question of whether marginal land is actually "marginal" from an environmental point of view, as it may have important functions that would be displaced by biomass production. While the displacement of important biodiversity on "marginal land" by annual biomass crops was widely framed as problematic, it is not clear whether this argument applies to perennial energy crops. These are framed as being beneficial for biodiversity in some cases. This can be seen in a quote from a UK NGO employee:

> UKNGO3: I think it would be beneficial for biodiversity, sort of a different kind of habitat for farmland in Britain and elsewhere. Which broadly speaking it's a good thing.

This is not universally the case however and it depends on what kind of marginal land is under discussion, what land use perennial energy crops are being compared to, what type of perennial energy crops are under discussion, and how perennial energy crops were grown: in monocultures or in strips. There also appear to be outright disagreements about the biodiversity benefits of perennial energy crops. The point of the analysis in this section is not to go into significant depth on this issue and carry out an exhaustive analysis, as it would potentially require more data to clarify issues. The point is rather to highlight the fact that these disagreements exist, show what the dimensions of the disagreements are and demonstrate that in this sense perennial energy crops are different to more “conventional” crops that are seen as unequivocally at odds with the use of marginal land use for biodiversity purposes. We will return to the issue of biodiversity from perennial energy crops in the next chapter.

DfT et al. (2012) states that perennial energy crop production is compatible with the aim within agriculture of improving biodiversity.

> By contrast, a number of reports show that perennial energy crops, such as short rotation coppice and miscanthus, if cultivated in the right place and in the right way, can be better for biodiversity and water quality than arable crops such as wheat and maize. (p.22).

Thus if the marginal land under discussion was currently used for arable production then perennial energy crops are framed as bringing biodiversity benefits. The biodiversity benefits of producing perennial energy crops are however also framed as less beneficial than leaving the land fallow in some cases. This contrast is highlighted by an NGO employee:

> UKNGO3: I’d always compare it with other crops because that is what is should be replacing. Emm as long as that’s the comparison you’re making and as long as that’s what it’s replacing then even for miscanthus it’s not such a bad thing, for SRC it’ll always be a good thing. If you’re planting it on marginal land or land that’s good for wildlife otherwise that’s when you've got a problem.

The biodiversity benefits are dependent on what kind of perennial energy crop is grown. Willow is seen as much more beneficial than miscanthus. A UK NGO employee speaks enthusiastically about the biodiversity gains from willow but states:

> UKNGO3: Miscanthus is different. If where if you’re going to start growing that in blocks several hundred hectares then you’re going to have very little wildlife in it.

As well as being framed as context dependent there also appears to be outright disagreement about the biodiversity benefits of perennial energy crop production. Some maintain that there is confusion over the matter, and there is a need for more research, as a UK government employee states:

> UKGov1: […] there’s always big debates between the biodiversity and biodiversity we do with other schemes and other environmental gains and what you get from energy crops, so I would suggest that one of the first things would be if growers of energy crops could demonstrate clearly that there are biodiversity and environmental gains from growing that crop as well as carbon gains from growing it.

In contrast to this a UK grower sees the matter as settled, and as a question of political will:

> UKG1: I've been campaigning for years about the biodiversity benefits of short rotation coppice with the RSPB, with Natural England, and it's just all fallen on deaf ears. They're not interested in comp- in any kind of stewardship payment or ELS payment that's linked to short rotation coppice and I think that's another missed opportunity because we can prove that the biodiversity within that crop is fantastic.

Other disagreements relate to the benefits of replacing grassland with perennial energy crops and whether or not it is beneficial for biodiversity if grown in monoculture. A UK grower states that growing willow on grassland and in monoculture are both still beneficial for biodiversity:

> UKG2: Well one of the big dilemmas against willow when we started planting was that it was monoculture and therefore it wouldn't be as advantageous as a grass field for instance for biodiversity. That proved to be very incorrect in that because it's a perennial crop you can actually allow natural fauna to develop in the undergrowth and clovers supply nitrogen for the crop […].

A UK academic in contrast states that growing perennial energy crops on grassland is not ideal. This disagreement about whether grassland counts as marginal land will reappear below in section 6.4.3.

> UKA2: […]so if that marginal land is rough grazing that's important for example for over wintering birds or for passage migrants or for eh the many other functions that this marginal land has other things to do with biodiversity and non-market value ecosystems services then we need to take those into account as well.

A UK government employee also states that growing PEC in monoculture is not desirable from a biodiversity point of view.

> UKGov1: It's edge habitat isn't it, that's all you get from short rotation coppice it's the edge habitat that's important.

UKNGO3 the NGO employee disagrees with this point of view stating that edge habits are important, but even grown in monoculture the biodiversity benefits of willow production are significant.

Thus the question of whether or not using marginal land for perennial energy crops can have a detrimental effect on the environmental functions of this kind of marginal land is a complex issue. It is context dependent, but there also appear to be disagreements over the issues. Some frame these conflicts as requiring more evidence to settle them while for others, the evidence is seen as sufficient but the problem arises from a lack of political will to use this evidence. For now we can note that certain perennial energy crops like willow are not generally framed as being the same as conventional arable crops from an environmental point of view, whereas others such as miscanthus are closer to these crops from a biodiversity point of view.

6.4.3 Definition 3. "Economically marginal land"

The third definition identified in the data is "economically marginal land". This definition can be seen to circumvent some of the challenges to the previous definitions that production would not be feasible and that this type of land does not exist. This definition however is based on the concept of marginal land within economics and can be seen to differ in normatively significant ways from the previous definition. This definition appears in 3 of the UK documents and is used by 4 interviewees. Two Danish interviewees and 2 documents used this definition, although one document (Bestmann, 2009) uses it when quoting the other document (Ministeriet for Fødervarer Landbrug og Fiskeri, 2008b). Ministeriet for Fødervarer Landbrug og Fiskeri (2008b) model the amount of economically marginal land that can be used for biomass production, as a cost effective way of reducing greenhouse gas emissions from agriculture: "Marginal land is defined as the areas which are not achieve a positive gross margin in alternative uses. In relation to the arrows [willow] cultivation are the relevant marginal soils primarily waterlogged areas." (p.103)[20].

Turley et al. (2010) use this definition and outline it in opposition to that given in the Gallagher Review: "Marginal land is more commonly defined as land where cost effective agricultural production is not possible under a given set of conditions." (p.7). Turley et al. (2010) is a report written by academics and consultants commissioned by the UK Department for the Environment, Fisheries and Rural Affairs (DEFRA) to estimate the amount of idle and marginal land in the UK available for energy crop production. The report models the amount of arable land "of marginal profitability"; fallow arable land; and grassland with low stocking rates; as well as certain types of non-agricultural land available for both arable and perennial energy crop production. The arable land identified as economically marginal is grades 3 and 4 land under the MAFF land classification (Ministry of Agriculture Fisheries and Food, 1988). This classification is based on the physical, climatic and fertility characteristics of the land, with grade 1 being the most productive and grade 5 the least.

[20] Original text: "Marginaljord defineres som arealer, hvor der ikke kan opnås et positivt dækningsbidrag i alternative anvendelser. I relation til piledyrkning er de relevante marginaljorde primært vandlidende arealer."

This definition is also found in a report on biomass by the Committee on Climate Change - a statutory body established under the UK 2008 Climate Change Act to advise the government on setting and meeting carbon targets. It estimates the amount of land that is either “not required or not suitable for arable crop production” globally that could be used for biomass production (Committee on Climate Change, 2011 p.17). Within this there are different subcategories of land, including marginal land: “areas where cost-effective production is not possible, under given conditions (e.g. soil productivity), cultivation techniques, agriculture policies, as well as macro-economic and legal conditions.” (p.17).

A UK government employee defines marginal land as:

> UKGov1: […] land that’s been agricultural farmed for quite some time and when you looked at the gross margins for an arable crop and compared them with the gross margin from energy crops you’d get a higher gross margin from energy crops then I would see it as a worthwhile activity for the farmer.

Similarly to the first two definitions, the classification “economically marginal land” is based on the land’s agricultural productivity; however it also has a different meaning. The concept of “marginality” in economics refers to a small increase or decrease in the stock of something one owns. As Peterson and Galbraith (1932) state: “In terms of the physical grade of land the economic margin is *at the ‘poorest’ land which can be ‘remuneratively’ operated ‘under given price, cost, and other conditions’.*” (p.296 italics in original). Economically marginal land for willow would be the lowest quality land that could be used for production under a given set of price conditions for inputs and the product. This land could be different for other energy crops and if the economic conditions were different. Turley et al. (2010) modelled different commodity prices and found that grades 3 and 4 arable and grass land could be used more profitably for energy crop production than for arable crops, making it the economically marginal land. As Turley et al. (2010) state “Less productive land is closer to the break-even economic margin and this is reflective of land where significant change in use is most likely to be observed.”

While the first two definitions of marginal land can be seen as normatively motivated concept – energy production *should only* take place on land unsuitable for food production, this second definition can be seen as more of a predictive concept – given a set of economic conditions this is the land that is *likely* to change use to energy crop production. Nalepa and Bauer (2012) advocate the use of this concept of marginal land as more realistic and useful than a static definition of marginal land based on the land’s fertility.

> Thus, the ‘marginality’ of a land parcel can only be determined in reference to the particular economic opportunities offered by the array of land use choices available locally at that moment and cannot be determined by analyzing land suitability for a single productive use. (p.415).

Richards et al. (2014) also found that marginal land was sometimes defined partly or solely in terms of this economic criteria in their analysis of academic articles.

Assumption 1. Using economically marginal land will reduce impacts of energy crops.

The assumption made within this definition is that the use of “economically marginal land” for biofuels would help overcome land use controversies. Turley et al. (2010) state that the aim of their study is: “[...] to identify potential ‘idle’ and marginal land areas where expansion of biomass production is possible without incurring significant impacts on sustainability and competing with food production” (p.2). We can consider a statement about marginal land from the UK Renewable Energy Strategy:

> Use of this [marginal] land will reduce the risk of competition with existing food crop production, and help ensure that any associated land use change does not have a significant impact on the anticipated greenhouse gas savings or pose any other significant detrimental environmental impact. (HM Government, 2009 p.114).

What the quote is actual referring to is “economically marginal land” in the UK.

Here we can see that the assertion about marginal land is somewhat watered down. It is not stated that use of economically marginal land will lead to *no* conflict with food production or incur *any* sustainability impacts, but that it will not lead to *significant* impacts and will *reduce the risk* of competition with food production. We can see that this weaker formulation of why “economically marginal land” should be used matches the less explicitly normative orientation of the concept and the fact that it involves displacement of some food production. The same is true of the 2008 analysis by the Danish Ministry of Food, Agriculture and Fisheries which estimates the amount of economically marginal land in Denmark for perennial energy crop production and states “The study focuses primarily on the exploitation of resources that do not compete significantly with food production and the inclusion of marginal land for biomass production.” (p.12)[21].

[21] Original text: “Undersøgelsen fokuserer derfor primært på udnyttelsen af ressourcer, som ikke konkurrerer væsentligt med fødevareproduktionen og på inddragelse af marginale arealer til biomasseproduktion.”

Here it could be pointed out that what counts as a "significant impact" on food production or sustainability is a value judgment. Using grades 3 and 4 land would lead to displacement of food production. Why is this level of food displacement or sustainability impacts acceptable? What alternative scenario is the level of impacts being compared to? The purpose of this analysis is not to criticise this value judgment and to state that *no* food production should be displaced but simply to point out that this *is* a value judgment. It could also be pointed out that labelling this level of impact as "not significant" is somewhat arbitrary given that the analysis is primarily practical, based on the land that is *likely* to change use, rather than explicitly normative. The authors may wish to defend the displacement of this level of food production or environmental impacts, given the benefits accrued, but this should be done on explicitly normative grounds, recognizing the trade-offs (Gamborg et al., 2012).

HM Government appear to use the concepts of "marginal land" and "land of currently marginal economic production value" interchangeably, which could confuse the reader (2009 p.114). There is also a fudging of the issue in a 2010 briefing paper by the Danish MFAF, which refers to the use of marginal land overcoming conflict with food production as outlined in the 2008 study in more categorical terms:

> A study from December 2008 from the Danish Ministry of Food, Agriculture and Fisheries has shown that Denmark has a huge potential for growing energy crops - namely cultivation of short rotation willow on marginal soils. This can be achieved without affecting the current food production. (Ministry of Food Agriculture and Fisheries, 2010 P.1).

We see then the 2008 statement about marginal land that does not cause *significant* conflict with food production has been changed to "without affecting" food production. This does indicate the fudging of the issue and ambiguity of the concept. We can ask whether the concept of economically marginal land adds any extra normative dimension to the debate about biomass production. Turley et al. (2010) model the same type of land as Booth et al. (2009) who disavow the concept of marginal land altogether.

Assumption 2. Economically marginal land includes grassland.

The second assumption is about the acceptability of using grassland for energy crop production. As we saw, grassland was included in the economically marginal land modelled by Turley et al. (2010). Thus under this view, use of grassland in the UK can help to avoid significant sustainability issues and conflicts with food production resulting from the use of biomass. Others have raised doubts about the use of grassland for energy crops because of the resulting soil carbon emissions. Booth et al.

(2009) estimate that converting grassland to willow production would result in a net carbon deficit when the foregone emissions from replacing coal with biomass are compared to the soil carbon loss from converting grassland. A report on the carbon saving credentials of biomass by the Environment Agency (2009) views displacement of food production onto permanent grassland *as* indirect land use change: "However, if demand for land to produce energy crops rises and leads to the displacement of other crops, the indirect effect may be to shift production of these crops onto permanent grassland, causing the same problem." (p.6).

Thus while Turley et al. (2010) view less productive grassland as a type of economically marginal land whose use could help overcome food versus fuel and environmental problems, the Environment Agency and UKA2 view it as land that could fall foul of ILUC. This points to further ambiguities in the concepts of marginal land and ILUC and highlights that decisions about what land should be used for production and what land should be spared from production because of its environmental credentials are not uniform and clear cut.

Assumption 3. Technology will make up the shortfall in food production.

The technical assumption is also made that if food production is displaced on this "economically marginal land" then yield increases on the remaining land will make up the shortfall. "Use of the proposed areas of uncropped and economically marginal land for biomass production will involve changes to habitats and intensification of agriculture." (Turley et al., 2010 p.70). The idea that increased productivity will free up land was explored in chapter 5, where it was placed within the industrial paradigm and the different proposed ways of pursuing increased productivity within life sciences integrated agriculture were considered. We can see that in this way the marginal land strategy is linked to the life sciences integrated model of agriculture. We can also note that such claims about technology use freeing up land go beyond the original logic of using "marginal land" to overcome land use controversies. The idea that marginal land use will not compete with food production is different from the idea that yield increases will make up for any shortfall in food production. If the latter idea is used to shore up arguments about the use of "economically marginal land" this is because economically marginal land is not marginal land as it was originally conceived.

6.5 Discussion and conclusion: marginal land for perennial energy crops as industrialism lite

This section will connect the analysis of the concept of marginal with the paradigms of agriculture. It was argued in the last chapter that the idea of using marginal land for perennial energy crops frames perennial energy crops as overcoming previous controversies raised by biofuels by placing them at the margins of the conventional, industrial agricultural system. This strategy was named “industrialism lite” because it accepts that agriculture and land use are environmentally damaging, or potentially socially detrimental activities and so aims to minimise impacts by minimising involvement in this system. Instead of addressing biofuels controversies through attempting large scale changes in land use policy, agricultural systems or global inequalities, this strategy attempts to switch perennial energy crops to a low impact type of land use. To use the metaphor of food consumption, a person on a diet doesn’t switch to different types of food or different eating patterns but rather to low calorie versions of the same food.

As we saw in the last chapter land use and land use change were seen to have negative connotations. The analysis in this chapter could support this idea. The concept of ILUC assumes that even if perennial energy crops are produced in a non-environmentally damaging way – they do not directly lead to the destruction of natural habitats or use of a large amount of inputs – they could still have environmentally detrimental knock on effects on the agricultural system because they use land. Agricultural systems that are relatively benign at the point of production are nevertheless implicated in the “dirty business” of agriculture through the global land use system and the concept of marginal land is used to distance perennial energy crops from this system as much as possible.

In this chapter we saw that originally the “marginality” of land or energy crops themselves was seen as something to be avoided or overcome in order to develop perennial energy crop production in the UK. After the land use controversies around biomass the idea of “marginal land” for biomass production was embraced by government and others to circumvent their negative environmental and social impacts. In this chapter the “marginal land” concept was analysed in more depth and three definitions of marginal land were identified. They all share the feature of being less productive land. Where they differ is whether or not the land is suitable for food production and whether the concept has an explicitly economic or normative rationale. This is a normative conception of marginal land: this land *should* be used to overcome land use issues. The idea of using “economically marginal” land can, in turn, be seen to overcome the problems with using very poor, unproductive land. This is a predictive conception of marginal land: this land is *likely* to be used because of economic circumstances.

There is nothing particularly “alternative” about any of the definitions of marginal land. The marginal land strategy does not involve harmony with nature and connectedness to the land advocated by some alternative agriculture positions, but rather that reliance on the environment, through land use, should be minimised because of the damage agricultural production does to it. The “land use is bad” rhetoric leads to the situation where land use for biomass is both desirable: because it will lead to energy production, and undesirable: it will lead to environmental damage. This tension leads to the industrialism lite strategy, which is not conventional agriculture that requires prime land, large amounts of inputs and is detrimental for biodiversity, but which is nevertheless situated within the same system. We can see this understanding of the concept voiced by a UK industry employee who also highlights this implicit assumption within the marginal land strategy that conventional agriculture for perennial energy crops is unacceptable:

> UKI1: So if your starting point is "it's unsustainable unless it's grown on marginal land" what you're basically saying is that as a mainstream option it's unsustainable, it's not acceptable.

This tension between produce from the land being both desirable and undesirable gives rise to the tension where perennial energy crops on marginal land should be both the same and different from conventional industrial agriculture. It should be the same to the extent that it "works": is economically feasible and provides sufficient quantities of biomass for the energy system's requirements and it should be different to the extent that it doesn't incur the same environmental impacts. We can see this tension played out in the difficult discursive work undertaken in painting a type of land that is abundant, free, and accessible and where production is feasible for biofuels production. This chapter reviewed some serious challenges to this strategy. If marginal land follows the original logic of overcoming land use controversies by using land unsuitable for food production, then many arguments have been made against the feasibility of its use for biofuels production. Many have argued it would not work in practice because this type of marginal land does not exist, production might not be possible on this land and it would be difficult to target production just to this land. If on the other hand marginal land is defined in a more practical sense, as more productive "economically marginal" agricultural land, then it can be pointed out that this does not follow the original logic of using marginal land to circumvent land use controversies. Whether or not use of this land would lead to lesser impacts and why these impacts are more acceptable is somewhat hazy.

It is important to be clear about exactly what type of land is being referred to. It is often difficult to pinpoint if definitions are being conflated because the term is often used in a vague and nondescript way, as we saw in definition two, with similarly nondescript claims being made on its behalf. We saw that normative and predictive definitions were potentially conflated in HM Government (2009) which changed between "marginal" and "economically marginal" land. We can see this being done in some Danish documents when a ministerial report models the amount of economically marginal for perennial energy crop production and states that it can be used without significantly impacting food production. This is then later quoted in a different governmental report as land which will involve no conflicts with food production (Ministry of Food Agriculture and Fisheries, 2010).

At this point some appeal to technology either to argue that production could be feasible on marginal land in the future, or that yield increases could make up a shortfall in food production. In relation to technological development we can see this strategy overlaps with ideas from the life sciences integrated paradigm because biotechnology methods are proposed to pursue industrialism lite that requires fewer inputs and can be grown on marginal land. As the report by the Nuffield Council on Bioethics (2011) express both reservations and optimism about the prospect for specially designed crops for marginal land:

> It is likely that, because land can be used for many purposes and because it often has a function even when it is *not* put to some particular use, even the development of crops which can grow on low-quality land will not entirely circumvent the problem of competition for land. However, while they are not the perfect solution that they have sometimes been promised to be, high-yielding crops with low input requirements certainly are one of the ways towards easing the pressures on land demand worldwide. (p.49)

These crops are biomass lite because they do not need the nutrients and water provided by prime land and they also do not require many inputs. Scientific innovation and technology are seen as the means through which this vision is possible and here we return to the narrative seen in chapters 3 and 4 that scientific and technological progress are the way forward for progress in agriculture.

If some see the real problem as being the inequalities and environmental destruction endemic in the structure of industrial agriculture, or the problem as being use of agricultural resources for energy rather than food (Oxfam International, 2008), then this strategy can be criticised for not attempting to address these issues. Indeed, Thompson (2012) point out that if the food versus fuel argument is taken to its logical conclusion then we can understand it in terms of use of resources to do *anything* other than feed the hungry being ethically problematic. Those who oppose industrial agriculture and see it as systematically unjust and unethical may still object to the industrialism lite strategy (McMichael, 2010). And in some cases more systematic change can be seen as a better practical strategy (Scott, 2011). The criticism of the first assumption of the first definition, that sufficient marginal land exists to meet biomass targets also resonates with a criticism that will be explored in chapter 9 about the scale of land and biomass needed to meet targets. Biomass in not as energy dense a fuel source as fossil fuels and requires a vast amount of land relative to the energy produced (McDonald et al., 2009). Issues of scale and energy density add to the scepticism about the availability of sufficient marginal land. Chapter 9 will return this important issue with an exposition of what is called the cross cutting criticism.

It is also worth noting that some voices in the debate have already moved beyond the term "marginal land" because of doubts about the rhetorical emptiness of the concept and criticisms of the term. In a review examining the potential land demand of second generation energy crops Valentine et al. (2012) state "We have avoided the use of the term 'marginal lands' in view of the objections raised by the African Biodiversity Network and others (2008)." (p.5). However they appear to make similar arguments to those highlighted above but use the term "so-called marginal land". They state that it is important to take into account the fact that "Energy crops are deep rooted perennials which may be more economic than food crops on so-called marginal lands or on agriculturally degraded and abandoned lands […]." (p.11). They use the term "so-called marginal land" to distance their claims from the controversies surrounding marginal land, but the argument remains the same. The argument that there is a type of land available in sufficient quantities to overcome the land use controversies around bioenergy can be made independently of the concept "marginal land". This could support the idea suggested in section 6.4.1 that the decreased support for marginal land among the interviewees compared to in documents shows the evolution of the debate away for wholesale support of the concept.

In conclusion, the idea of using marginal land for perennial energy crop production is one way of overcoming controversies raised by food crop biofuels, which this analysis placed in an "industrialism lite" model of agriculture. There are challenges raised against this strategy. The next chapter will deal with the concept of "environmentally marginal land", which has a different, local rationale to the type of marginal land discussed in this chapter.

Chapter 7 Multifunctional beneficial biomass on environmentally marginal land in Denmark.

7.1 Introduction

The last chapter explored the strategy of using marginal land to overcome previous land use controversies raised by food crop biofuels. Three definitions of marginal land were identified and were all placed within the "industrialism lite" strategy that sought to distance perennial energy crop production from the negative aspects of conventional agriculture, whilst maintaining that profitable production was also possible on marginal land. While exploring the idea of "marginal land" for perennial energy crops another definition of it was also found. The focus of this chapter will be on the idea of using "environmentally marginal land" for perennial energy crop production which seeks to address local environmental problems caused by industrial agriculture, rather than the global land use controversies. This concept was found predominantly in Denmark, with only one instance of its use in the UK by an interviewee. Denmark has a history of trying to use marginal land for environmental purposes. Thus the chapter will focus on Denmark and Danish land. The purpose of the chapter is to highlight the existence of this different concept of marginal land which is not widely used in the international biomass debate, to explore its meaning, consider its history in Denmark and explore conflicts over the use of this land. In terms of paradigms of agriculture these conflicts will then be explored in more depth in relation to the idea of multifunctional agriculture, which as we saw in chapter 3 was placed within the alternative paradigm because it involves a move away from productionist agriculture towards more extensive production and the provision of different goods and services from agriculture. In this way it seeks to contribute to answering the question of whether perennial energy crops can be seen to involve a different model of agriculture that will overcome previous controversies.

The chapter begins with some background about the concept of marginal land in Denmark. There is then an exploration of what "environmentally marginal" land is. The reasons why the use of environmentally marginal land is proposed for perennial energy crops are then considered. The chapter considers two conflicts over its use: between the water quality benefits of perennial energy crop production and perceived preferable biodiversity benefits of grass; and the perceived negative landscape impacts of growing perennial energy crops. Within both of these conflicts grass production is promoted by some as a better use of land for energy production than perennial energy crops. The different interests over the use of environmentally marginal land will be then be analysed in terms of different, opposing multifunctional aims for land use. Different environmental services are preferred by different people on the same piece of land and the provision of certain environmental services from perennial energy crops can be seen to conflict with the post-productionist conception of agriculture as a consumption space, within which people express a preference for open and closed landscapes.

7.2 Background.

Land is often framed as a scarce resource in Denmark. More than sixty five percent of Danish land is used for agricultural production (Danmark Statistik, 2013). There has been active debate within Denmark on the use of these lands. The term "marginal land" or "*marginale arealer*" or "*marginaljord*" in Danish has appeared in Danish land use policies since the late 1980s. In 1987 a Marginal Land Strategy was presented in Parliament which aimed to promote the use of marginal land for nature purposes, with the assumption that more land would become marginalised in the future due to intensive agriculture practices. Marginal lands were defined as lands that were not – or almost not - suitable for agricultural production due to natural, technical or economic reasons. Extensive agricultural practices, afforestation as well as management or restoration of natural areas were identified as core measures. The strategy was partly followed up by the Nature Management Act in 1989, and was later incorporated into a new Nature Protection Act in 1992, which extended the types of land protected to include e.g. meadows. The result has been a number of nature restoration projects, including wetlands and afforestation, primarily through public acquisition (20,000 ha), land allocation and voluntary agreements (Miljøministeriet Naturstyrelsen, n.d.). The EU Habitats Directive has led to strict protection of Natura 2000 areas: planting of perennial energy crops is subject to strict conditions on Natura 2000 areas under the Nature Protection Act.

Since 1992 there has however been few new political initiatives addressing marginal lands – apart from the initiatives linked to the reduction of nutrient pollution of the aquatic environment e.g. by wetland restoration. In 2001 a Government Committee – the Wilhjelm Committee – presented a number of recommendations for improving the state of nature (Wilhjelm-udvalget, 2001) but there was a limited political follow-up to the recommendations. These clear linkages between marginal land and environmental interests are likely to have influenced the Danish discussion on the use of marginal lands for biomass production as it will be demonstrated in the analysis below.

7.3 Analysis of "environmentally marginal land"

7.3.1 What environmentally marginal land is

Based on the data, environmentally marginal land can be defined as environmentally sensitive land where intensive agricultural production results in adverse effects. The analysis will now turn to the nuances in the definition of this type of land, the way it is promoted, its history, and conflicts over its use. Seven out of twelve Danish interviewees and four documents mention this type of land.

We can see the environmental definition of marginal land in a statement by a Danish academic:

> DA4: Then it seems like we have quite a few hectares of low land or you could say semi wet, which seen from an agricultural perspective is marginal, you cannot use it intensively.

Another Danish academic similarly defines it as land that cannot be used intensively because it could damage the land itself.

> DA3: […] the marginal lands of the river valleys and so on and some of the steep slopes and so on if you do the annual crops there you will damage the resource for the common generations or you will mine the carbon you will promote erosion [...]

Another reason the land is marginal is that its cultivation leads to nutrient leaching in the surrounding streams. A government employee describes this type of land as “politically marginal”: the motivation not to use it intensively is a political one.

> DGov1: I don’t think it’s eh applicable in a physical sense in Denmark but in a political sense it is. […] there are certain areas eh which their physical conditions etc. are in such a way that cultivation will lead to excess eh loading of nutrients into the streams etc. So the political issue is then they are marginal.

Different types of land are discussed as environmentally marginal: DA4 sees it as semi wet lowlands; DA3 sees it as steep slopes and river valleys. Some focus on very specific types of land. A Danish NGO employee describes it as:

> DNGO2: And we have drained a lot of land that maybe shouldn’t have been drained. Eh we have made basis analyse of the loss of nutrients from agricultural land and it’s mostly from lowland and it’s located some specific places in Denmark, mostly about the Limfjord in the northern part of Jutland.

This description of drained lowlands, and possibly DA4’s description above corresponds to what is called “*lavbundsjorde*” or “*lavbundsområder*”: low wet land, often sandy or peaty soils that have been drained. As Jørgensen & Schelde (2011) explain:

> *Lavbundsområder* is the common name for a variety of low-lying areas previously meadows, ponds and marshes, drained lakes and drained coastal areas (marshes) and previous fjord arms, which is now largely cultivated for agricultural purposes. A large proportion of these low-

lying areas is today drained and is often part of normal rotation. Common to them is that they typically have a high content of organic matter in the upper soil layers ('organogenic' soils) and a naturally high ground water levels , which counteracted by draining or possibly pumping of excess water. (p.6).[22]

Hansen (1989) states that the main factor impeding production on agricultural land in Denmark has always been water: either there is too much water or too little. During the 1800s large amounts of wet land, particularly in Jutland, were drained to allow for agricultural production (Madsen, 1989). This had slowed by the 1930s when legislation was introduced necessitating an environmental review before land could be drained (Reenberg & Jensen, 1989). The Limfjord which DNGO2 refers to is a shallow inlet in the North West of Jutland that separates a series of islands. It has the highest proportion of drained land in the country (Nordjyllands Amt et al., 2006).

7.3.2 Environmental benefits of perennial energy crops on environmentally marginal land

Because drained *lavbundsjorde* is low lying it again becomes saturated with water over time and needs further draining. This draining process releases CO2 stored in the land, contributing to concentrations of atmospheric greenhouse gases, and also reducing the land's water cycling benefits. Un-drained wet lands have significant water cycling benefits by storing nutrients and purifying water but when it is drained it is also more susceptible to nutrient leaching of nitrogen and particularly phosphorus (Environment Agency, 1991).

Government bodies and NGOs have called for *lavbundsjorde*[23] to be taken out of cultivation to reduce CO2 emissions and ensure water cycling benefits. Government bodies such as the state appointed Climate Commission and a recent report by the Interministerial Working Group on the cost effectiveness of different schemes for reducing greenhouse gas emissions have called for this measure to be implemented, as well as NGOs including the Danish Society for Nature Conversation and the climate change think tank Concito. Rothenborg & Korsgaard (2013) state this latest call to leave *lavbundsjorde* fallow is the fifth from the government, with none having been implemented so far. Certain groups are opposed to this measure, such as the main farmer's organisation Landbrug og

[22] Original text: Lavbundsområder er fællesbetegnelsen for en række forskellige lavtliggende områder, tidligere enge, kær og moser, afvandede søer og tørlagte kyststrækninger (marsk) samt tidligere fjordarme, som nu i vidt omfang er opdyrket landbrugsmæssigt. En stor del af disse lavbundsarealer er i dag drænede og indgår ofte i normal omdrift. Fælles for dem er, at de typisk har et højt indhold af organisk stof i de øvre jordlag ('organogene' jorde) og en naturligt høj grundvandstand, som modvirkes ved afdræning eller evt. bortpumpning af overskydende vand.

[23] Although, it must be stressed that "environmentally marginal land" as it is described in the data is not always the same thing as *lavbundsjorde.* But the debate over this type of land is illustrative of issues at stake for environmentally marginal land.

Fødevarer who state that it would mean loss of Danish jobs and competitiveness (Rothenborg, 2013).

Production of perennial energy crops on environmentally marginal land, whether it be *lavbundsjorde* specifically or another type, such as land on steep slopes or river banks, is seen as desirable because perennial energy crops do not require as many inputs as arable crops and so will result in reduced levels of nitrogen and phosphorus leaching to surrounding water bodies and reduced levels of pesticide and herbicide pollution. Ministeriet for Fødervarer Landbrug og Fiskeri (2008b) states that environmental benefits can be achieved "by shifting from cereal production in environmentally sensitive land for perennial energy crops with low nutrient and low pesticide consumption."[24] Perennial energy crops also have water cycling benefits beyond their reduced nutrient needs: they can have a remedial effect on soils, removing nutrients from *lavbundsjorde* saturated with phosphorus (Jørgensen and Schelde, 2011). The Organic Research Centre (2010) list the five water benefits of perennial energy crops, specifically short rotation coppice trees, as reducing surface runoff from fields, filtering surface runoff, filtering groundwater runoff, reducing bank erosion and filtering stream water. They state that the 'safety net' hypothesis suggests that the trees' deep roots intercept leached nutrients and reduce leaching compared to bare soil.

This rationale is used by interviewees and in documents for the use of environmentally marginal land. Ministeriet for Fødervarer Landbrug og Fiskeri (2008b) states that the "*fugtige marginaljorde*" (moist marginal land) identified as economically marginal could also have these environmental benefits. Two government documents specifically advocate use of *lavbundsjorde* for perennial energy crops to help fulfil water framework directives, but do not call this land marginal (Ministeriet for Fødervarer Landbrug og Fiskeri, 2008a; Ministry of Food Agriculture and Fisheries, 2010). Other interviewees state that using environmentally marginal land for perennial energy crop production could help fulfil water framework directive targets for reducing water pollution.

The idea of taking advantage of EU land use policies to achieve environmental outcomes goes back a long time in Denmark, with recommendations that EU set aside policy, introduced in 1987, could be fulfilled by taking environmentally sensitive land out of cultivation, thus achieving some of the environmental objectives mentioned above (Dubgaard, 1989; Hansen, 1989).

7.3.3 Conflicts over use of environmentally marginal land

Biodiversity benefits v. water quality benefits

[24] Original text: "[...] ved omlægning fra kornproduktion på miljøfølsomme arealer til flerårige energiafgrøder med lave næringsstoftab og lavt pesticidforbrug."

There are however different views about the proposed uses of environmentally marginal land. There is a perceived conflict between perennial energy crop production on this land to achieve water quality benefits and soil remediation, and leaving the land fallow or cultivating grass, which is seen as providing better biodiversity benefits, as a document by the Danish Ecological Council (Det Økologiske Råd) highlights: "Willow is particularly suitable for *lavbundsjorder*, which also at the same time the need for action in relation to loss of nutrients. But for the sake of biodiversity and nature, should these soils rather applied with permanent grass?" (Det Økologiske Råd, 2010 p.37)[25]

A Danish farming representative advocates the use of very wet soils and organic soils for perennial energy crop production. When asked about marginal land he highlights the difficulty in using this land in practice because much of it is classed as nature protected Natura 2000 land. He states that this land can be kept as grassland instead and harvested for biogas production, if a market is established:

> DI1: But it's in these areas it's difficult to change but then you can use the grass if there's nowhere- it's not interesting using the grass at the moment because we don't have a market for it. […] But in a few years I'm sure we'll have a lot of biogas plants coming up in the next two years.

Similarly, DA4 who above called semi wet lowland marginal land and UKNGO3 state that keeping the land as grassland and harvesting biomass from it retains the land's natural biodiversity and yields biomass for energy, and prevents nutrients leaching into water bodies, a win-win outcome.

> DA4: […] say we go out there and we harvest the biomass once or twice a year depending and then we use that for some intelligent purpose, bioenergy for example and we also remove the nutrients because if it's just laying there all your nutrients are going to the water, in the end in the end.

This issue can be explored in more detail by considering how the biodiversity benefits of willow are framed by interviewees. The idea that perennial energy crops are not ideal for biodiversity can be seen as somewhat surprising given that biodiversity gains were promoted elsewhere as one of the environmental *benefits* of growing perennial energy crops. The issue of biodiversity benefits from perennial energy crops was considered in chapter 6, where we saw that under some circumstances it

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[25] Original text: Energiudbyttet på de gode jorder kan være på højde med majs – og der er et stort potentiale, også på de ringere jorder. Pilen er specielt egnet til lavbundsjorder, hvor der også samtidig er behov for en indsats ift. tab af næringsstoffer. Men af hensyn til biodiversitet og natur bør disse jorder hellere udlægges med vedvarende græs?

was framed as being very good for biodiversity, as expressed by a UK perennial energy crop biodiversity expert:

> UKNGO3: And that [PEC] supports higher order wildlife groups particularly breeding birds for example so willow crops, willow short rotation coppice is *fantastic* for biodiversity.

In contrast, in Denmark biodiversity of perennial energy crops are not framed in such glowing terms. Some frame the biodiversity as better than arable production but not as good as leaving the land fallow, as we can see in the following quote.

> DNGO2: I think one problem is that the amount of biodiversity inside the willow is not very good. It's better than it might be in the intensive farming land but it's not as good as it is in the areas with less amount of nutrients, we need some open air, open air countryside for a lot of the biodiversity.

The UK biodiversity expert UKNGO3 might agree with this point of view, that biodiversity in willow production is better than in arable production but not as good as grass production, as he made some similar points, but it is interesting to note how different the framing is. UKNGO3 said willow biodiversity was "fantastic" and DNGO2 said it's "not very good". The data suggests this negative framing of biodiversity of willow may relate to a question of the right "type" of biodiversity. There is a distinction made between "open" landscapes and "closed" landscapes in the above quote by DNGO2. The Danish Ornithological Society (Dansk Ornitologisk Forening, 2011) state:

> The open countryside is a broad term for the land in rural areas where sunlight can get to. The terrestrial part of the open land includes cultivated arable, meadows, marshes, grasslands, heath and meadow, but excludes forests and cities; there are wet habitats such as lakes and rivers. (p.12).[26]

There are calls for more natural open land in Denmark, which are not compatible with perennial energy crop production. A government document states:

> On biodiversity, the concern is that perennial energy crops will benefit some animals connected to more closed landscapes e.g. field hare, roe, fallow, and red deer to the disadvantage of birds of the open land such as waders, ducks and geese. (Ministry of Food Agriculture and Fisheries, 2010 p.2).

[26] Text in original: "*Det åbne land er en bred betegnelse for de arealer i landzonen, hvor sollyset kan komme til. De terrestriske dele af det åbne land inkluderer den dyrkede ager, enge, enge, overdrev, hede og strandeng, men udelukker skove og byer, dertil kommer våde biotoper som søer og åer.*"

A Danish NGO representative states that they need more open countryside to fulfil the biodiversity convention.

> DNGO2: So we have to be careful not to put willows into all lowland areas in Denmark, we need to- for fulfilling the biodiversity convention we need to have more open land than we have now.

This framing may explain some of the preference expressed for harvesting biomass from natural grassland rather than planting perennial energy crops. Grassland is open land and perennial energy crops are closed land. A Danish energy grower expresses frustration over the issue and feels that the question of biodiversity benefits from perennial energy crops is being misunderstood or misrepresented by NGOs. He states there is a view that they do not get "the right bird":

> DG1: Then there was this problem and we do not get the right birds but I say when I tell them [NGO representatives], "but come on compare with a wheat field then you'll gain hundreds more things of insects, of wildlife then a total sprayed wheat field". And then they said "yes yes, but you have to- you build up these fences of willow, sort of like a bricked wall in the- in nature".

A different kind of biodiversity to that provided by willow is required. Thus we can see that the "environmental benefits" of using environmentally marginal land are not as straightforward as one might assume. There are different, competing environmental aims at work: water quality benefits of perennial energy crops versus the perceived superior biodiversity benefits of leaving the land fallow or for grass production. We will further explore the idea of "open" and "closed" landscapes in the final section.

Water quality benefits v. landscape value

Another conflict that has arisen over environmental marginal land was about the use of watercourse buffer zones for perennial energy crop production. As a follow-up to the 2009 Green Growth Agreement, farmers were obliged to retain a buffer zone of 10 metres along watercourses and lakes above 100 m2 to reduce nutrient leaching into rivers and lakes. (Danish Government & Danish People's Party, 2009). Originally, cultivation of perennial energy crops were allowed in the buffer zones because of the water cycling benefits of perennial energy crops and this type of land was referred to as marginal land by one government document. MFAF (2010) discusses "marginalised areas like buffer-strips alongside streams, ponds and lakes" that can be used for perennial energy crop production under the Green Growth agreement (p.1). There was also an amendment of the Nature Protection Act where cultivation of perennial energy crops were exempt from the general prohibition to plant crops within a 150 m landscape protection zone along designated watercourses. The possibility of growing perennial crops in the buffer zones was, however, repealed by the new Government in 2012 with reference to the potential negative effects of e.g. willow on the landscape. The exemption in the Nature Protection Act to plant perennial crops within the 150 m landscape protection zone has not (yet) been subject to similar controversies.

The agricultural organisation employee DI1 again sees the landscape issue as a reason to favour grass production over perennial energy crop production.

> DI1: […] there's a problem if you need eh not the nature, but the landscape the view over the landscape, there's when willow is 8 metre high it changes the landscape but we can produce almost the same amount of biomass if we have some types of grasses and they don't change the landscape.

A Danish NGO employee sees the landscape issue as a barrier to use of environmentally marginal or "sensitive" land more generally.

> DNGO3: […] they're just not only produce energy but they also contribute to landscape or to biodiversity or to protecting some eh sensitive areas from nitrate. But again the landscape, shooting it into a landscape is a challenge for some of them so it's a question of how can you do this in a in a way which looks good.

Similar to the debate about biodiversity, this is again related to "open" and "closed" landscapes as we can see below. "On the landscape issues, there is concern about 'forestification' of the open agricultural landscape, where 4-6 meter high 'green walls' of willow block the view." (Ministry for Food, Agriculture and Fisheries, 2010a p.2)

A government representative uses the same language of "closing" the landscape.

> DGov1: Because they don't want this to close down on the rivers they want to you're able to see the landscape.

The grower DG1 again frames the question as a misperception about the "naturalness" of willow production. In this case willow is seen as something that is not natural in the landscape, hence why people object to it.

> DG1: But then also people in eh with the environmental angle eyes glasses on some of them think willow is something that the bad man created because it doesn't looks very nature-like and it's difficult, […].

Here again we can see that the use of environmentally marginal land for perennial energy crops to achieve environmental benefits is contested. There are competing aims for the land, in this case keeping the land as an “open” rather than “closed” landscape which again favours grass production.

7.4 Analysis of environmentally marginal land in terms of paradigms of agriculture

To understand the different views about environmentally marginal land better we will draw on notions of multifunctional and post-productionist agriculture described in chapter 3. As we saw in chapter 3 the idea of a multifunctional agriculture has been promoted since the early 1990s in Europe as a way around the ills caused by industrial “monofunctional” agriculture, especially within the EU Common Agricultural Policy (Potter & Tilzey, 2005). Van Huylenbroeck and Durand (2003) define multifunctionality simply as "[…] the joint production of commodities and non-commodities by the agricultural sector." (p.1). Multifunctionality is seen to involve a move from productionism towards extensification, on-farm diversification and environmental protection. In the policy context it means the withdrawal of production subsidies and a move towards different subsidies for the retention of minimum environmental standards, environmental initiatives and diversification. In chapter 3, multifunctional agriculture was placed within the alternative paradigm because of this emphasis on environmental outcomes and sustainable rural communities, and because it involves many of the production systems seen to be within alternative agriculture such as farmers’ markets and low input production systems. Without going into the different theoretical strands of multifunctionality and arguments about the extent to which it is happening in reality, this section will consider ideas that are relevant to the analysis.

While the industrialism lite strategy was at the margins of the industrial system, use of environmentally marginal land can be seen as within the alternative multifunctional paradigm of agriculture. The idea of producing biomass on environmentally marginal land, which will be referred to as the “multifunctional beneficial biomass” strategy, can be seen as a type of alternative agriculture because it is a move away from the previous productionist model and has little in common with the life sciences integrated model. Though it is not entirely independent of the productionist model, but is suggested as a response to the environmental damage caused by productionist methods. While the productionist era was characterised by a policy emphasis on encouraging production, multifunctional agriculture involves imposing restraints on intensive production, which perennial energy crops do by mopping up the nutrient surplus caused by intensive cultivation (Wilson, 2007). One Danish NGO employee voiced opposition to this strategy because he wanted more radical and systematic changes within agriculture.

> DNGO1: Why don't you stop producing so much nitrogen in eh in artificial fertilisers? I mean the Haber-Bosch process is a very energy requiring process and eh we produce huge amounts of artificial fertiliser and this country is saturated if you will with nitrogen and phosphorus. Y'know we need a lot less of it. But why not stop putting it onto the land rather than talking about "oh wonderful willow can soak up some of it".

Thus this strategy could be seen not as a different model of production, like ecologically integrated agriculture is supposed to, but relates to different non-production roles and priorities for farmers and land use, which perennial energy crops can fit within. Some promoted CAP reform after 1992 as a way to ensure the competitiveness and efficiency of productive sectors of agriculture and move less productive areas towards a role of environmental service provision (Levidow and Boschert, 2008). Levidow & Boschert (2008) quote a proponent of this type of reform: "[…] where European agriculture can be competitive, this competitiveness should, within environmental limits, be maximised. Where it cannot be competitive, farming per se should be downgraded behind good environmental husbandry as the linchpin of a subsidy/welfare system." (Haskins, 2002 p.7 in Levidow and Boschert, 2008). Tim Benton, the UK Champion for Food Security echoes this view: "Some areas can naturally produce food more easily than others, and conversely, some areas are better at providing other ecosystem services (such as biodiversity, the cultural value of the landscape, providing flood defences or clean water.)" (Benton, 2012). Potter (2009) similarly states that there are two rationales for supporting agriculture with public money: the working land rationale and the public goods rationale. He maintains that food crop biofuels were promoted within the working land productionist mindset while also being touted as achieving certain environmental outcomes. The beneficial multifunctional biomass strategy could be seen to swing more towards the public goods side. It is not primarily driven by the aim of producing vast amounts of biomass from the energy sector, but rather of meeting environmental aims for land use. A UK interviewee voiced a similar view about different types of land use accomplishing two different aims.

> UKGov1: Yeah yeah yeah it depends where you think farming's going to go in the future you've got the sort of sustainable intensification agenda so does that what in theory would be the best farmland will be farmed more intensively as we move forward but marginal land will be used for the other benefits that it it could provide for for the country.

Some farmers have objected to this aim because it would make smaller and less productive farmers more dependent on subsidies while boosting the industrial, large scale sector of agriculture (Levidow and Boschert, 2008).

But as we saw above, the use of environmentally marginal land for perennial energy crop production was contested. Both uses of environmentally marginal land discussed in this chapter, perennial energy crop production for water quality benefits or the production of grass for biodiversity and landscape benefits can be theorised in terms of multifunctional agriculture. Van Huylenbroeck and Durand (2003) conceptualise the new role of farmers as multifunctional land managers in three areas: space, where farmers provide stewardship and landscape services; production of food and other products; and service functions in maintaining rural areas and contributing to biodiversity and rural development. Perennial energy crops on marginal land is promoted in terms of farmers' service functions in providing environmental benefits in the form of water quality benefits and their production role by producing energy feedstocks. The production of grass on environmentally marginal land can be seen to fulfil all three objectives: farmers provide stewardship and landscape services, production of bioenergy feedstocks and environmental benefits. It could be suggested that the grass v perennial energy crops question represents opposing multifunctional aims for land use. Farmers' role of providing water cycling benefits through perennial energy crop production is seen to conflict with other environmental services in the form of biodiversity benefits, and farmers' role as stewards of environmental landscapes.

The first aim of providing water quality fits with some farmers' post-productionist role as a "local environmental manager" as Marsden (2003 p.139) puts it. Marsden and Sonnino (2008) use the term "post-productionism" to mean a particular form of multifunctionality, which replaces a farm-based approach to agricultural management with a land-based approach. Here land is seen as a consumption space to be exploited by urban and ex-urban populations. It highlights the different ecological, production, landscape and social functions of land. This role is putting a different kind of pressure on farmers. Scopolleti et al. (2012) state that human preferences for landscapes are due to aesthetic preferences and social conventions that are passed down through human culture from one generation to the next. Marsden (2003) maintains that in recent years there has been increasing migration of urban dwellers to the countryside in the UK consisting of commuters to an urban base, retirees and tourists. These people may have a preference for what the countryside should look like, and their preservationist, anti-development mentality can conflict with farmers' diversification and enterprise schemes, creating areas where a preservationist mentality prevails, or areas of "contested countryside" (Marsden, 2003 p.103). We can see the same dynamic echoed in the case of perennial energy crops described in Denmark. A UK interviewee sees this dynamic as one of age difference and farming versus non-farming dwellers, rather than urban versus rural populations.

> UKGov1: It’s like anything, change people don’t like change do they? And certainly if you look at the population in England it tends to be older more affluent people who live in rural areas so therefore they have more of a conservative view of what they what they expect. So you get less and less people as time goes on involved actively with agriculture and so more and more people that live in the villages around the farms aren’t directly involved in it but have, want to have a say in how things, how the landscape looks, so you’ve got quite interesting sort of dynamic there really.

Thus we can suggest that the second conflict between the water quality benefits of perennial energy crops and its effect on the landscape can be understood in terms of two different multifunctional uses of land: provision of environmental services and as a post-productionist landscape consumption space. For now this is just a suggestion and more research into population countryside dynamics and why people object to willow in the landscape would be needed to substantiate this particular interpretation. But it provides a useful way for thinking about the conflicts on environmentally marginal land within the multifunctional agriculture model.

This point about countryside “consumer” preferences for types of landscapes also taps into a wider debate about open and closed landscapes. Tscharntke et al. (2005) see the preference for open as opposed to closed landscapes, which we saw in the data, as being motivated by a preference to maintain agricultural landscapes from the 19th century: “In these human-dominated landscapes, conservation strategies are a matter of public debate over which type of ecosystem or landscape is wanted and should have priority for conservation. The diverse habitat mosaic created by low-intensity agriculture, as practiced in the middle of the 19th century, is the most appealing vision of a complex rural landscape for most conservation-minded people. Few conservationists argue in favour of just deciduous forests as natural, late-succession ecosystems. Hence, conservation programmes usually combine traditional man-made ecosystems (mainly grassland, heathland) with little used forests." (p.859). This debate has been particularly lively in France since the 1970s (Le Floch et al., 2005). The term “closed landscape” has been used in debates about land use to oppose the forestification of agriculture land, either through voluntary forestation schemes or through natural processes that followed agricultural land being taken out production. Le Floch et al. (2005) state that the term “closed landscape” had connotations of isolation and disconnection and associations with the abandonment of agriculture land, loss of rural populations and culture. The contingent and culturally conditioned nature of preferences for open and closed landscapes is underlined in a study by Lepart et al. (2000) on a karst region in France. At different times from the 19th century to the present closed, forested landscapes and open, pastoral landscapes were seen as preferable for environmental and social reasons.

This issue also connects to a debate about what “natural” land management means, whether protected and changed by human action or left to its own devices. Friedberg (2000) explores the nuances in farmers’ and tourists views of open and closed landscape of a karst landscape in France and finds that the landscapes people prefer can neither be said to be “artificial” or “natural” but correspond to the landscape as it was in a particular time in the landscape’s evolution. The description of willow by a grower as “unnatural” suggests that some associate open landscapes with natural landscapes in Denmark. More work could be carried out investigating the exact meaning of open and closed biodiversity and landscapes within a Danish context and why there is a preference for these types of land use.

In terms of the conflicting open and closed biodiversity benefits, we can note that biodiversity, like marginal land, is a contested concept whose definition is not fixed (Swingland, 2001). Swingland (2001) states that the simplest definition of biodiversity is the number of species but more nuanced definitions include the genetic diversity, species richness and ecosystems diversity among other factors. Thus stating that grass is “better” for biodiversity than willow production could seem to mean at first sight that it houses more species. But the debate appears to be more complicated. Different biodiversity aims are not necessarily always compatible: maximising genetic diversity may not involve the same strategy as maximising ecosystems diversity. There is a wider debate within conservation and agriculture about what “type” of biodiversity should be preserved that relates to open and closed landscapes. A blogger advocating more natural spaces expresses frustration at the preference for open landscapes and suggests a reason for this in terms of numbers of species and a perception of what “the natural order” is:

> It is hard to engage conservation professionals in discussion about the nature of wild landscapes. Theirs is a commitment to predominantly open landscapes as it offers the greatest response in maximising species diversity and number counts as a result of their management action. Without much analysis, they take these managed open landscapes as being indicative of the natural order. (Fisher, 2009).

His description is reflected in the above analysis where open landscapes were preferred to closed. Thus in this account biodiversity benefits of grass are seen in terms of a higher species diversity and richness. More work could be undertaken to explore why open landscape is preferred in Denmark from a biodiversity point of view. Fisher above states that it is seen to provide the highest species count and diversity in the UK and it would be interesting to investigate why more open land is needed in Denmark to fulfil the biodiversity convention as one agriculture industry representative stated.

To summarise, while the multifunctional model was placed within the alternative paradigm, the production of perennial energy crops on this type of multifunctional land use does not represent a production system that is a significant departure from productionism, unlike ecologically integrated agriculture, but rather in some sense complements industrial production. The use of *environmentally* marginal land is a step further than the production of perennial energy crops on marginal land because it not only aims to produce little or no harm to the environment, but rather aims to clean up some of the environmental damage of industrial production in what is being referred to as multifunctional beneficial biomass. Though, as we saw, the place of perennial energy crops is contested within this framework because of opposing multifunctional aims for land use, which can be understood in terms of preferences for open rather than closed landscapes.

7.5 Conclusion

Marginal land for biomass production, particularly perennial energy crops, is seen by many as a way around the previous global land use controversies faced by food based biofuels that used prime land. Many maintain that "marginal land" as it is conceived in the global biomass debate as low quality agriculture or non-agricultural land, does not exist in significant quantities in industrialised countries. We see in this chapter that the term "marginal land" is thus also promoted with a different meaning: land where intensive agricultural production results in significant damage to the land itself or the surrounding area. It is not necessarily the case that commercial agricultural production is not possible on this land, but rather it is not considered *desirable* because of these local environmental impacts. This concept has a somewhat different aim to "marginal land": it does not aim to overcome global land use controversies but rather focuses on addressing local environmental problems caused by intensive agriculture systems. This definition was found almost exclusively in Denmark and refers to e.g. wet lowlands, steep land along rivers and water course buffer zones. Some of the land discussed can be put under the category of *lavbundsjorde*: drained low land peaty or sandy soils that are porous and susceptible to nutrient retention and leaching when used for arable production.

Wider biofuels land use controversies are global in nature: they see land in one part of the world as connected to land in another through changes in demand for land. Palmer (2014) states that in the EU, land for biofuels is discussed in a very narrow, abstracted way so that land use becomes reduced to a question of greenhouse gas accounting related to ILUC. We can see that this is not necessarily the case in the Danish land debate. The motivation for using environmentally marginal land for biomass production does not come from the global biofuels land debate but rather relates to the role marginal land historically has had for environmental and nature protection purposes in Denmark, suggesting the existence of a parallel, place-specific marginal land for biomass discussion.

The other important point to take from this is that advocating use of marginal land does take not away inherent land use related conflicts. Achieving synergies between biomass production and environmental aims appears like a win-win strategy but it is not always straightforward in practice. There are different environmental aims of using the land and the analysis suggests some believe that perennial energy crops are not the best crops to achieve these. It should also be noted that use of this type of land does not contribute to tackling the food versus fuel and ILUC issues, which could remain an issue for this type of land use, if one considers these to be problematic.

Perennial energy crop production can be seen as a more environmentally beneficial use of land compared to arable production because it will reduce leaching, increase soil carbon and restore degraded soils. Conflicts arise however over the proposed use of perennial energy crops on environmentally marginal land when it is compared to grass production. The water quality benefits of growing perennial energy crops are seen to conflict with the superior biodiversity benefits of managing the land as grassland. While perennial energy crops are framed as being better for biodiversity than arable production, some maintain that Denmark needs more open land, such as grassland which supports a different kind of biodiversity compared to the closed landscape of perennial energy crops. The water quality benefits of perennial energy crops are also seen to conflict with its effects on the landscape. The 2009 law allowing the production of perennial energy on water course buffer zones was repealed in 2012 due to objections to the impact of perennial energy crops on the landscape. They were seen to close off the landscape and restrict view. This conflict again shows a preference for open landscape such as grass rather than closed landscapes like willow, which are not perceived by some as “natural”.

It was suggested that perennial energy crop production on environmentally marginal land fits with the multifunctional model of using agricultural land to produce different products and fulfil environmental aims within the alternative paradigm of agriculture. The conflicts over the use of the land for perennial energy crops can be seen to relate to different multifunctional aims for agriculture: providing different environmental services and farmers as stewards of the landscape for “consumers” of the countryside. This means that it is one step further than industrialism lite described in the previous chapter that seeks to minimise the negative impacts of biomass production. Instead it tries to synthesise the aims of producing biomass for energy and improving the quality of agricultural land and the surrounding environment. It does not represent a radically different production system from productionism and could be seen to fit within (though all the proponents of this view might not necessarily see it this way) a bifurcation of agricultural land into productive internationally competitive land and non-productive or less productive land that is subsidised and fulfils environmental aims.

Chapter 8 Biomass within multipurpose agricultural systems

8.1 Introduction

This chapter will explore the idea of perennial energy crop and crop residue use within multipurpose agricultural systems, as it is described in interviews and documents. Chapter 7 analysed the use of environmentally marginal land for perennial energy crop production in terms of multifunctional agriculture. The term "multipurpose agriculture" is devised here for the purposes of this analysis and is being used here in a different way to "multifunctional" agriculture. It does not refer to the multifunctional model described in the previous chapter but rather is a different answer to the question of how perennial energy crops and crop residues will help overcome controversies raised by food based biofuels. The answer within this chapter is that they will overcome these controversies by using these feedstocks to produce different things at the same time, overcoming resource constraints. This is seen as happening within two different models of agriculture: within the industrial life sciences integrated model and the alternative ecologically integrated model. Multifunctional agriculture in the last chapter dealt with the production of biomass and environmental services at the same time. Here "multipurpose" biomass production means primarily producing biomass for energy at the same time as other material goods, and potentially environmentally services as well. Within the industrial life sciences integrated model this means using biomass in a biorefinery within the larger bioeconomy, and within the alternative ecologically integrated model this means the production of multiple products on the same piece of land to harness synergies between products. The purpose of the chapter is to examine the assumptions, theories and nuances involved in the life sciences integrated and ecologically integrated multipurpose systems in order to address the core research questions namely, whether and how perennial crops and residues are seen as overcoming previous controversies raised by food crop biofuels.

This chapter will outline the life sciences integrated model and then the ecologically integrated model. Particular concepts that appear to cut across the life sciences integrated and ecologically integrated agriculture concepts will also be identified, that arguably represent a bottom-up Danish conception of multipurpose biomass production. The chapter will then consider the place of perennial energy crops and crop residues in these systems in more depth, if they have a place or if other feedstocks are preferred, before concluding.

8.2 Life sciences integrated model of multipurpose biomass production

8.2.1 Background

First the chapter will give a brief overview of the bioeconomy concept in the UK and Denmark to provide some background information for this section. The industrial life sciences integrated multipurpose biomass model examined in this chapter is basically the same as the bioeconomy strategy first highlighted in chapter 2. However this chapter is framed in terms of multipurpose biomass rather than the bioeconomy to facilitate a comparison between the life sciences integrated model and the ecologically integrated model because the ecologically integrated model, as it explored in the data, is not always framed in terms of the bioeconomy[27]. The Knowledge Based Bioeconomy (KBBE) strategy was launched in the EU in 2005 as a way of integrating previously existing visions of the Knowledge Based Economy – the idea of an economy built on communication and information services – and the bioeconomy – (European Commission, 2005). The EU's 2020 Strategy for a bioeconomy in Europe was proposed as a way to ensure the sustainable use of resources, whilst ensuring competitiveness and fostering innovation in Europe. It aims to safeguard food and energy security whilst overcoming resource constraints, dependence on non-renewable resources and tackling climate change. The strategy is based on the idea of using food and non-food agricultural goods to produce a range of materials, similar to those from an oil refinery, in what is called a biorefinery.

Industrial biotechnology – the technology underpinning the bioeconomy – has been promoted by the UK government since the 1970s as a way to achieve economic growth and global competitiveness (Birch, 2009). Biotechnology is the exploitation of biological processes for industrial and other technological applications. The bioeconomy is promoted as a research and development priority within the UK and has been promoted by influential academics as the way forward for bioenergy use (Taylor, 2008). The UK government set up the Industrial Biotechnology Innovation and Growth Team (IB-IGT) in 2007 with the aim of making recommendations to the UK government about how to develop the bioeconomy (NESTA, 2011). The IB-IGT published their recommendations of how to fund and resource bioeconomy research in the UK (BERR, 2009), which have been largely adopted by the government. The biotechnology and biological sciences research council (BBSRC) officially linked bioenergy with the bioeconomy concept and named this as one of their three priority areas in the 2010-2015 strategy (BBSRC, 2009). Biomass was also linked to the development of the bioeconomy in the 2012 government Bioenergy Strategy, as we will see below. Thus we can see that

[27] Though there is an ecologically integrated version of the bioeconomy strategy in the wider literature (Levidow et al., 2013). We will come back to this point later.

the bioeconomy concept is important in the UK, though biofuels and biomass for heat and power were originally promoted separately from the concept of the bioeconomy. As was detailed in chapter 2 biomass and biofuels for energy were promoted to fulfil energy security, climate change mitigation and rural development priorities and were later joined up with the bioeconomy agenda.

By comparison with the UK the bioeconomy concept was a more integral part of biofuels policy in Denmark (Hansen, 2014)[28]. The Danish government was initially reluctant to implement EU biofuels targets because of concerns about sustainability and the cost effectiveness of carbon saving, but introduced the Sustainable Biofuels Act in 2009 because of pressure from the EU and lobbying by the biotechnology industry that Denmark risked being left behind in the race towards the bioeconomy (Hansen, 2014). Thus its importance for the future bioeconomy was one of the rationales for biofuels promotion within Denmark. The development of a thriving bioeconomy sector in Denmark is now an important aim for the government. A report by the Ministry for Business and Growth sets out the Danish strategy for developing the bioeconomy (Erhervs-og Vækstministeriet, 2013). Denmark has been funding biotechnology research since 1987 and is a hub of biotechnology companies, including Novozymes and Danisco, two of the largest enzyme companies in the world (Suschems et al., 2009). The report by the Ministry for Business and Growth seeks to develop supply chains, foster a European market for biobased products, further research on biobased products in Denmark and ensure there are sustainability criteria for all biobased products (Erhervs-og Vækstministeriet, 2013). The government has put forward various funding streams for research and development of the bioeconomy, one of the main ones being the Green Development and Demonstration Program (GDDP; in Danish *Grønt Udviklings- og Demonstrations Program* (GUDP)) which funds research and development in agricultural sciences. This has funded projects such as the Danish Roadmap towards the biobased society from 2011 to 2012 led by Novozymes, DONG energy – Denmark's largest energy company and Haldor Topsøe, a Danish catalysis company. There are currently several pilot biorefineries up and running in Denmark, including Inbicon, a plant established in 2009 that produces cellulosic ethanol and is working towards producing jet oils and biodiesel (Inbicon, n.d.). In 2013 the Danish government established the National Bioeconomy Panel consisting of industry, academic, NGO and other experts in the area to advise the government on how best to work towards a bioeconomy vision (Ministeriet for Fødevarer Landbrug of Fiskeri, 2013).

The chapter will now explore the life sciences integrated model of multipurpose biomass production, which as stated earlier has much in common with the bioeconomy strategy.

[28] Though the same is not true of biomass for heat and power, which has a longer and more established history, as described in chapter 2

8.2.2 Analysis of life sciences integrated model of multipurpose biomass production

Processing of biomass into multiple products

The production of multiple products from biomass within a biorefinery was promoted in documents and interviews in the UK and Denmark, though to a much greater extent in Denmark. Concepts related to multipurpose agriculture were expressed by nine Danish interviewees and four UK interviewees. The life sciences integrated version of this idea involves growing grain, grass or perennial energy crops in the type of production systems outlined in chapter 5, which are then processed into food, feed, industrial produce such as chemicals and plastics, and energy production in the biorefinery. Similar to the goal expressed in the European Commission's 2005 Strategy, interviewees maintained that using biomass in multiple ways could help overcome previous resource competition for both food production and environmental services. This is particularly the case for the use of crop residues, which are painted as making production of crops dual use. A Danish industry representative states:

> DI3: […] we're talking yeah food *and* fuel. And we should look at in that perspective. We should not look at it only, we should not see this as two things that are actually competing against each other we should see this as a feedstock which can produce both.

A Danish academic states that the bioeconomy concept is about producing win-win outcomes for agriculture and the environment:

> DA2: But I'd really like to combine the efforts on bioenergy with the efforts of generally decreasing environmental impact of agriculture. So I think that's a key aspect that we can't solve just one problem at a time we have to solve several aspects because we only have one piece of land, one globe and we have to rethink things and make win-win solutions.

The production of multiple goods from lignocellulosic feedstocks such as perennial energy crops and crop residues is advocated in a report on Denmark's biomass potential from Gylling et al. (2012):

> Concretely speaking, the cellulose and hemicellulose is converted into sugars and fermented to produce fuels and chemicals. Lignin can be incinerated for the production of heat and electricity or gasified and refined into fuels and materials and, finally, proteins and oils

> converted to feed and food. When all else extracted from the biomass is converted, the remaining part is turned into biogas together with waste and manure. (p.9)[29]

The production of multiple products can substitute for land use, in the same way that increased productivity was seen to free up land, as outlined in chapter 5. In their report Gylling et al. (2012) state that a smaller amount of land will be needed to produce today's levels of food and fodder because fodder can be produced in biorefineries in conjunction with other products. They state: "An important element in the use of new technology for optimized conversion of biomass is that it will reduce land use." (p.9)[30]

The biorefinery concept is also seen as something that can be used in tandem with increasing yields that can help overcome scarcity and competition. As explained by a Danish academic:

> DA2: If we double yield and use the biorefinery concept we would be able to produce still the amount of food we produce today or feed and upon that energy and materials so we can avoid this conflict of food and fuel.

The bioeonomy concept is more commonly promoted in Danish than in the UK data, in both interviews and documents. One of the few instances of its use in a UK document was in the 2012 Biomass Strategy (DfT et al., 2012). One of the stated aims of the strategy was to analyse the links between the use of biomass in bioenergy and in the wider bioeconomy. They see bioenergy as part of a wider bioeconomy strategy that has the potential to reduce carbon emissions and increase the UK's economic competitiveness. They state:

> Bioenergy can also offer further opportunities by driving innovation in materials that can be used in non-energy sectors (for example, the production of biofuels through a variety of advanced conversion technology routes could be used to produce a range of co-products in what could be termed as a 'biorefinery'). (p.36).

The analysis in the Biomass Strategy however deals with the possibility of conflict over resources use between energy production and other sectors. They consider if sectors that currently use biomass can switch to other materials, given increased competition for these materials in future. Thus, while

[29] Text in original: "Princippet er at anvende biomassens komponenter der, hvor de gør størst nytte og derfor typisk også har størst værdi. Det vil I praksis sige, at cellulose og hemicellulose omdannes til sukre og fermenteres til brændsler og kemikalier. Lignin skal forbrændes til produktion af varme og elektricitet eller forgasses og raffineres til brændsler og materialer, og endelig skal proteiner og olier udvindes til foder og fødevarer. Når alt andet er udvundet af biomassen omdannes den resterende del til biogas sammen med affald og gylle."

[30] Original text: "Ved at udnytte biomassens komponenter optimalt kan der produceres flere ydelser fra det samme areal."

rhetoric in Denmark tends to deal largely with the bioeconomy and biorefinery concept *overcoming* resource conflicts, it is not endorsed in such a wholesale way in the UK documents analysed, with the Biomass Strategy considering resource *conflicts* within the future bioeconomy. This could suggest that the bioeconomy concept is having more of an impact on the ground within the bioenergy sector in Denmark than the UK, possibly because the bioeconomy concept was a more integral part of the establishment of biofuels policy in Denmark than the UK (Hansen, 2014). Interviewees were not asked specifically about the use of biomass within the bioeconomy, but Danish interviewees spontaneously used the concept to a large extent. But more research would need to be carried out to substantiate this finding.

Environmental sustainability through intelligent production systems and ingredients view of biomass

Both life sciences integrated and ecologically integrated models of multipurpose agriculture systems were promoted with environmental sustainability in mind. Different versions of environmental sustainability were promoted by the different models. Levidow et al. (2013) found that the industrial version of the multipurpose agriculture saw previous sustainability problems as caused by inefficient use of resources. This can be remedied by greater productivity and efficiency through the application of scientific innovation, as was highlighted in chapter 5. Levidow et al. (2013) found an emphasis within the life sciences integrated conception of multipurpose agriculture on the use of scientific innovation and development to optimise biomass production for the bioeconomy from groups attempting to influence EU policy. As well as getting more from agriculture by increasing productivity and producing different things, extra value can be extracted from the product in the biorefinery itself, through “innovative”, “smart” and “intelligent” production systems. This was reiterated in the interviews with some interviewees stating that productivity should be increased not through the old model of adding more inputs but through scientific research and innovation and the use of “precision” farming, with targeted use of inputs and genetically engineered crops, which we also saw in chapter 5.

It also involves substantially redesigning agricultural production to meet the needs of the biorefineries (Levidow et al., 2013; CREPE, 2011). This was reiterated by a Danish academic interviewee, showing the place of lignocellulosic feedstocks such as perennial energy crops within this system:

> DA2: [...] we have to introduce totally new production systems in the primary agriculture so they should deliver high volumes of biomass for biorefineries instead of producing grain and straw as they do today.

This is linked to the idea of biomass being divisible into “ingredients” that can be recombined at will. As CREPE (2011) state: “Research seeks generic knowledge for identifying substances that can be extracted, decomposed and recomposed along value chains; […].” They point out that this is similar to one of the ways in which novel foods are differentiated in today’s market. Allaire and Wolf (2004) state that foods can either be identified as a mass produced product, the logic of standardisation; by their region of origin, in schemes such as the Appellation d’Origine Controlée in France, called the logic of identity; or in terms of a bundle of constituent components, which they call the logic of decomposition/recomposition. Under the logic of decomposability the biomass is seen in scientifically reductionist terms, it is identified by the characteristics that make it suitable for processing in the biorefinery, such as “degradability”, and the ingredients that can be used. As mentioned earlier, this is seen as a way around the food versus fuel problem. If one crop can be used for both then there is less of a conflict. This decomposition/recomposition logic is intended to provide greater flexibility in the system and the biomass can be used where it is most needed. A Danish NGO employee states:

> DNGO3: We are going to take out some ingredients for feed, some for food and the rest for other purposes. Which means that we can get more flexibility in the system.

This is part of the framing of biomass as the fossil fuel of the future (Hansen, 2014). A Danish government representative voices this framing.

> DGov1: Well it is the building stone so to speak for a lot of things. Whatever you have in the fossil fuels you have in biomass.

This view is reiterated in Gylling et al. (2012). Interestingly, in some cases, the scientific reductionist logic of decomposition/recomposition is seen to replace traditional identification of the crops in terms of their identity as a food or feed crop etc. The Danish farming industry employee states that in time the same things can be produced from a crop no matter what “type” of crop it is:

> DI1: But we are working on it so in the next ten, fifteen, thirty years we will actually be much better of producing feed and energy on- from the same areas no matter what type of crops it is we have on the field.

Another interviewee reiterates this point saying that efficiency and sustainability are what matter. When asked whether the distinction between food and fuel crops is an important one a Danish NGO employee states:

> DNGO2: […] personally not not as a principle, as a principle if if the sustainability criteria is good, if it's very efficient, if you get a lot of energy from this crop then I then I think it's very difficult to distinguish between eh willow and wheat for example, if you have a technology which is as efficient in the wheat crop as in the willow crop.

This is an interesting framing of energy crops that breaks down the food and fuel distinction, as it would be "difficult to distinguish" between wheat and willow. If future technologies mean that all "types" of crops can fulfil food, fuel or feed roles then these distinctions are not necessary. As we see here, similar to the findings of Levidow et al. (2013), Schmid et al. (2012), CREPE (2011) and Levidow (2008) efficiency in production and in the crops themselves is promoted as a very important value.[31] The Danish academic DA2 states that the most "efficient" crops should be sought as the best energy sources. In this context he discusses producing animal feed from perennial energy crops, which are not traditionally viewed as feed crops.

> DA2: […] we can utilise some these more efficient crops, put them in the biorefineries, take out feed stocks for the animal and then use the rest for bioenergy. Then we don't reduce necessarily at least, we can choose, we can wait how much we will use for food or for energy depending on a lot of factors. We have the choice to keep the production of food from the perennial energy crops.

Thus within the life sciences integrated model of agriculture, the kind of crop that perennial energy crops are is negotiable. This suggests that the debate may be moving on from the rationale seen in chapter 2 of using perennial energy crops because they were non-food crops. DA2 frames perennial energy crops as potential sources of animal feed, and he uses the word "food" above, suggesting that what is valued in feedstocks under the life sciences integrated bioeconomy conception is their flexibility rather than whether they are a food crop or a non-food crop. This analysis is based on a limited number of sources but it suggests that the parameters of the debate may be changing and within the bioeconomy system perennial energy crops and crop residues are expected to overcome previous controversies raised by food based biofuels not because of their status as non-food feedstocks but because of their flexibility, efficiency and the usefulness of their ingredients.

[31] We dealt briefly with the meaning of crop "efficiency" in chapter 5. It was stated that crops becoming more efficient means that plants can use fertiliser, nutrients and water more "efficiently" in growing, and produce more of the desired output per unit of input (Levidow et al., 2013).

Extract maximum value from biomass

The idea of extracting the maximum value from biomass was also expressed within the agro-industrial model. Here value generally means economic value. The ingredients view of biomass facilitated this idea, as biomass that was decomposed could then be targeted to the most valued use. Burning was seen as a low value use of biomass. The Danish grower stated that willow was “too good to burn”. A Danish agriculture employee went so far as to call combustion a “very destructive” use of biomass. This quote from a Danish government employee resonates with what Rødsrud et al. (2012) call the “biorefinery strategy” of extracting the maximum economic value from biomass, and with the industrial conception of the bioeconomy that sees biomass in terms of its economic value (Birch et al., 2010; Levidow et al. 2013; CREPE, 2011; Schmid et al., 2011).

> DGov1: Most of the biomass will have to be used- or will be used for energy is a low value relatively speaking. You will possibly get in the future other uses of biomass that is higher value for materials, plastics or whatever.

Its use in a biorefinery was also framed by a Danish industry representative and a UK industry representative as “adding value” to the biomass that can actually result in a product which is more valuable than what you started off with. The same is true of crop residues. A UK bioenergy industry employee discusses how using crop residues in the energy sector is seen as adding value to the product and making the most out of a resource intensive production, he mentions using more of the biomass “for all the inputs we put into it.”

> UKI2: […] we’ve been asked by industrialists who are looking at straw who also are aware of other companies that are looking at ethanol production, actually can we add value to their product. So there are clear interests in synergies in looking at whole crop utilisation for bioenergy, which would improve its GHG credentials if we’re using the straw as well as the grain.

8.3 Ecologically integrated multipurpose biomass

The section will explore the ecologically integrated model of multipurpose biomass production within the alternative paradigm. It will explore the way biomass is framed within this model and assumptions underpinning these framings, before going on to consider overlaps between the systems.

Biorefinery concept

The biorefinery concept is also advocated to a limited extent by people promoting alternative, ecologically integrated multipurpose biomass systems. The words “biorefinery” or “bioeconomy” were not found in sources that could be considered to have an overall alternative view of agriculture but themes related to these were found. A document by the International Centre for Research on Organic Food Systems (ICROFS) discusses the idea in a document outlining their BioConsens research project: “The objectives are: Conversion of grass-clover, animal manure, energy crops (e.g. maize and rye) and agro-industrial byproducts from organic farming to biogas, bioethanol and fodder protein in laboratory and full scale studies.” (p.2).

It can be noted that the language describing residues from agriculture as “agro-industrial byproducts” blurs the boundaries between agriculture and industry. This is an organisation and project that would normally be put in an “alternative” model of agriculture because it is researching organic systems. Similarly a Danish academic who otherwise holds an alternative view of biomass production states:

> DA1: […] the bioenergy should contribute as much as eh relevant for not destroying the environment and also for not reducing the the source for for food and fodder and fibres and chemicals also so I think biomass is a very valuable eh resource which should not just be burned. And and which should not be used to drive your car to the supermarket.

Levidow et al. (2013), Schmid et al. (2012) and CREPE (2011) explore alternative visions of the KBBE from groups involved in alternative agri-food networks, thus there are alternative agriculture visions of the bioeconomy concept out there. This chimes with the point made by Lang and Heasman (2004) that the ecologically integrated model, like the life sciences integrated model, sees developments within the biological sciences as the way forward for agriculture. A specifically alternative bioeconomy, biorefinery vision was not evident in the majority of the data in this study, but rather the multipurpose aspect of biomass production was at the level of *production* on the farm, rather than at the level of *processing* in a biorefinery. So while it is important to acknowledge that this alternative vision of the biorefinery exists, the focus of multipurpose biomass production on the farm level within alternative systems will be at the level of production in this chapter.

Multipurpose land use

Much of the alternative multipurpose production of biomass involved the use of “agro-forestry” methods: the combined production of energy crops and food. This was promoted by six interviewees. A secondary food crop can be grown alongside the energy crop, or pigs or chickens can graze underneath the crop. Production systems of this type are seen as a way to overcome resource constraints and the increasing demands placed on agriculture, as the ORC (2010) state:

> This ‘food–fuel–biodiversity’ conflict calls for multifunctional land use which can simultaneously meet the various demands of food and fuel production, environmental and biodiversity protection, in addition to providing the capacity for adaptation or resilience to climate change. (p.7).

A Danish academic contrasts this with large scale purpose grown energy crop production, which she does not agree with:

> DA1: […] if you have agriculture with trees in between the fields like in agro-forestry for instance then you might use in small scale the perennials for energy production at a local scale or so. But these huge plantations just for energy as energy crops I think that’s the wrong way to use the land.

Although the promotion of agro-forestry was mostly a Danish phenomenon within the data, it can also be seen in two UK documents. The Centre for Alternative Technology state:

> We presume increased multi-functionality in agriculture. There are always several potential parallel yields from a given farm or area of land, and they should all be taken into account and if possible given an economic value. (CAT, 2010 P.211).

They state that perennial energy crops could be grazed with animals.

The document analysed from the Organic Research Centre (2010) in the UK focuses on synergies between products and environmental benefits produced from agro-forestry systems. There is a clear message that they envisage this type of production as something different from conventional agriculture, which has not yet come to fruition.

> Many temperate agroforestry systems are only one step up from conventional, intensive monocultures; while these systems benefit in a number of ways from integrating trees with crops or livestock, the full potential of agroforestry as a low-input, biodiverse approach to sustainable production and ecosystem service delivery is yet to be realised. (ORC, 2010 P.20).

Environmental sustainability

The ecologically integrated agriculture model, in contrast to the life sciences integrated model, sees sustainability problems within agriculture as caused by political-economic systems that promote mononcultural, intensive, productivist agriculture (Levidow et al., 2013). It is also linked to a need for agriculture to diversify and move away from monocultural production. This was reflected in the interview data. A UK grower, a Danish grower, and two Danish academics state that systems need to be changed to remedy the damage brought about by monocultural agriculture. As the UK grower states:

> UKG1: Already we're seeing crop failure, monoculture crop failures in say large forests we're seeing- we're reaching our limits on say wheat production […] I think the next development is going to have to be looking at these poly-cultures and how can we how can we grow fuel, food and all of these things together so that the cycle actually works for itself.

Levidow et al. (2013), CREPE (2011), Schmid et al. (2012) and Levidow (2008) found that in these integrated production systems environmental sustainability is framed in terms of nutrient cycling at the farm level and closed loop systems, rather than the precision use of external inputs and efficiency promoted under the agro-industrial model. This also emerged as a very important element of alternative multipurpose biomass systems in the interviews and document analysis. A Danish NGO employee states:

> DNGO3: […] we see biogas technology as a way to have a more controlled circuit of matter and nutrients and energy so the biogas vision that we have is not just to produce energy but just as much to have a more to be self sufficient with eh nutrients.

This "closed circuit of matter and nutrients and energy" at the farm level was part of the goal of reducing agriculture's dependence on fossil fuels and external inputs, as was a prominent feature of agro-ecological agriculture as it was originally conceived (Lang and Heasman, 2004). The idea is also promoted at the societal level, as Jørgensen et al., (2005) express in their vision for the use of sewage sludge as fertiliser for perennial energy crops: "The utilisation of wastewater and sewage sludge is not allowed in organic farming in Denmark. However, utilisation of these waste products would help close the gap in the nutrient cycle between agriculture and the cities." (p.244).

The ingredients view of biomass was not used within the alternative multipurpose agricultural model, but rather crops were identified as energy or food crops that could be grown together to produce synergies. Holism and systematic thinking are trademarks of the alternative agriculture model, as we saw in chapter 3 (Lang and Heasman, 2004). This was generally promoted at the level of crop production rather than processing. We saw in chapter 5 how a systems approach to agricultural production was proposed as a way to overcome competition for crop residues. One interviewee dismissed the idea of using lignocellulosic materials to feed animals, as suggested by an interviewee above within the life sciences integrated model, seeing it as unrealistic.

> UKNGO2: […] even FAO has written- how can we make animals eat bark, left over from lignocellulosic, add a few vitamins and feed it to the cattle (laughs), that's one thing and I don't think that that's tenable either so anyway.

Holism and systematic thinking were valued within this model to ensure production of multiple products and ecosystems services. A Danish academic states:

> DA1: I think also if you are having an ethical view then you should think in a system more using a system approach and so yeah ask to ask about how our future agricultural systems should look like.

A Danish NGO employee highlights the synergies involved in producing energy crops alongside animals:

> DNGO3: […] it should be integrated and if we integrate you can also make some interactions supportive interactions where we for instance for chickens using eggs for instance if you have the yard for the hens with willows or other trees then this will increase their the animal welfare.

Working within nature and using traditional knowledge

We also see a reintroduction of the importance of nature within the alternative agriculture model of the multipurpose biomass production expressed by the interviewees. This resonates with literature on ecologically integrated agriculture: it was stated in chapter 3 that critics of industrial agriculture maintain it views nature as something passive to be controlled and replaced to some extent, whereas alternative agriculture attempts to re-introduces nature as an visible, active agent in the process (Murdoch et al., 2000; Goodman, 1999). Two interviewees described the multipurpose use of biomass being shaped by a consideration of the fact that these products come from nature and the land. A Danish academic explains that using biomass for multiple purposes is the best way because they come from nature.

> DA1: […] all organic materials come from agriculture or come from nature you could say, from the land so we should use these products in the best way and with a lot of steps, not produce them and use them for one thing.

Here nature is not viewed as something passive but rather something which should influence how we use these products. This approach could be seen as analogous to that of using all parts of a slaughtered animal, out of respect for the animal. A UK grower stated that agricultural production should aim to work within nature rather than surpass it.

> UKG1: And we have to look to nature as to how it works within nature we always think that we can do better than nature but actually there's a lot a lot to learn from that.

This view can be seen to fit in with Jackson's (1987) characterisation of the disagreement between agricultural paradigms as one between "human cleverness folk" and "nature's wisdom people." (p.85, quoted in Beus and Dunlap, 1990 p.596).

Levidow et al. (2013) state that agro-industrial versions of the KBBE seek to use abstracted scientific knowledge whereas agro-ecology systems make greater use of local knowledge, and indeed at times reconciles local with scientific knowledge. This idea is found in the interview data. ORC (2010) state: "As traditionally employed, these benefits were intuitive to the farmers and landowners that managed agroforestry systems, although the scientific evidence to support such benefits is only now coming to light [43-45]." (p.12). They frame agro-forestry methods as both old and new, harking back to practices that were used for millennia and stopped being used relatively recently because of mechanisation and post-war demand for increased productivity.

> The practice of pasturing in woodland by humans is one of the oldest land use practices in our history. Wood-pasture remnants in England, such as the New Forest, feature some of the oldest and widest trees in Europe, providing valuable resources for a wide range of associated biodiversity, as well as having historical and cultural value [8]. (p.12).

The goal of weaning agriculture off fossil fuels is also linked to a return to more traditional methods of production. Hauggaard-nielsen et al. (n.d.) state of the strip intercropping method: "This kind of cropping strategies was common in developed countries before the 'fossilisation' of agriculture" (p.2).

Thus we can see that nature and local knowledge have a somewhat different place in the ecologically integrated model compared to the life sciences integrated model.

8.4 Overlaps between paradigms

This section will consider some overlaps between the life sciences integrated multipurpose biomass model and the ecologically integrated multipurpose biomass model. We have already seen that the biorefinery concept was promoted to a limited extent within the ecologically integrated model. We saw that both models promote environmentally sustainability, interpreting the term in different ways. In the life sciences integrated model it means eco-efficiency through technological innovation, whereas for the ecologically integrated model it means closed nutrient cycles and diverse cropping systems. This section will consider more substantive overlaps between the systems.

Quality biomass in the life sciences integrated model

Quality production, defined in different ways, would normally be placed within the alternative agriculture paradigm. As we saw in chapter 3 Sonnino and Marsden (2006) and Goodman (2004) view quality as the defining characteristics of alternative agriculture, and Levidow (2008) calls this model the "quality" agriculture paradigm.

In the interview data however, quality biomass is advocated by individuals who espouse an otherwise life sciences integrated conception of the use of biomass in the bioeconomy. Biomass was not only framed as an abstract scientific and economic entity but was also defined in terms of territoriality, retaining some sense of place and connection with the surroundings by the same people. A Danish academic for instance, whose views could otherwise be seen to be within the life sciences integrated framework because he promoted the use of "smart" technology, suggested that biorefineries should be tailored to local biomass supply:

> DA4: […] a biorefinery in this part of Denmark might not be the same as a biorefinery over here because it might be different crops and also again you might consider Denmark as a very small place which it is which means again there are differences which means over here it is better to make this and this and this energy crop and over here it's better to make this and this and this.

Thus different crops may be suited to different a region, which in turn means that the biorefineries that use them will produce different products. This is what Allaire and Wolf (2004) call the "logic of identity" and Levidow et al. (2013) call "integral product integrity", which works through features such as territorial identification.

Quality is also emphasised within the life sciences integrated perspective as a way Danish biomass can distinguish itself from cheaper, mass produced, conventionally produced biomass (CREPE, 2011). DI1 otherwise promotes intensification of agriculture and other life sciences integrated concepts but we see here that Danish biomass is viewed as an alternative which must distinguish itself from the wider global market of cheaply produced biomass.

> DI1: So they will buy as cheap as possible they will not look for quality. And we will try to make the straw for biorefining, make sure that it's the right type of straw and have the right moisture content and we can deliver it every year, make sure that there will always be a supply of what type of biomass they need for their production and that's what we hope that that we can supply from a Danish point of view.

The costs of Danish production are likely to be higher than those from many competing countries so Denmark can only hope to compete on quality rather than price. Some might object that this does not represent agriculture within the alternative paradigm because it involves standardisation of agriculture to suit the industrial processes within biorefinery and the continued viewing of agriculture within the industrial paradigm. It could be pointed out however that this interviewee does see a need to distinguish Danish biomass from the more “generic”, “cheap” type produced on the global market. This can be seen as similar to the Norwegian label “Godt Norsk” (Good Norwegian) that markets products based on their Norwegian origin, and taps into a consumer preference for local and more natural products (Nygård and Storstad, 1998). So this view arguably does represent something of a cross over between industrial and alternative agriculture perspectives.

As well as an association with a particular region “quality” agricultural produce can mean better environmental and general “ethical” credentials (Renting et al., 2003). A Danish energy grower appears to distinguish Danish biomass in this way from cheaper, environmentally damaging imports.

> DG1: The big energy companies in Denmark, they just have one interest: cheap energy, they don’t care if they are going to lose a lot of carbon have a lot of emissions during transport, they don’t care, they just think of price. So it’s easy just to import rubber trees from Africa I think it’s the wrong way to go.

Here the grower frames the import of biomass as thoughtless and environmentally damaging, motivated by price. Nygård and Storstad (1998) state that Norwegian consumers viewed Norwegian products as being inherently safer, they were not susceptible to the same health threats as foreign imports. In a similar way a UK grower, who could otherwise be seen to be within the life sciences integrated paradigm, views imported biomass as inherently less sustainable than UK biomass, more likely to result in the deforestation of land or other destruction of natural habitats. DG2 states “you lose sight of it [biomass]” when it is imported, suggesting a similar concern with transparency as expressed by Norwegian consumer. This is also similar to how Goodman (1999) describes production within agri-industrial system, as an opaque black box, which is unpacked and made visible by alternative agriculture systems such as organic.

The above quotes suggest a cross-pollination of life sciences integrated and ecologically integrated agriculture views of biomass production within multipurpose agricultural systems, which is different from the clear cut division between agro-industrial and alternative agriculture views of the KBBE found by Levidow et al. (2013) and others within the EU context. Similarly, Sonnino and Marsden

(2006) state that case studies of egg production in Italy and dairy production in Norway and Wales have shown that while distinctions can be made between conventional and alternative systems, no clear boundaries exist in reality and the situation on the ground is often more complex. They also state that farmers' choice to move towards alternative systems of production may be motivated by economic concerns rather than ideological considerations. This could be seen to be true of the argument put forward by DI1 and DG1 for quality biomass production in Denmark and DG2 for quality UK biomass. DI1 is a representative of the largest farming and food organisation in Denmark and his main concern is the competitiveness and economic success of Danish agriculture. Thus the emphasis on quality production can be seen as a way for Danish farmers to distinguish themselves in a competitive global market rather than as a complete rejection of conventional systems of standardised mass production.

Another method of increasing productivity within the ecologically integrated multipurpose biomass system

Ecologically integrated multipurpose biomass models are at times promoted over conventional, industrial systems, because of their productivity. Chapter 3 placed productionism, the philosophy which maintains that increasing production is the main goal of agriculture, within the industrial paradigm. Chapter 5 explored the idea that increased productivity could free up land for energy crop production and placed it within an industrial paradigm. In the data increasing productivity to overcome land use conflicts was also promoted within an alternative paradigm. A UK NGO representative questions how productive monocultural systems actually are. She appears to describe productivity differently to how it is understood in monocultural systems. It does not mean more of one thing, but rather a diversity of different products and increased land health.

> UKNGO2: if you look at what I would call a green desert in East Anglia, a huge corn field how much is that actually producing? In comparison to what it *could* produce if you turned it into in a different system. If you turned it over to a different system you might find that actually you produced a huge amount more of food and resources for humans as well as improving the soil.

A Danish academic states that the environmental benefits mean productivity will be increased naturally.

> DA1: […] use agro-forestry such that the farm could produce more food with lower inputs because there is a better interaction between the land as such is more healthy so that it can produce more.

ORC (2010) compare productivity of agro-forestry systems favourably to monocultural systems:

> A central hypothesis in agroforestry is that productivity is higher in agroforestry systems compared to monoculture systems due to complementarity in resource-capture i.e. trees acquire resources that the crops alone would not [11]. This is based on the ecological theory of niche differentiation; different species obtain resources from different parts of the environment. (p.8).

They support this theory by using a “land equivalent ratio” which compares the amount of land needed to produce products in an agro-forestry system to land in a monocultural system, and finds that agro-forestry systems are more productive.

Thus we can see that “productivity”, though it still refers to the level of output per unit of input, has a somewhat different meaning here to the industrial paradigm. This meaning reflects the holistic approach of alternative agriculture, the ethic of land care some promote and the emphasis on diversity of production rather than monocultures. This emphasis on increasing productivity could be seen as part of the bid by ecologically integrated agriculture to vie with life sciences integrated agriculture in replacing productionism. Lang and Heasman (2004) stated that this model also accepts the view that more agricultural production is needed to meet the demands of a growing population. Thus this can be seen as part of the call for more productivity within agriculture after research on increasing production was somewhat neglected following the excesses of the CAP. From a philosophical point of view it is unclear if productionism and an emphasis on increasing productivity necessarily belongs in the industrial paradigm, or if it belongs there because historically it was pursued through industrial methods. Some see an appreciation of the limitations of natural resources and an ethic of sufficiency rather than maximising productivity as features of the alternative paradigm (Hansen, 2014; Leopold, 1949). And this can be seen as important to the alternative paradigm to the extent that it shares common roots with the environmental movement, including the idea of limits to growth and the necessity of limits on human appropriation of ecosystems (Beus & Dunlap, 1990). More analysis would be needed however to establish how philosophically interesting the promotion of increased productivity, even with this non-industrial meaning, is within the alternative paradigm.

8.5 The place of perennial energy crops and crop residues within multipurpose systems

So far this chapter has dealt with biomass within multipurpose agricultural systems in broad terms, considering the framing and concepts from industrial and alternative models. It has used examples that show the place of perennial energy crops and crop residues within these systems, but it has also used examples of other feedstocks such as grass and manure. This section will now take stock of the place of perennial energy crops and crop residues within these systems.

Crop residues can be seen to have a place in the industrial multipurpose systems because they are framed as residues or co-products of arable crops. Their use in energy production is framed as making the crop dual use, in effect, as we saw above. Research is under way into specifically using crop residues in biorefineries, particularly in Denmark. The Inbicon pilot plant uses straw as one of its feedstocks. The report on the future of the bioeconomy in Denmark states that the government is placing special emphasis on research into processing straw into bioethanol in biorefineries (Erhervs- og Vækstministeriet, 2013). Crop residues are thus promoted as having a place within the life science integrated vision of multipurpose biomass use, but this may be dependent on the development of technologies that can process them economically.

In relation to the ecologically integrated model we saw in chapter 5 that there were perceived conflicts between the use of crop residues for energy and their use as a soil conditioner in organic agriculture in Denmark expressed in documents. We also saw that a representative of the Danish organic sector expressed a more conciliatory position, stating that they realised it was not possible for the organic sector to oppose all straw use in energy production. But straw use was not widely put forward within alternative agriculture as an energy source, potentially because of the need to use it in soil conditioning.

Perennial energy crops can be considered to have a natural place within ecologically integrated multipurpose systems, on the other hand, because these are largely based around agroforestry production, which perennial energy crops are suitable for and are seen to bring about many of the production synergies and environmental benefits. There is however little of this type of production happening in practice at the moment (ORC, 2010). At the same time, some prefer grass production within alternative systems. The reasons why the environmental benefits of grass might be considered preferable to those of perennial energy crops in Denmark were explored in the last chapter. DNGO3 offers another reason, stating that because grass production does not disrupt crop rotations as much as perennial energy crops, it is a more flexible feedstock than perennial energy crops.

> DNGO3: they [perennial energy crops such like miscanthus and willow] are very different because they are they are they will be in the ground the soil for many years but the perennial crops that we use [grass] in the crop rotation will be there two or three, well one to three years maybe.

Thus the place of perennial energy crops within alternative multipurpose systems is not completely assured. Since these systems are not widely in commercial application the feedstock of choice will emerge in time.

Within the life sciences integrated model, the multipurpose aspect of biomass use happens at the processing stage rather than the production stage, and thus the place of perennial energy crops within the bioeconomy is framed as more dependent on technological innovation. As one UK academic states:

> UKA2: And it's the perennial crops that have the greatest potential for the future, particularly those like the energy grasses and the short rotation coppice if we can master lignocellulosic technologies I think those have the those have the greatest potential in the future.

The "if we can master lignocellulosic technologies" presumably refers to a cost and energy effective way to break down the lignin and access the cellulose and hemicellulose within these feedstocks to ferment it into ethanol. As we saw above the Danish academic DA2 stated that it could be possible to use lignocellulosic feedstocks for animal feed in future. They were worth growing because of their superior solar energy efficiency compared to other crops.

In summary it can be maintained that there are two aspects that determine the suitability of perennial energy crops to multipurpose biomass systems: their suitability to multipurpose production systems and their suitability to multipurpose processing in the biorefinery. When perennial energy crops are framed as a flexible and efficient feedstock for processing, environmentally beneficial and efficient crops then they are seen as having a place within the life sciences integrated multipurpose systems. Their suitability to the biorefinery process is framed as to some extent dependent on technological innovation. Their place within alternative systems depends on the type of production system promoted, agro-forestry or a crop rotation system. Other feedstocks such as grass are framed as potentially more for crop rotation systems.

Crop residues are framed as being multifunctional at the level of crop production within industrial multipurpose biomass systems, because they are by-products of other crops. At the level of processing there is enthusiasm for increased use of crop residues in biorefineries, particularly in Denmark. Their other uses, such as for soil conditioning means that they are not as whole heartedly endorsed as a fuel source within alternative agriculture.

Thus while perennial energy crops and crop residues are framed as overcoming previous controversies raised by food crop biofuels, in terms of their production in alternative and industrial multipurpose biomass systems, it is important to note that they are not necessarily whole heartedly endorsed within these systems and other feedstocks that are seen to better meet the needs of the system are also promoted. This analysis of their place within the ecologically integrated and life sciences integrated models is by necessity somewhat vague because these systems are largely not in operation yet and are proposed as visions for the future, so there remains some uncertainty about how they will develop. It was also often difficult to pinpoint interviewee's exact views on the matter as they would express a view in favour of these feedstocks and then a different view against them at another point. The views weren't necessarily contradictory but just reflect the complexity of the area and their different views on different parts of it. So drawing conclusions to the effect that "stakeholders were in favour of" or against perennial energy crops and crop residue use in particular systems would be misleading. Rather the analysis above attempts to represent and analyse some of the complexity.

8.6 Conclusion

This chapter shows how the use of biomass within both life sciences integrated and ecologically integrated multipurpose systems is proposed in the UK and Denmark as a way around the previous controversies raised by food crops biofuels. The chapter explored the assumptions and theories within these two different conceptions of multipurpose systems. The concept was more prominent among Danish interviewees than those in the UK. The chapter has outlined significant themes associated with the concept. Previous studies on views of the KBBE among EU stakeholders by CREPE (2011); Schmid et al. (2012); Levidow et al. (2013); Levidow (2008) and Birch et al. (2010) divided data into agro-industrial and agro-ecological agriculture paradigms. The themes identified in this study resonated with the findings of those papers and data could also be analysed in terms of these conceptions. Agro-industrial, or in the terminology of this thesis life sciences integrated, conceptions generally involve multifunctionality at the level of crop processing; environmental sustainability in terms of efficiency; "intelligent" or "smart" production systems; an ingredients view of biomass; extracting maximum value from biomass. Alternative agriculture conceptions involve multifunctionality at the level of biomass production, involving agro-forestry and the combined cultivation of energy crops, food and ecosystems services; an emphasis on holism and systems thinking; environmental sustainability in terms of closed loop nutrient and energy cycles on the farm. The overlap with the framing of the KBBE suggests that people working at the coal face of biomass research, production use and lobbying are being influenced by these "top down" European conceptions of the biomass production within multipurpose systems that are found in EU policy documents and elsewhere.

There also appears to be a “bottom up” conception of the multipurpose agriculture however, particularly in Denmark, which involves an overlap between the life sciences integrated and ecologically integrated models. This can be seen in relation to the concept of quality, normally associated with the alternative agriculture perspective, used within an otherwise agro-industrial paradigm. Quality biomass was framed in terms of territoriality: biomass from different regions in Denmark would have different characteristics needing different processing methods. Production of quality biomass tailored to biorefineries’ needs was also seen as a way Danish produce could distinguish itself from cheaper imports. Danish and UK biomass were also framed by growers as more environmentally beneficial and traceable than imports. These views may be due to a desire to promote domestic biomass and ensure farms’ economic viability. We saw that one document by an organic agriculture research organisation advocated the use of biomass in a biorefinery, using agro-industrial sounding language. This may suggest some cross pollination of alternative agriculture and agro-industrial views. It may also suggest that as the meaning of “quality” food varies from country to country, the specifics of the agro-industrial and alternative agriculture conceptions of multipurpose agriculture may also vary from country to country.

However it is important to emphasise that the place of perennial energy crops and crop residues within these multipurpose systems was not always endorsed. The place of perennial energy crops was framed as dependent on technological innovation and their flexibility and efficiency within biorefinery processing systems. The place of crop residues within life sciences integrated systems appeared more secure, though they are dependent on the same technologies to break down lignocellulosic feedstocks. This may be because crop residues are seen as not requiring additional land, unlike perennial energy crops. Crop residues were not widely promoted within the ecologically integrated system because they have other uses for soil fertilisation which cannot be readily replaced. Perennial energy crops have a place within the ecologically integrated model as part of agro-forestry systems. But some promote grass for biogas production as part of a crop rotation system over perennial energy crops within agro-forestry because of the greater land use flexibility.

Chapter 9 Cross cutting criticism of agricultural biomass production for energy

9.1 Introduction

The research questions for the project focused on how one can understand claims that perennial energy crops and crop residues will, or will not, overcome previous controversies raised by food crop biofuels, and what theories and assumptions underpin these claims. This involved considering how key stakeholders frame questions of if, where and how these feedstocks should be produced. The theories and assumptions can refer to paradigms of agriculture or empirical assumptions.

The previous chapters have explored models of agriculture that broadly agree that agricultural biomass, and to a greater or lesser extent perennial energy crops and crop residues, have a place within the energy system. We saw in chapter 5 how perennial energy crop and crop residue production was framed as taking place within a broadly industrial system. Here land use and land use change were framed as being negative, and land as being abstracted from place as a globally fungible entity. Within the industrial paradigm two strategies to bring biomass production forward and overcome previous controversies were identified, which were called i) industrialism lite and ii) life sciences integrated. These strategies are not mutually exclusive, but were elucidated separately to make them clearer. Two other production models were identified in the alternative paradigm: iii) beneficial multifunctional biomass – involving the production of perennial energy crops on environmentally marginal land and iv) ecologically integrated agriculture – involving multipurpose biomass production such as agro-forestry systems.

The purpose of this chapter is to introduce a perspective that cuts across all the models of perennial energy crop and crop residue production introduced so far. From this perspective, which was briefly mentioned in chapters 5 and 6, no or very little agricultural biomass should be produced for energy because of the vast scale that it requires, biomass' inferior energy density compared to fossil fuels, and the negative impacts of production. The argument is considered important because it broadly goes against the analysis that has been presented so far. It will be called the cross cutting criticism. It also forces the broadening of arguments away from just the production of biomass to a consideration of how it is used. This chapter will present this argument and then consider how arguments could be made within the alternative and industrial agriculture paradigms in response to the challenge it poses. This will then inform the summary of answers to the research questions in the next chapter.

9.2 Cross cutting criticism of agricultural biomass production in energy

This section will outline the "cross cutting criticism". Several interviewees, the majority of whom were from NGOs, answered the first research question in the negative: perennial energy crops and crop residues will not necessarily overcome controversies raised by food crop biofuels and so very little or no biomass for energy should or could be produced from agriculture regardless of the type of agricultural system used. All the interviewees who proposed this view supported a type of alternative agriculture; nobody who supported industrial agriculture expressed this view. There was some overlap between this view and the alternative paradigm: some of those who supported the ecologically integrated biomass production system maintained that it should only be produced to a very small extent.

This view starts with an argument about scale: the scale of biomass needed to replace any significant amount of fossil fuel is prohibitive because the land footprint is very high. As a UK NGO employee states:

> UKNGO1: That basically, the underlying con- the underlying background is the fact that the land footprint, the land footprint of bioenergy is inherently incredibly high if you compare it types of energy that we would see as genuinely renewable. And that's basically because photosynthesis only converts a minute amount of sunlight to new energy so if you use that that mechanism to generate any significant amount of energy then the land footprint is inevitably enormous.

Here UKNGO1 frames biomass as not "genuinely renewable" and biomass production as inherently limited, regardless of the type of system it is produced within, because the underlying mechanism of photosynthesis only produces a small amount of "new", useable energy. Another UK NGO representative makes a similar argument along the lines of scale and energy density. When asked about her views on biomass she states:

> UKNGO2: Pretty sceptical, there's a lot of reports that show it's not it's energy dilute, you need an awful lot of land to produce it. It's, coal and oil and so forth our fossil friends have been in the soil, have been underground for a long time and been worked and heated and they're much more energy dense than biomass. […] I remain sceptical about the ratio of amount of land required to the amount of energy that can be produced and I have seen nothing so far that would change my feelings of scepticism about that.

Again, the argument is framed in terms of the underlying process of producing energy through photosynthesis being "energy dilute" in terms of the amount of land needed and in comparison to the energy density of fossil fuels. Here, biomass itself is framed as the issue, rather than the type of agricultural system it is produced within. This view could be used to criticise the life sciences integrated biorefinery model that sees biomass as the fossil fuel of the future. Under this framing, there are important differences between them.

This argument widens the type of considerations at play around biomass production. It is not only about how the biomass itself is produced but society's energy use should also be taken into account. For UKNGO1 there is a mismatch between the way industrial society uses energy and the amount and type of energy that can come from agriculture.

> UKNGO1: Well it's really a question of scale I mean we don't see that bioenergy, if you're looking at current bioenergy consumption and you're looking at replacing any significant proportion with another type of energy then doing it sustainably with biomass is really not going to be possible. Now, we would I mean clearly very low energy societies em yeah, really traditionally low energy in low energy communities have y'know historically and in the present y'know found ways of using a small amount of bioenergy locally sustainably, but I think that's really different from what we're speaking about with y'know that's great but I think that's really different from the industrial large scale vision.

In her view only low energy societies could rely on biomass to any significant extent for energy. Another UK NGO employee similarly states that we need to reduce society's energy use before we can consider using any significant amount of biomass in the energy system:

> UKNGO2: Okay so we have to move from fossil, that's absolutely clear but we can't move from fossil to biomass while expanding our energy use, that's not possible. Our energy use we can't even do it on the energy use that we've got at the moment, I don't think.

Interestingly, this issue of scale is brought up by a Danish government employee but he does not come to the same conclusion that no or very little biomass should be used. Rather he states that only industrial biomass production is feasible and can deliver the scales required. He does this when talking about his version of the different paradigms of agriculture: "story telling" agriculture and "big bulk production". In his argument "story telling" agriculture cannot produce the volumes required. Energy use in industrial society requires industrial agriculture.

> DGov1: In general at least here in Western Europe it will possibly go towards more organic, more what do you call it more storytelling involved in what producers are producing and then also a quite big bulk production with maybe some of it will be energy. So there is two segments

so to speak one where where the story and what people eat matters, the other one is where you could be for energy, energy crops or things like that.

OS: So you have this kind of split. That's an interesting phrase, the storytelling so it's transparent and people know about it and then the bulk production is opaque and emmm and do you see any storytelling type biomass production?

DGov1: Not really no. No.

OS: Why do you say that?

DGov1: Because it's eh what do you call it? It's a clearly defined area and if you have to be self-sufficient in energy you can do that at a farm but at a farm level but then you don't produce very much. So I would say you have to go out in more larger areas. If you have a larger area you can have your storytelling beside this actually give a brand to whatever other things that are produced there.

Thus DGov1 broadly agrees that the issue of scale is a problem for biomass production, but believes that this means only large scale, industrial biomass production is feasible. This is in direct contrast to those who support the cross cutting criticism, who maintain that no significant agricultural biomass production is desirable or feasible; indeed UKNGO1 above stated that the "industrial large scale vision" was the problem. The next section will explore this disagreement in terms of different views of agriculture and its relationship to the energy sector.

9.3 Answers from the paradigms of agriculture to the cross cutting criticism

Alternative agriculture

The alternative agriculture position maintains that agriculture has some significance to society beyond its material contribution which is not captured by treating agriculture as another sector of the industrial economy. We saw in chapter 5 that one of the criticisms of ecologically integrated systems is that some see the promises made for increased, environmentally friendly production as unrealistic and the model as a whole as an esoteric niche that will not compete with the dominant industrial paradigm (Forssell and Lankoski, 2014). Furthermore alternative production systems are seen by some as positively unethical because they have lower yields compared to industrial systems and more food is needed to feed the world (Trevawas, 2001). Thus the cross cutting criticism may be particularly problematic for this model, in the way that DGov1 above stated that it applied to alternative "storytelling" systems because of their lower yields, but not to large scale, industrial systems because of their higher yields. The same could be true of the beneficial multifunctional biomass strategy, where production only takes place on a restricted type of land, though the amount and type of land promoted varied as we saw in chapter 7.

As described in chapter 8 many argue that alternative systems need not necessarily lead to reduced production compared to industrial systems, if one takes a different measure of productivity. Another part of the response of those within the ecologically integrated model to the cross cutting criticism is that these systems often involve more modest aims for using energy, such as on-farm self-sufficiency and/or local energy generation and/or a significant reduction in energy use. Agriculture will be de-industrialised in some sense and so the use of energy it provides should also follow a different model. One interviewee promoting the cross cutting criticism quoted above does potentially see some sort of role for perennial energy crops in local energy production.

> DA1: […] if you have agriculture with trees in between the fields like in agro-forestry for instance then you might use in small scale the perennials for for energy production at a local scale or so.

Another of the supporters of the cross cutting criticism also states:

> UKNGO1: So we wouldn't say that we're against all biomass in that on a very small scale local use basis that wouldn't be true. But on a large scale energy policy basis yeah, I think y'know I think that's large scale.

A grower who promotes agroforestry states similarly:

> UKG1: I really believe that the future lies in small decentralised biomass power stations.

UKG1 also states that he uses 80% of the energy he produces on his own farm, resonating with the alternative agriculture plan for increased on-farm energy self-sufficiency.

The issue of energy *generation* from biomass has not been explored in any depth because it is a huge topic and is beyond the scope of this project which focuses primarily on production. Here we can note that changing the scale of energy generation is part of the answer within the alternative paradigm to the cross cutting criticism. Alternative, local, small scale biomass production requires local, small scale energy generation.[32]

This only partly answers the cross cutting criticism however. It states that small scale energy production should be used in plants that only need a relatively small amount of feedstocks, but this

[32] Though it should be noted that small scale energy generation was also advocated for various reasons by many of those promoting some form of industrial biomass production. There was not room in this thesis to explore issues of the scale of biomass production and use.

does not solve the issues of biomass' inferior energy density to fossil fuels and the scale of the *population's* energy use. Other parts of the answer relate to reduced energy use in conjunction with different production and generation methods, and reduced meat consumption to make way for more energy production, as we saw was also promoted in industrialism lite. Chapter 5 outlined this argument whereby some meat production was framed as a very inefficient, environmentally damaging, luxury product, often for export and was contrasted with biomass production in terms of the production of a necessity for local use. Some maintained that people could cut down on meat consumption to free up more resources for fuel production on the land. A UK grower maintains that people do not appreciate the importance of energy security, which would involve locally grown biomass, because food and energy are so plentiful at the moment.

> UKG1: Because again we're all we're too well fed, we are too complacent about energy we are wasteful, we we haven't lived through a crisis in these in this term at all and I think it's going to take crisis for people to focus their brains on this and to realise how important energy security will be in the future.

A Danish academic emphasises the importance of reducing demand for energy:

> DA1: I think there is too much hope for the bioenergy to solve many problems on energy supply because yeah I basically I think that one needs to reduce energy use as much as possible.

The answer to the cross cutting criticism by the alternative model is framed in terms of a different system of energy generation and reduced energy and meat consumption.

Industrial paradigm

The cross cutting criticism introduces another challenge for biomass use in addition to the environmental and food versus fuel controversies introduced in chapter 2, by claiming that there is a mismatch between the pace of society's energy use and the pace of agricultural production which makes any sort of ambitious biomass production unfeasible. We saw above that DGov1 accepts the argument, but only in relation to alternative, or what he calls "storytelling" agriculture. There need not necessarily be a mismatch between the pace of *industrial* agricultural production and society's energy use, so he maintains that this is a further reason why highly industrialised agricultural biomass production is the only viable model. DGov1 also states that small scale biomass production is not possible because of the returns to scale mean that only large scale production is economically feasible.

DGov1: […] we're talking sizes, we're talking economics as well. […] if you're going to produce biomass for non-food purposes you will still have to come up with some very large areas or units actually to be efficient.

The answer to the criticism here is to bring agriculture up to the speed of society's energy use: industrial energy use requires industrial energy production.[33] Thus, in stark contrast to how it is used by adherents, the cross cutting criticism here also serves to further motivate the industrialisation of agriculture and agricultural energy.

From the cross cutting criticism perspective there are important differences between recently living energy: biomass, and long dead energy: fossil fuels. We saw in chapter 8 how the biorefinery concept collapses this difference and sees biomass as the fossil fuel of the future. We saw how the type of crop a feedstock was, whether food or fuel was less important than the efficiency and flexibility of the feedstock in the biorefinery system. And metaphors related to machines were used in relation to crops by those who promote the biorefinery concept (Levidow et al., 2013). One paper that promotes the biorefinery strategy does reiterate the core point of the cross cutting criticism that photosynthesis is an inherently energy inefficient mechanism: "[...] natural plant photosynthesis has low theoretical energy efficiencies from solar energy to chemical energy of 4.6 and 6.0% for C3 and C4 plants, respectively [38]." (Zhang, 2013 p.31). The author does not reach the same conclusion as those who promote the cross cutting criticism however but instead promotes the idea that artificial photosynthesis could overcome the limitations of natural photosynthesis:

> In a word, next generation biorefineries based on artificial photosynthesis would not only bridge the current and future primary energy utilization systems aimed at facilitating electricity and hydrogen storage but also address such sustainability challenges such as renewable biofuel and chemical production, CO2 utilization, and fresh water conservation [90]. (Zhang, 2013 p.38).

This takes the blurring of boundaries between plants and machines further. Levidow et al. (2013) pointed out how one of the characteristics of the life sciences integrated paradigm was the replacement of previously natural mechanisms in agriculture with non-natural ones, which we can see here extends to the plants themselves. Plants are not the best energy sources to meet the needs of industrialised societies, and using artificial photosynthesis reduces the environmental impacts of agriculture involving natural photosynthesis. In this way they would defend and extend the "biomass = fossil fuels" framing.

[33] Though of course many interviewees who promoted the industrial view also stated that a reduction in energy demand and energy use efficiency were also needed in tandem with this strategy.

Another part of the rebuttal to the cross cutting criticism from the industrial paradigms is about where biomass should come from. In contrast to the small scale, local vision outlined above by those in the alternative paradigm, several interviewees stated that the issue of the scale of biomass needed meant that local or even national biomass production was not sufficient and imports would be necessary to meet energy targets. A UK industry employee states that local supply chains are desirable, but not feasible for the large scale developments that are planned in the UK.

> UKI2: […] if there's a relationship with a local farm suppliers and you've got local farmers involved who can work together to supply a deal, to me that's the ideal relationship, and one that will sort of promote y'know long term emm reliability and long term supply chains. If we then start thinking, y'know, get to larger and larger scales and think at the far end we start thinking about these large scale biosyngas productions are of an immense scale and need immense through-puts. Emmm, then there's no way on earth that you're going to sort supply just from local resources.

He adds:

> UKI2: I mean we know that for one large generator already considering conversion, they can be talking about 4 million tonnes of wood coming in per year. That's not something you can sort of supply in the UK, that's going to have to come from overseas and that means developing supply chains.

Those whose views represent a cross cutting criticism would maintain that both of these visions are unfeasible, to a greater or lesser degree, as we will see below.

Cross cutting criticism of agricultural biomass production for energy

As a response to the last two perspective, some would not necessarily agree, or not agree wholeheartedly, with the alternative agriculture answer to the cross cutting criticism in terms of different methods of energy generation and reduced energy and meat consumption. Those who promote the cross cutting criticism would almost definitely not agree with the industrial vision, seeing the scale of production as unfeasible and the impacts it would incur as unsupportable. An exploration of this argument can draw out the cross cutting criticism further. A UK NGO employee links the scale of energy consumption to the scale of biomass needed to replace fossil fuels:

> UKNGO2: I think that emm somebody was telling me that one household needs two hectares of woodland to use to selectively cut and to take emm timber from per year and I haven't done sums on how many hectares that would require for our populations. Somebody else should do

> that. And the other thing was I asked somebody in the black forest, because the black forest is massive, I mean it seems huge to me in Germany, wonderful, and I asked somebody who lives in a small town on the edge of it emm could the local population of the black forest use the black forest as a source of energy emm into the foreseeable future, would this be sustainable and he said “absolutely not” unless they do huge huge work on making their houses energy proof.

Here biomass use is painted as fundamentally incompatible with industrialised societies’ energy use. In terms of paradigms of agriculture, it was stated above that of those who supported this argument all spoke disparagingly about industrial agriculture and favoured alternative agriculture. This is one step further than those promoting ecologically integrated or beneficial multifunctional biomass in terms of maintaining that agriculture is not just another sector of the industrial economy. This view marks a very clear line in the sand between agriculture and the energy sector, based on empirical arguments about scale. It may have been possible to provide sufficient, sustainable energy from agriculture in the past, and it is still possible in low energy societies, but not given the scale of energy use in industrialised societies. In this respect industrialised countries’ energy and agricultural systems are out of step.

Some would criticise the way in which the cross cutting criticism emphasises energy use reduction, maintaining that the energy consumption reductions necessary to make local biomass use possible would be prohibitive though, of course, not everyone would agree with that view. A UK industry employee who supports industrial biomass production highlights the potentially catastrophic impacts of sincere efforts to reduce energy consumption:

> UKI1: We should of course be reducing our consumption. But are you prepared to say what governments must do to reduce that consumption? Well the first thing of course is that prices should go up. If things are too cheap you will waste. Do you seriously mean that taxes on roadfuels must go up drastically? That we must find ways of constraining, y’know rationing things that we waste, that food prices should go up drastically. Oh hang on a second, one of the NGO arguments is that bioenergy will push up food prices and that will be bad. So if you’re not prepared to do the drastic things to cut consumption we have to accept that most things we do to cut consumption will not result in a step change. They will be percentage reductions worth having but not dramatically change the need to do something to meet anticipated future demand.

Thus those who promote the cross cutting criticism would not see the answers supplied above from the industrial and alternative paradigms as adequate, though there are also criticisms in turn of the cross cutting criticism, as highlighted above by the quote from UKI1.

9.4 Conclusion

This chapter reintroduced the question of how we can understand claims that perennial energy crops will/will not overcome previous controversies raised by food crop biofuels and the second question about the assumptions and theories that underpin these claims. The cross cutting criticism was introduced that maintains no or very little agricultural biomass should be used in energy production because of its inferior energy density to fossil fuels and the scale of resources needed to produce it. This perspective had some overlaps with the alternative agriculture perspective because it was most critical of industrial agriculture. We explored the answers from the different models of agriculture to this new challenge. The opposing argument from the alternative model to the cross cutting criticism is to use biomass on a smaller, more local scale. The rebuttal from the perspective of the industrial paradigm is to ramp up the scale of biomass production to meet the needs of industrial society, and use science and technology to make systems more efficient and to source biomass from further afield to meet the needs of power plants. Those who promote the cross cutting criticism may not be satisfied with these answers because they maintain that the problem relates to the incompatibility between the scale of society's energy use and the inferior energy density of biomass compared to fossil fuels, meaning that even small scale bioenergy is not adequate to meet industrialised society's energy needs. They see more fundamental differences between the agriculture and energy sectors. To address these issues they maintain that energy demand has to be reduced.

The next chapter summarises the answers to the research questions, considers the limitations of the research and presents areas for further research.

Chapter 10 Conclusion

10.1 Introduction

The aim of the project was to explore the ethical and social issues raised by the agricultural production of perennial energy crops and crop residues for energy generation. The project was motivated by Thompson's (2012a) claim that views about agriculture can be divided into those that see it as an industrial sector of the economy and those that see it primarily as a sector which has some special significance beyond its economic contribution to society. He maintains that arguments about new technologies often revolve around philosophical disagreements between these two paradigms and exploring the assumptions and values within these arguments is a fruitful way to shed light on debates within agriculture. In chapters 1 and 2 we presented analysis that saw this as the case for food crop biofuels. Thompson (2008b) states:

> However, many analysts interpret all of the above themes [food versus fuel, environmental impacts of biofuels] as attaining significance as forms of resistance to the coalition of politically and economically powerful interests that currently control land use and food-system policy in the developed world. (p.152).

Many actors working in NGOs and the media framed biofuels as a sort of neo-industrial agriculture: they were produced in the globally organised competitive, high tech industrialised model and to add insult to injury they were sold to energy companies and used to feed machines rather than people. As Action Aid (2010) state: "Biofuels, like many cash crops before them, are following the traditional large-scale, industrial, monoculture and export model." (p.8), "The sheer scale of industrial biofuels – from large-scale intensive agricultural plantations to the export of the raw material – is not sustainable." (p.14). This raised the question of what fate would befall the proposed use of perennial energy crops and crop residues. Were they seen as developing in the industrial paradigm or as representing some other sort of alternative agriculture production?

The overall research question for the project asked how claims that perennial energy crops and crop residues will, or will not, overcome previous controversies raised by food crop biofuels can be understood. Second, what theories and assumptions underpin these claims? This involved considering how key stakeholders frame questions of if, where and how these feedstocks should be produced. The theories and assumptions can relate to paradigms of agriculture or empirical assumptions.

Based on the forgoing analysis, three answers to the main research questions can be identified. The first answer is to overcome controversies by further industrialising agriculture and biomass production; the second answer is to move away from industrial agriculture towards an alternative model of biomass production and use; and the third answer is from the cross cutting criticism that agriculture and energy production represent different value chains and little or no agricultural biomass should be used in energy production. The next section will reflect on these three answers.

10.2 Answers to the research questions.

Industrial perennial energy crops and crop residues

The first answer comes from the industrial paradigm and can be understood as maintaining that perennial energy crop and crop residue production can overcome controversies raised by food crop biofuels through the further industrialisation of agriculture. The details of this were explored in the industrialism lite and life sciences integrated models of biomass production outlined in chapters 5, 6 and 8. The production of perennial energy crops and crop residues within industrialism lite and life sciences integrated agriculture are framed as overcoming previous controversies both because those models solve the problems of productionism which caused biofuels controversies, and also because proponents of this position might not agree that the controversies are due to certain problems with industrial agriculture. In terms of the first type of response, we examine in chapter 3, life sciences integrated agriculture largely leaves the underlying economic and techno-centric philosophy of productionism intact as well as the structures that govern industrial production of large scale, agri-business control and global supply chains. Some see these structures themselves as the problem (Biofuelwatch et al., 2009). Analysts have pointed out that within the industrial paradigm in contrast, issues related to biofuels controversies are framed in terms of a lack of efficiency and lack of investment in scientific and technological solutions (Levidow et al., 2013). Life sciences integrated agriculture is framed as making industrial agriculture more productive, efficient, and high tech. As we saw in chapters 5, 6 and 8 the way forward for perennial energy crops and crop residues involve greater resource use efficiency, more efficient crops and greater land productivity.

There are also some direct answers to the problems of productionism and food crop biofuels. Industrialism lite is framed as a more environmentally friendly, frugal form of industrial agriculture, compared to productionism, which could be seen in the meat versus fuel argument in chapter 5 where perennial energy crop production was compared favourably with more industrial meat production and in the framing of increased productivity freeing up land. This was also seen in the production of perennial energy crops on marginal land to use agricultural resources more efficiently and reduce competition with food production in chapter 6. Life sciences integrated agriculture is also framed as a move away from the excesses and environmental damage caused by productionism. We saw the emphasis put on environmental sustainability in chapter 8 framed in terms of eco-efficiency and "intelligent" production systems advocated for their flexibility. Biomass was seen as divisible into ingredients that could be recombined into different products at will, constructed as the oil wells of the 21st century. We can see this in a quote from a paper that promotes the biorefinery concept:

> In a word, the cost-effective transformation of non-food cellulose to starch could not only revolutionize agriculture by promoting the cultivation of plants chosen for rapid growth rather than those optimized for starch production [68–70] but also could maintain biodiversity and minimize agriculture's environmental footprint [71]. (Zhang, 2013 p.33).

By painting this as a "revolution" in agriculture, the author differentiates biorefineries from productionism that went before. We saw in the last chapter that the answer within the industrial paradigm to the cross cutting criticism was to further ramp up the scale and intensity of production. In some people's view, such as the Danish government employee, if this option is followed then the cross cutting criticism only really applies to alternative agriculture systems.

If those who understand biofuels controversies in terms of disputes about agricultural paradigms, including the author of this research, are correct in our analysis, then the further industrialisation of biomass production will not resolve previous conflicts and be controversy free. This is because different options of land use are always likely to arouse some controversy and because of the nature of the industrial systems. Those who oppose industrial agriculture will continue to criticise these systems as more of the same, or indeed greater and bolder steps in the wrong direction: greater power in the hands of agri-business, greater reliance on science and technology, the support of controversial technologies such as GM that could have undesirable consequences and the neglect of the real causes of controversies in terms of over-consumption and an inappropriate techno-scientific, eco-efficiency based approach (Levidow and Paul, 2008).

Thus, the important point to note is that the promotion of perennial energy crops and crop residue production to overcome previous biofuels controversies within the industrial paradigm involves the assumption that certain aspects of the industrial system need to change and certain other aspects do not. Aspects of industrial food crop biofuels production that do not need to change include large scale, globalised production systems controlled by large agri-business; the use of science and technological innovation in a reductionist model to solve problems in agriculture; and the concept of value understood in economic terms and the pursuit of increased efficiency. Certain things such as the environmental impacts and resource use inefficiency of productionism were seen as needing to change, through for example multipurpose biomass use in biorefineries; marginal land use;

increased use of crop residues; increased productivity to free up land; and fuel production rather than meat production. Life sciences integrated agriculture was a term that already existed in the literature to describe the way forward for industrial agriculture (Lang and Heasman, 2004) and industrialism lite was a term developed in this analysis to describe the framing of perennial energy crop production at the margins of the industrial system.

Alternative perennial energy crops and crop residues

Another answer to how to overcome controversies raised by food based biofuels is for perennial energy crops and crop residues to move away from the industrial paradigm towards an alternative paradigm in an ecologically integrated model or a beneficial multifunctional model which can bring about environmental and other benefits. Those who promote these systems would most likely broadly agree with the analysis of biofuels controversies as caused by the problems of industrial agriculture. Multifunctional agriculture is the attempt to move agriculture away from a monofunctional productionist model towards on-farm diversification and provision of environmental services. This was described in chapter 7 where this model was applied to the use of environmentally marginal land for perennial energy crops in Denmark. Use of environmentally marginal land for perennial energy crops is seen to have water quality benefits and act to restore land that was degraded or incurs environmental damage if used intensively. We also saw that production of perennial energy crops on environmentally marginal land was not as straightforward as it might appear with different, conflicting aims for the use of the land. The water quality benefits of perennial energy crops conflict with the perceived superior biodiversity and landscape benefits of grass production. These conflicting preferences were analysed in terms of different multifunctional aims for using the land and different preferences for open and closed landscapes. This strategy does not address the food versus fuel issue or the issue of ILUC but it does seek to address the local environmental issues caused by productionist food crop biofuels. We saw that this strategy could fit within policy objectives that aim to support intensive, competitive agriculture on the most productive land and promote environmental services on less productive land (Levidow and Boschert, 2008). Farmers on the less productive land may object to the downgrading of their role to environmental managers and it is worth noting that this strategy does not represent a different kind of alternative agriculture production, but is more of a semi-productive complement to the continued functioning of industrial agriculture.

Those who promote the ecologically integrated model would agree that industrial production was the cause of food crop biofuels controversies. The approach advocated here does attempt to move away from the structures and production methods of industrial agriculture. It shares the features of alternative agriculture outlined in chapter 3 including respect for nature, production that intends to mimic natural ecosystems dynamics through closed nutrient and energy cycling, a different model of using science and technology that incorporates local knowledge and a holistic approach, local small scale production, and a different way of measuring productivity to industrial agriculture. For some stakeholders considered in this project, and to a greater extent in the wider literature, this production system included the use of biomass in a biorefinery. In the project data the ecologically integrated model was manifest through the multipurpose use of land, particularly agroforestry systems. It was framed as overcoming some of the resource competition related to food crop biofuels, tackling the environmental impacts through producing perennial energy crops as well as other crops or raising animals on the same piece of land. Agroforestry systems were seen by some as a departure from conventional, monocultural systems, rather than an add-on or tinkering at the margins of the system (ORC, 2010). They frame the difference as being about the way the system is operated and its benefits: it is low input, sustainable and biodiverse agriculture. There is ambivalence about the potential to use crop residues for energy production within the ecologically integrated model because these are needed for soil conditioning, to a greater extent in organic models than conventional agriculture because organic agriculture does not use artificial fertilisers. There was also some ambivalence about the place of perennial energy crops, with some preferring grass production for anaerobic digestion because of its greater flexibility for inclusion in crop rotations and for the reasons given against perennial energy crop production on environmentally marginal land of landscape and biodiversity disbenefits compared to managed grassland systems.

It can be noted that the ecologically integrated and beneficial multifunctional biomass models are broadly compatible with the criticism of food crop biofuels in terms of problems with productionist agriculture. They see answers lying in perennial energy crops and crop residue production moving away from the industrial model towards different, alternative methods of production and production on environmentally marginal land for local environmental benefits. We saw in the last chapter that part of the answer to the cross cutting criticism in this paradigm was to change the scale of bioenergy production and use. People should potentially use less energy and bioenergy should be generated on a smaller, local scale, to match the small scale of biomass' energy yield compared to fossil fuels.

Critics of the alternative paradigm saw its claims to increased productivity, under a different model to industrial production, and claims of environmental sustainability as unrealistic and saw the system as a whole as marginal. Those who agree with the third answer below may not necessarily agree that alternative agriculture models of biomass production could overcome previous controversies.

Cross cutting criticism of agricultural biomass production for energy

The third answer comes from the cross cutting criticism introduced in the last chapter and answers the research questions in the negative that production of perennial energy crops and crop residues cannot overcome previous controversies raised by food based biofuels, regardless of the paradigm of production (though proponents generally saw alternative agriculture more favourably than industrial agriculture). This is because of the inferior energy density of biomass compared to fossil fuels: biomass is living or recently living matter whereas fossil fuels are previously living matter that has been in the ground for millions of years, being condensed into an energy dense, easily transportable, excellent source of energy for human societies. Industrial societies in the global North have been built around the use of fossil fuels and biomass is not a suitable alternative to be used at any significant scale because of its lower energy density and the huge scale of resources required to produce it. They see it as logistically unfeasible and the impacts it incurs as too high. Instead they propose either a very limited use of biomass in energy systems, generally following some features of the alternative models outlined in previous chapters, or use of other renewable sources instead of biomass and/or large scale energy demand reduction and/or substantial efficiency increases.

Those who promote this view would largely agree with the analysis in chapters 1 and 2 of biofuels controversies as caused by issues around industrial agriculture. But they also maintain that the controversies relate to the *scale* of biomass needed, which is not as widely discussed as the food versus fuel and environmental impacts of biofuels. The issue of scale was briefly introduced in chapter 2 under issues raised by biomass which have received less attention. Those who make the argument of the cross cutting criticism maintain that perennial energy crops and crop residues cannot overcome previous controversies raised by food crop biofuels because there are important and fundamental differences between the agriculture and energy sectors that no type of feedstock or scientific innovation can easily overcome.

Areas of overlap between paradigms

Thus understandings of perennial energy crops and crop residues were analysed in terms of the two paradigms of agriculture: industrial and alternative that were the initial framework for the research. There were also areas of overlap between the paradigms, which were mainly considered in chapter 8. These will be summarised here to show that the theoretical underpinnings of the three answers were not entirely straightforward and there was arguably some cross pollination, or at least ambiguity between them.

Thompson (2012a) states that dialogue about philosophical views of agriculture can yield cross fertilisation of ideas and new philosophies "[…] a conscientious effort to put such contrasting philosophies into dialog with one another would spur totally new ideas." (p.63). This research has not actively put contrasting philosophies into contact with each other but has identified some areas of cross over between the industrial and alternative paradigms as it was expressed by key stakeholders. We saw in chapter 8 that the idea of "quality" biomass, which is a hallmark of alternative agriculture, was also expressed within the industrial paradigm by Danish stakeholders. Here "quality" biomass meant region-specific biomass, biomass from one part of the country would produce different products from biomass in a different part of the country; biomass that was tailored to the needs of biorefineries that could distinguish itself from cheaper, lower quality imports; and biomass with better environmental credentials than imports. In the alternative paradigm quality produce can be seen as a region-specific way in which alternative producers distinguish themselves from industrial rivals or rivals from further afield (Vanloqueren and Baret, 2009) and/or an expression of the alternative view that greater connection between people and the land through farming is desirable and beneficial. Quality biomass tailored to biorefineries and quality biomass which has better environmental credentials than imports could be understood as the former type of "quality" biomass that is pursued as a way to promote domestic biomass and ensure farms' economic viability. The fact that one interviewee included the local specificity of biomass in his vision for the biorefinery shows that he was not thinking of it wholly in terms of the dominant framing of the biorefinery as a homogenising mechanism that produces the same products regardless of what type of feedstocks it uses. More work could be carried out to further investigate the idea of quality biomass within the industrial paradigm.

An "industrialism lite" model of agriculture is a neologism that was developed in this project to help understand some ways in which perennial energy crops and crop residues were promoted in the industrial paradigm to help overcome the controversies raised by food crop biofuels. Marginal land use for perennial energy crops and the "meat versus fuel" argument were placed within this model. In chapters 5 and 6 we saw that this system seeks to overcome previous food crop biofuels controversies through pushing perennial energy crops and crop residues production to the margins of the industrial system in order to reduce their impacts on the system as a whole. This strategy does not seek to change the structures of industrial agriculture, but rather paints a vision of production that is less damaging and intrusive than food crop biofuels because it has fewer impacts on and interactions with the global agricultural land use system. The perceived inherent moral correctness of agriculture, in that it is involved in the business of feeding the world (Zimdahl, 2000), can be seen not to apply to biofuels because they defy Jonathan Swift's productionist maxim that producing more food from the same piece of land is the most morally worthy aim for farmers (Thompson, 1995). Because of this perennial energy crops and crop residues are not promoted with the same productionist rhetoric as calls to increase agricultural productivity to “feed the world” but appeal to this more subtle industrial vision. It would be interesting to investigate if similar visions of industrial agriculture are found in different contexts and for different feedstocks and how these differ from industrialism lite.

Productionism was identified as an industrial philosophy of agriculture in chapter 3, but the idea of increasing productivity was also promoted within alternative agriculture as we saw in chapter 8. Here a somewhat different meaning of productivity was sometimes used, when it was often applied to the production of several different outputs from a piece of land, rather than the outputs of monocultural production. It was stated that an emphasis on increasing productivity was compatible with Lang and Heasman’s (2004) view of ecologically integrated agriculture as an up and coming alternative paradigm that is vying with life sciences integrated agriculture as the way to feed the world while reducing the environmental impacts of productionism. Alternative agriculture is not necessarily backwards looking and anti-technology, as it is sometimes criticised as being (Thompson, 2008c), but rather involves a different vision of a technologically savvy agriculture. It would be interesting to investigate the role that visions of increasing productivity play in alternative agriculture.

Thus we can see that there are areas of overlap, or at least ambiguity, between the industrial and alternative paradigms of agriculture and a “different” biomass specific paradigm of industrial agriculture in industrialism lite. This shows that while the paradigms are useful for investigating visions of agricultural production they are theoretical constructs and opinions and practices on the ground are messier. This is emphasised in section 10.3 below on the limitations of the study in that there were many other areas of overlap and ambiguities which it was not possible to investigate in more depth.

10.3 Limitations of the study

Due to the methods and the type of study undertaken the project did not aim to get a representative sample of views of perennial energy crops and crop residues from within the chosen stakeholder groups in the UK and Denmark. The aim was not to make generalisation from the data to those within a particular sector, such as to industry or to the NGO sector as a whole. The goal was not to generalise about countries and make comparisons, but rather to combine the data from the two countries.

The goal of understanding perennial energy crops and crop residues in terms of paradigms of agriculture was considered a worthwhile exercise, as was explained in the introduction, but there was a concern of reifying these categories or merely labelling the data and closing down debate rather than opening it up. The labels could be seen to entrench perceptions of differences and conflicts between different groups, rather than looking for greater understanding or common ground. It was considered necessary however to tell a story, or multiple stories from the data before complicating that story. The data was analysed in terms of these paradigms but the story was complicated along the way by looking at overlaps between them and nuances and counter arguments within the paradigms. There were a lot more overlaps and nuances in the data, particularly the interviews, which there was not enough space to delve into in greater detail.

The issue of scale and where biomass processing would take place, whether locally, regionally or on a larger scale, and the size of operations was asked about during interviews and explored in the document analysis. There was not enough room to consider these issues in detail in the PhD.

10.4 Final remarks and areas for future research

This research aimed to shed light on debates about the production of perennial energy crops and crop residues for energy by exploring how exactly they are seen as overcoming previous controversies raised by crop based biofuels, in terms of different paradigms of agriculture. The purpose was to explore different visions of their production by key stakeholders in the bioenergy sectors in Denmark and the UK and the assumptions and philosophical agricultural positions that underpin them. The work started with the view that empirical evidence is not always enough to understand or resolve debates on controversial areas but work needs to be done on where people's views "come from" and what the fault lines of disagreement are and where they are likely to sit in future (Sarewitz, 2004). To this end the research analysed views of perennial energy crops and crop residues in terms of alternative and industrial paradigms of agriculture.

The bioenergy debate is a fast moving one with fluctuating policies, scientific evidence, technological development and opinions all influencing the issues at stake and how these are framed. The analysis represents a static snap shot of the debate in the documents chosen and the interviewees' views at the time of being interviewed. Here it is worth highlighting a few key points from the analysis and suggesting ways that the debate may progress in future.

One such key point was the framing of crops in terms of their efficiency and flexibility for deconstruction in the biorefinery system rather than their identification as food, feed or fuel crops in chapter 8. We saw in chapter 2 that perennial energy crops were originally promoted as solving some of the problems of food crop biofuels because of their status as non-food crops. It has increasingly been pointed out that the important issue at stake is not the type of crop, but how much land it uses (Biofuelwatch et al., 2009). If the marginal land argument is not accepted then energy crops lose a lot of their superiority over food crops, and indeed they use land for longer, and take that land out of crop rotation for longer than food crop biofuels. The multipurpose biomass argument that frames crops in terms of efficiency and flexibility for the biorefinery could represent a new way forward in the food versus fuel argument. If perennial energy crops are not seen as the most efficient and flexible feedstock in this system, and there were doubts about this as we saw in chapter 8, then they may not be seen as preferable over food crop biofuels.

It is also worth reflecting here on the importance of the cross cutting criticism which was introduced in the last chapter. In the data this criticism was made by people who are opposed to industrial agriculture. There are suggestions however that there are increasing concerns from all sectors about the feasibility of producing energy from biomass to directly replace fossil fuels given the issues of scale and density. At a recent conference on bioenergy an industry representative commented that it was not only policy and technological uncertainty that was deterring investment in lignocellulosic biofuels plants, but also concerns about the long term feasibility of these projects and whether domestic production of bioenergy in the UK would ever be feasible given the availability of feedstocks and the amount of feedstocks required. A figure was quoted by another conference attendee that all the straw that is currently incorporated in UK soils could supply 1.5% of UK's petrol consumption (Glithero et al., 2013). It was stated that though this does not provide a large proportion of the UK's energy consumption it still represents a significant scale of straw use. The economic and technological feasibility of both large scale and small scale biomass production in many of the models described in the analysis remains to be seen in the UK. Denmark already has a more substantial biomass infrastructure but the feasibility of the large scale biorefinery vision, as well as the beneficial multifunctional biomass vision on environmentally marginal land also remain to be seen. While the biofuels strategy was linked up with the biorefinery concept in Denmark almost from the beginning, as we saw previously, (Hansen, 2014), there are increasing indications that this is happening in the UK, where bioenergy research funding will be linked to industrial biotechnology (DfT et al., 2012). Given the issue of scale for energy use there are suggestions that biorefinery research may increasingly focus on developing technologies that can be patented and producing chemical and materials, for which there is no other alternative than fossil fuels, rather than energy for domestic use. Thus, the biorefinery area may become further industrialised and less connected with domestic energy production. As was stated earlier this was not asked about directly during the interviews but emerged organically as an important theme for interviewees in Denmark in particular. It would be interesting to investigate in more detail how the term is being used and seen in the UK, as there is plenty of evidence, as we saw in chapter 8 that it is an increasingly important theme for biomass in the UK.

The issue of biodiversity of perennial energy crops threw up some interesting questions, as we saw in chapters 6 and 7 on marginal land. The biodiversity benefits of perennial energy crops were framed as dependent on different factors including the growing conditions, what they were replacing, how they were grown etc. And there were also outright disagreements about biodiversity: some seeing the matter as settled: it had been established that perennial energy crops had excellent biodiversity benefits and this had to be recognised in policy, and some seeing a need for more evidence. The reasons behind this difference of opinion could be investigated in more detail. There was also the question of biodiversity benefits of open landscapes like grass production being preferred over the biodiversity benefits of closed landscapes like perennial energy crops. One Danish interviewee commented that more open landscape was needed to fulfil the biodiversity convention. More work could be undertaken to examine what is behind this statement and what lies behind the preference for open over closed landscapes.

The theoretical framework developed in chapter 3 could be applied to other countries and other products to see if it could shed any light on these and it would in all probability be again amended and adapted to a different situation. It would also be interesting to test and further develop the philosophical underpinnings of the framework in more detail with other agricultural cases.

Bibliography

Action Aid. (2010). *Meals per gallon: the impact of industrial biofuels on people and global hunger*. London.

Adams, P. W., Hammond, G. P., McManus, M. C., & Mezzullo, W. G. (2011). Barriers to and drivers for UK bioenergy development. *Renewable and Sustainable Energy Reviews*, *15*(2), 1217–1227.

Adorno, T. W., & Horkheimer, M. (1997). *Dialectic of enlightenment*. London: Verson.

Agriculture and Horticulture Development Board. (2014). Straw - what is it good for? Retrieved from http://www.ahdb.org.uk/projects/straw.aspx [Accessed June 2014].

Aiken, M., & Balan, S. (2011). An analysis of google translate accuracy. *Translation Journal*. Retrieved from http://www.bokorlang.com/journal/56google.htm [Accessed February 2014].

Aiken, M., Ghosh, K., Wee, J., & Vanjani, M. (2009). An Evaluation of the Accuracy of Online Translation Systems. *Communications of the IIMA*, *9*(4), 67–85.

Ajanovic, a., & Haas, R. (2010). Economic challenges for the future relevance of biofuels in transport in EU countries. *Energy*, *35*(8), 3340–3348.

Allaire, G., & Wolf, S. A. (2004). Cognitive Representations and Institutional Hybridity in Agrofood Innovation. *Science, Technology & Human Values*, *29*(4), 431–458.

Altieri, M. a., & Toledo, V. M. (2011). The agroecological revolution in Latin America: rescuing nature, ensuring food sovereignty and empowering peasants. *Journal of Peasant Studies*, *38*(3), 587–612.

Amigun, B., Musango, J. K., & Stafford, W. (2011). Biofuels and sustainability in Africa. *Renewable and Sustainable Energy Reviews*, *15*(2), 1360–1372.

Andersen, R. S., Towers, W., & Smith, P. (2005). Assessing the potential for biomass energy to contribute to Scotland's renewable energy needs. *Biomass and Bioenergy*, *29*(2), 73–82.

Anthony, R. (2010). Building a Sustainable Future for Animal Agriculture: An Environmental Virtue Ethic of Care Approach within the Philosophy of Technology. *Journal of Agricultural and Environmental Ethics*, *25*(2), 123–144.

Astrup, T., Tonini, D., Hamelin, L., & Wenzel, H. (2011). *Environmental assessment of renewable energy scenarios towards 2050*. Aalborg.

Bandaru, V., Izaurralde, R. C., Manowitz, D., Link, R., Zhang, X. S., & Post, W. M. (2013). Soil Carbon Change and Net Energy Associated with Biofuel Production on Marginal Lands: A Regional Modeling Perspective. *Journal of Environmental Quality*, 42, 1802–1814.

Bauen, a W., Dunnett, a J., Richter, G. M., Dailey, a G., Aylott, M., Casella, E., & Taylor, G. (2010). Modelling supply and demand of bioenergy from short rotation coppice and Miscanthus in the UK. *Bioresource Technology*, 101(21), 8132–43.

BBC. (2007). Biofuels “crime against humanity.” Retrieved from http://news.bbc.co.uk/1/hi/world/americas/7065061.stm [Accessed March 2011].

BBSRC. (2009). The Age of Bioscience: Strategic plan 2010-2015. Swindon.

Beauchamp, T. L., & Childress, J. F. (1994). *Principles of Biomedical Ethics*. Oxford: Oxford University Press.

Beck, U. (1999). *World Risk Society*. Cambridge: Blackwell Publishers.

Benford, R. D. (1997). An Insider’s Critique of the Social Movement Framing Perspective. *Sociological Inquiry*, 67(4), 409-430.

Benton, T. (2012). Supply and demand: Increasing production and efficiency sustainably. *Food Ethics: The Magazine of the Food Ethics Council*.

BERR. (2009). *IB 2025 Maximising UK Opportunities from Industrial Biotechnology in a Low Carbon Economy*. London.

Bestmann, L. S. (2009). *Energipil og betydende faktorer for optimale dyrkningssteder*. Copenhagen.

Beus, C. E., & Dunlap, R. E. (1990). Conventional versus alternative agriculture: The paradigmatic roots of the debate. *Rural Sociology*, *55*(4), 590–616.

Bhardwaj, A. K., Zenone, T., Jasrotia, P., Robertson, G. P., Chen, J., & Hamilton, S. K. (2011). Water and energy footprints of bioenergy crop production on marginal lands. *Global Change Biology Bioenergy*, *3*, 208–222.

Biofuelwatch, Carbon Trade Watch, Corporate Europe Observatory, Econexus, Ecoropa, Grupo de Reflexion Rural, Munlochy Vigil, NOAH (Friends of the Earth Denmark), Rettet Den Regenwald, Watch Indonesia (2007) Agrofuels: Towards a reality check in nine key areas. Edinburgh.

Biomass Energy Centre. (2011). Grants and Support. Retrieved from http://www.biomassenergycentre.org.uk/portal/page?_pageid=77,15133&_dad=portal&_schema=PORTAL#SUPP [Accessed June 2012]

Birch, K. (2009). The knowledge-space dynamic in the UK bioeconomy. *Area*, *41*(3), 273–284.

Birch, K., Levidow, L., & Papaioannou, T. (2010). Sustainable Capital? The Neoliberalization of Nature and Knowledge in the European “Knowledge-based Bio-economy.” *Sustainability*, *2*(9), 2898–2918.

Blanco-Canqui, H. (2010). Energy Crops and Their Implications on Soil and Environment. *Agronomy Journal*, 102, 403–419.

Bondi, L. (2003). Empathy and Identification : Conceptual Resources for Feminist Fieldwork. *ACME: An International E-Journal for Critical Geographies*, *2*(1), 64–76.

Booth, E., Walker, R., Bell, J., Mccracken, D., Curry, J., & Biddle, A. (2009). An Assessment of the Potential Impact on UK Agriculture and the Environment of Meeting Renewable Feedstock Demands. Edinburgh.

Borgmann, A. (2004). Focal Things and Practices. In D. M. Kaplan (Ed.), *Readings in the Philosophy of Technology*. Lanham: Rowman & Littlefield.

Borras Jr, S. M., & Franco, J. C. (2010). Contemporary Discourses and Contestations around Pro-Poor Land Policies and Land Governance. *Journal of Agrarian Change*, *10*(1), 1–32.

Borras Jr., S. M. (2011). The politics of biofuels and mega land and water deals: insights from the Pro-Cana case, Mozambiqu. *Review of African Political Economy*, *38*(128), 215–234.

Borras Jr., S. M., McMichael, P., & Scoones, I. (2010). The politics of biofuels , land and agrarian change: editors ' introduction, *Journal of Peasant Studies, 37*(4), 575–592.

Borry, P., Schotsmans, P., & Dierickx, K. (2004). What is the role of empirical research in bioethical reflection and decision-making? An ethical analysis. *Medicine, Health Care, and Philosophy*, *7*(1), 41–53.

Boucher, P. (2011). What next after determinism in the ontology of technology? Distributing responsibility in the biofuel debate. *Science and Engineering Ethics*, *17*(3), 525–38.

Boucher, P. (2012). The role of controversy, regulation and engineering in UK biofuel development. *Energy Policy*, *42*, 148–154.

Boucher, P., Smith, R., & Millar, K. (2014). Biofuels under the spotlight: The state of assessment and potential for integration. *Science and Public Policy*, *41*(3), 283–293.

Braiser, K. J. (2002). Ideology and discourse: Characterizations of the 1996 Farm Bill by agricultural interest groups. *Agriculture and Human Values* , *19*, 239–253.

Brara, R. (1992). Are grazing lands wastelands? Some evidence from Rajasthan. *Economic and Political Weekly*, *27*(9), 411–418.

Bringezu, S., Schutz, H., O'Brien, M., Kauppi, L., Howarth, R. W., & McNeely, J. (2009). *Towards sustainable production and use of resources: assessing biofuels*. Gummersbach.

Brown, N. (2003). Hope Against Hype – Accountability in Biopasts , Presents and Futures. *Science Studies*, *16*(2), 3–21.

Bryman, A. (1988). *Quantity and quality in social research*. London: Unwin Hyman.

Bryman, A. (2001). *Social Research Methods*. Oxford: Oxford University Press.

Buttel, F. H. (1994). The global impacts of agricultural biotechnology: a post-green revolution perspective. In T.B. Mepham, G.A. Tucker, & J. Wiseman, (Eds.), *Issues in Agricultural Bioethics*. Nottingham: Nottingham University Press.

Butterbach-Bahl, K., & Kiese, R. (2013). Biofuel production on the margins. *Nature*, *7433*, 483–485.

Cacciatore, M. a., Scheufele, D. a., & Shaw, B. R. (2012). Labeling renewable energies: How the language surrounding biofuels can influence its public acceptance. *Energy Policy*, *51*, 673–682.

Callicott, J. B. (1990). The metaphysical transition in farming: From the newtonian-mechanical to the eltonian ecological. *Journal of Agricultural Ethics*, *3*(1), 36–49.

Carbon Trust. (2011). The Renewables Obligation. Retrieved from http://www.carbontrust.co.uk/policy-legislation/energy-supply/renewable-energy/pages/renewables-obligation.aspx [Accessed November 2012].

CAT. (2010). *Zero Carbon Britain 2030: A new energy strategy*. Powys.

CEESA. (2011). *Coherent Energy and Environmental System Analysis*. Aalborg.

Christian Aid. (2009). *Growing pains: the promises and problems of biofuels*. London.

Coelli, T. J., Prasada Rao, D. S., O'Donnell, C. J., & Battese, G. E. (2005). *An Introduction to Efficiency and Productivity Analysis, second edition.* New York: Springer.

Committee on Climate Change. (2011). *Bioenergy Review: Technical paper 2. Global and UK bioenergy supply scenarios*. London.

Connor, P. (2003). UK renewable energy policy: a review. *Renewable and Sustainable Energy Reviews*, *7*(1), 65–82.

Copeland, J., & Turley, D. (2008). *National and regional supply/demand balance for agricultural straw in Great Britain*. York.

CREPE. (2011). *Agricultural Innovation : Sustaining What Agriculture? For What European Bio-Economy?* Project-wide final report. Milton Keynes.

Crutzen, P. J., Mosier, A. R., Smith, K. A., Winiwarter, W., Jolla, L., & Pleasant, M. (2008). N2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels, *Atmospheric Chemistry and Physics, 8*, 389–395.

Dagnall, S., & Prime, J. (2012). *Renewable sources of energy*. London.

Danish Energy Agency. (2010). *Danish Energy Policy 1970-2010*. *Renewable Energy*. Copenhagen.

Danish Energy Agency. (2012). *Energy Statistics 2012*. Copenhagen.

Danish Energy Authority. (2008). *Renewable Energy in Denmark*. Retrieved from http://www.ambottawa.um.dk/NR/rdonlyres/8A89D4E5-1E40-4042-BA20-1B983B0EB40B/0/renewable.pdf [Accessed November 2011].

Danish Government. (2011). *Energy Strategy 2050 - from coal, oil and gas to green energy*. *Strategy*. Copenhagen.

Danish Government, & Danish People's Party. (2009). *Agreement on Green Growth*. *Nature*. Copenhagen.

Danmark Statistik. (2013). *Danmark i tal 2013*. Copenhagen.

Dansk Ornitologisk Forening. (2011). *Alle har ret til en rig nature. Om naturens problemer med det industrialiserede landbrug*. Copenhagen.

De Lattre-Gasquet, M., Vermersch, D., Bursztyn, M., & Duee, P. H. (2010). Bioenergies: unveiling the ethos of agrarian research. In C.M. Romeo Casabano, L. Escajedo San Epifanio, and A. Emaldi Cirion, (Eds.), *Global Food Security: Ethical and Legal Challenges*. Wageningen: Wageningen Academic Publishers.

DECC. (2013). *Use of UK biomass for electricity and CHP*. London.

Defra. (2007). *UK Biomass Strategy*. London.

Defra. (2011). The Energy Crop Scheme. Retrieved from http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000IL3890W.16NTBX8B9X613G [Accessed June 2012].

DEFRA. (2012). *Farming Statistics Final Land Use , Livestock Populations and Agricultural Workforce at 1 June 2012 - England*. London.

Delshad, A. B., Raymond, L., Sawicki, V., & Wegener, D. T. (2010). Public attitudes toward political and technological options for biofuels. *Energy Policy*, *38*(7), 3414–3425.

Denzin, N. K., & Lincoln, Y. S. (1998). Introduction: Entering the Field of Qualitative Research. In *Collecting and Interpreting Qualitiative Materials* (pp. 1–35). London: Sage Publications.

Department of Transport. (2011). Renewable Transport Fuels Obligation. Retrieved from http://www.dft.gov.uk/topics/sustainable/biofuels/rtfo/ [Accessed November 2012].

Det Økologiske Råd. (2010). *Biomasse og bioenergi*. Copenhagen.

DfT. (2014). *Renewable Transport Fuel Obligation statistics : obligation period 5, 2012/2013, report 6*. London.

DfT, DECC, & Defra. (2012). *UK Bioenergy Strategy*. London.

Dingwall, R. (1997). Accounts, Interviews and Observations. In G. Miller & R. Dingwall (Eds.), *Context and Method in Qualitative Research*. London: Sage Publications.

Don, A., Osborne, B., Hastings, A., Skiba, U., Carter, M. S., Drewer, J., Flessa, H., Freibauer, A., Hyvonen, N., Jones, MB., Lanigan, GJ., Mander, U., Monti, A., Njakou Djomo, S., Valentine, J., Walter, K., Zegada-Lizarazu, W. & Zenone, T. (2012). Land-use change to bioenergy production in Europe: implications for the greenhouse gas balance and soil carbon. *Global Change Biology Bioenergy*, *4*, 372–391.

Doornbosch, R., & Steenblik, R. (2008). *Biofuels : Is the cure worse than the disease ? Round Table, The* (Vol. 33). Paris.

DTI, & DEFRA. (2004). *A strategy for non-food crops and uses Creating value from renewable materials*. London.

Dubgaard, A. (1989). Marginalisering - økonomisk belyst. *Geografisk Tidsskrift*, *89*, 31–35.

Dürnberger, C., Formowitz, B., Grimm, H., & Uhl, A. (2009). Technological Innovation and Social Responsibility – Challenges to Bavarian Agriculture and the Provision of Bioenergy. In K. Millar, B. Nerlich, & P. Hobson West (Eds.) *Ethical Futures: Bioscience and food horizons*. Wageningen: Wageningen Academic Publishers.

Edge, D. (1995). Reinventing the Wheel. In *Handbook of science and technology studies*. London: Sage Publications.

Elliot, K. C. (2009). The ethical significance of language in the environmental sciences: Case studies from pollution research . *Ethics, Place and Environment*, *12*(2), 157–173.

Entman, R. M. (1993). Framing : Towards Clarification of a Fractured Paradigm. *Journal of Communication*, *43*(4), 51–58.

Environment Agency. (1991). Vand- og stofbalance på lavbundsjord. Retrieved from http://www.mst.dk/Publikationer/Publikationer/1991/01/87-503-8844-4.htm [Accessed February 2014].

Environment Agency. (2009). *Biomass : Carbon sink or carbon sinner ?* London.

Erhervs-og Vækstministeriet. (2013). *Danmark i arbejde: Væskplan for vand, bio and miljø-løsninger*. Copenhagen.

European Biofuels Technology Platform. (2011). Biofuels and Sustainability in Europe. Retrieved from http://www.biofuelstp.eu/sustainability.html

European Comission. (2012). *Proposal for a Directive of European Parliament and of the Council amending Directive 98/70/EC to the quality of petrol and diesel fuels and amending 2009/28/EC on the promotion of the use of energy from renewable sources* (Vol. 0288). Brussels.

European Commission. (2000). *Green paper: Towards a European Strategy for the Security of Energy Supply*. *Journal of medicine and life* (Vol. 3). Brussels.

European Commission. (2005). New Perspectives on the knowledge based bio-economy. In *The knowledge-based bio-economy. Transforming life sciences knowledge into new, sustainable, eco-efficient and competitive products.* Brussels.

European Commission. (2010). *Report from the commission to the council and the European Parliament*. Brussels.

European Commission. (2012). *Innovating for Sustainable Growth: A bioeconomy for Europe*. Brussels.

European Commission. (2013). Kyoto emissions targets. Retrieved from http://ec.europa.eu/clima/policies/g-gas/kyoto/index_en.htm [Accessed January 2014].

Ewing, M., & Msangi, S. (2009). Biofuels production in developing countries: assessing tradeoffs in welfare and food security. *Environmental Science & Policy*, *12*(4), 520–528.

Fairley, P. (2011). Introduction: Next generation biofuels. *Nature*, *474*(7352), S2-S5.

FAO. (2008). *The state of food and agriculture. Biofuels: prospects, risks and opportunities*. Rome.

FAO. (2012). *FAO Statistical Yearbook. World Food and Agriculture* (pp. 312–352). Retrieved from http://www.fao.org/docrep/015/i2490e/i2490e00.htm [Accessed July 2013].

Fargione, J., Hill, J., Tilman, D., Polasky, S., & Hawthorne, P. (2008). Land clearing and the biofuel carbon debt. *Science*, *319*(5867), 1235–8.

Fisher, M. (2009). The craze for conservation grazing. Retrieved from http://www.self-willed-land.org.uk/articles/craze_graze.htm [Accessed March 2014].

Forestry Commission Scotland. (2007). *Biomass action plan for Scotland*. Edinburgh.

Forssell, S., & Lankoski, L. (2014). The sustainability promise of alternative food networks: an examination through "alternative" characteristics. *Agriculture and Human Values*, DOI 10.1007/s10460-014-9516-4

Franco, J., Levidow, L., Fig, D., Goldfarb, L., Honicke, M., & Luisa Mendonca, M. (2010). Assumptions in the European Union biofuels policy: frictions with experiences in Germany, Brazil and Mozambique. *Journal of Peasant Studies*, *37*(4), 661–698.

Frey, R. G. (2013). Bioethics. In E. Craig (Ed.), *Concise Routledge Encyclopaedia of Philosophy*. London: Routledge.

Friedberg, C. (2000). Does a landscape need to be closed or open. *Nature Sciences Sociétés*, *8*(4), 26–42.

Friends of the Earth. (2007). Declaration on Agrofuels. Retrieved from http://www.foei.org/en/what-we-do/agrofuels/global/agrofuels-declaration [Accessed January 2012].

Fuller, G., Mckeon, T. A., & Bills, D. D. (1996). Nonfood Products from Agricultural Sources. In *ACS Symposium Series; American Chemical Society*. Washington DC.

Funtowicz, S., & Ravetz, J. R. (1993). Science for the post-normal age. *Futures*, *25*(7), 739–755.

Gamborg, C., Millar, K., Shortall, O., & Sandøe, P. (2012). Bioenergy and Land Use: Framing the Ethical Debate. *Journal of Agricultural and Environmental Ethics*, *25*(6), 909–925.

Gamborg, C., Sandøe, P., & Anker, H. T. (2012). Setting the rules of the game: Ethical and legal issues raised by bioenergy governance methods. In T. Potthast & S. Meisch (Eds.), *Climate Change and Sustainable Development: Ethical perspectives on land use and sustainable development*. Wageningen: Wageningen Academic Publishers.

Garzon, I. (2006). *Reforming the Common Agricultural Policy: a history of paradigm change*. London: Palgrave MacMillan.

Geels, F., & Raven, R. (2006). Non-linearity and Expectations in Niche-Development Trajectories : Ups and Downs in Dutch Biogas Development (1973 – 2003). *Technology Analysis & Strategic Management*, *18*(3-4), 375–392.

Gelfand, I., Sahajpal, R., Zhang, X. S., Izaurralde, R. C., Gross, K. L., & Robertson, G. P. (2013). Sustainable bioenergy production from marginal lands in the US Midwest. *Nature*, *493*(7433), 514.

German, L., Schoneveld, G., Skutch, M., Andriani, R., Obidzinski, K., Pacheco, P., … Dayang Norwana, A. A. . (2010). *The local social and environmental impacts of biofuel feedstock expansion: a synthesis of case studies from Asia, Africa and Latin America*. Bogor. Retrieved from http://www.cifor.cgiar.org/nc/online-library/browse/view-publication/publication/3295.html [Accessed June 2011].

Giddens, A. (1999). Risk and Responsibility. *The Modern Law Review*, *61*, 1–10.

Gilbert, N. (2011). Local benefits: The seeds of an economy. *Nature*, *474*(7352), S18-S19.

Glithero, N. J., Wilson, P., & Ramsden, S. J. (2013). Straw use and availability for second generation biofuels in England. *Biomass and Bioenergy*, *55*(2012), 311–321.

Goffman, E. (1974). *Frame Analysis*. Cambridge, M.A.: Harvard University Press.

Gomiero, T., Paoletti, M. G., & Pimentel, D. (2009). Biofuels: Efficiency, Ethics, and Limits to Human Appropriation of Ecosystem Services. *Journal of Agricultural and Environmental Ethics*, *23*(5), 403–434.

Goodman, D. (1999). Agro-Food Studies in the " Age of Ecology": Nature, Corporeality, Bio-Politics. *Sociologia Ruralis*, *39*(1), 17-38.

Goodman, D. (2004). Rural Europe Redux? Reflections on Alternative Agro-Food Networks and Paradigm Change. *Sociologia Ruralis*, *44*(1), 3–16.

Google translate. (2013). Find out how our translations are created. Retrieved from http://translate.google.com/about/intl/en_ALL/ [Accessed September 2013].

Gopalakrishnan, G., Negri, M. C., & Snyder, S. W. (2011). A novel framework to classify marginal land for sustainable biomass feedstock production. *Journal of Environmental Quality*, *40*, 1593–1600.

Graffy, E. (2011). Agrarian Ideals, Sustainability Ethics, and US Policy: A Critique for Practitioners. *Journal of Agricultural and Environmental Ethics*, *25*(4), 503-528.

Graham-Rowe, D. (2011). Agriculture: Beyond food versus fuel. *Nature*, *474*(7352), S6-S8.

Grant, W. (1997). *The Common Agricultural Policy*. London: MacMillan Press.

Griffin, K. (1974). *The political economy of agrarian change*. London: MacMillan Press.

Gross, P. R., & Levitt, N. (1998). *Higher Superstition: The academic left and its quarrels with science*. Baltimore: The John Hopkins University Press.

GTZ. (2009). *Jatropha Reality Check: a field assessment of the agronomic and economic viability of Jatropha and other oilseed crops in Kenya*. Nairobi.

Gylling, M., Abildtrup, J., Vodder Nielsen, K., Petersen, S. M., & Varming, S. (2001). *Langsigtede biomasseressourcer til energiformål - mængder , omkostninger og markedets betingelser*. Copenhagen.

Gylling, M., Jørgensen, U., Scott Bentsen, N., Kristensen, I. T., Dalgaard, T., Felby, C., & Kvist Johannsen, V. (2012). *+ 10 mio. tons planen*. Copenhagen.

Hammersley, M. (1992). *What's wrong with ethnography?* (p. 230). London: Routledge.

Hansen, J. (2014). The Danish Biofuel Debate: Coupling Scientific and Politico-Economic Claims. *Science as Culture*, *23*(1), 73–97.

Hansen, L. (1989). Jordbrugsmæssig anvendelse af tørre, sandede jorder. *Geografisk Tidsskrift*, *89*, 35–38.

Hardeman, E., & Jochemsen, H. (2011). Are There Ideological Aspects to the Modernization of Agriculture? *Journal of Agricultural and Environmental Ethics*, *25*(4), 657–674.

Hauggaard-nielsen, H., Jensen, E. S., Carter, M. S., Johansen, A., & Ambus, P. (n.d.). *Strip intercropping strategy for biomass to energy production while on the same time maintaining soil fertility*. Copenhagen.

Haughton, A.J., Bond, A.J., Lovett A.A., Dockerty, T., Sunnenberg, G., Clark, S.J., Bohan, D.A., Sage, R.S., Mallott, M.D., Mallott, V.E., Cunningham, M.D., Riche, A.B., Shield, I.F., Finch, F.W., Turner, M.T., Karp, A.. (2009). A novel, integrated approach to assessing social, economic and environmental implications of changing rural land-use: a case study of perennial biomass crops. *Journal of Applied Ecology*, *46*(2), 315–322.

Hedgecoe, A. M. (2004). Critical bioethics: beyond the social science critique of applied ethics. *Bioethics*, *18*(2), 120–143.

Helm, D. (2002). A critique of renewables policy in the UK. *Energy Policy*, *30*(3), 185–188.

HM Government. (2009). *The UK Renewable Energy Strategy*. London.

Hunsberger, C. (2014). Sustainable biofuels in the global South. *Geoforum*, *54*, 243–247.

ICROFS. (n.d.). *Biomass and bioenergy production in organic agriculture. Bioconcens.* Copenhagen.

IEA. (2010). Global Renewable Energy Policies and Measures. *IEA*. Retrieved from http://www.iea.org/textbase/pm/?mode=re&action=view&country=Denmark [Accessed November 2011].

IEA. (2011). *Technology Roadmap: Biofuels for Transport*. Paris.

IEEP. (2014). *Re-examining EU biofuels policy: A 2030 perspective*. Brussels.

Inbicon. (n.d.). Inbicon global solutions. Retrieved from http://www.inbicon.com/global_solutions/Pages/global_solutions.aspx [Accessed June 2014].

Jamieson, D. (2008). *Ethics and the Environment: an Introduction*. Cambridge: Cambridge University Press.

Jank, M. J., Kutas, G., do Amaral, L. F., & Nassar, A. M. (2007). *EU and U.S. Policies on Biofuels: Potential Impacts on Developing Countries*. Washington.

Jasanoff, S. (1999). STS and Public Policy: Getting Beyond Deconstruction. *Science Technology & Society*, *4*(1), 59–72.

Jasanoff, S. (2004). Ordering knowledge, ordering society. In S. Jasanoff (Ed.), *States of Knowledge: The co-production of science and social order*. New York: Taylor and Francis.

Jasanoff, S. (2005). *Designs on Nature: Science and democracy in Europe and the United States*. Princeton: Princeton University Press.

Jay, M. (2007). The political economy of a productivist agriculture: New Zealand dairy discourses. *Food Policy*, *32*, 266–279.

Johnson, D. G., & Wetmore, J. M. (2008). STS and Ethics: Implications for Engineering Ethics. In E. Hackett, O. Amerstdamska, M. Lynch, & J. Wacjman (Eds.), *New Handbook of Science and Technology Studies*. Cambridge, M.A.: The MIT Press.

Jonas, H. (2004). Technology and Responsibility. In D. M. Kaplan (Ed.), *Readings in the Philosophy of Technology*. Lanham: Rowman & Littlefield.

Jørgensen, M. S. (2007). Transition towards sustainable consumption and production ? The case of organic food in Denmark. In *Cases in Sustainable Consumption and Production*. Paris.

Jørgensen, U. (2007). *Combined production of biomass for energy and clean drinking water - A miscanthus demonstration project on the " Renewable Energy Island " Samsø*. Retrieved from http://www.ieabioenergytask43.org/Task_30_Web_Site/PDFs/IEA_BiomassforEnergySamsoe.pdf [Accessed June 2011].

Jørgensen, U., Dalgaard, T., & Kristensen, E. S. (2005). Biomass energy in organic farming—the potential role of short rotation coppice. *Biomass and Bioenergy*, *28*(2), 237–248.

Jørgensen, U., & Schelde, K. (2011). *Næringsstoftab efter omlægning fra omdrift til dyrkning af flerårige energiafgrøder*. Aarhus.

Kaiser, M., Millar, K., Thorstensen, E., & Tomkins, S. (2007). Developing the ethical matrix as a decision support framework: GM fish as a case study. *Journal of Agricultural and Environmental Ethics*, *20*(1), 65–80.

Kang, S., Post, W., Wang, D., Nichols, J., Bandaru, V., & West, T. (2013). Hierarchical marginal land assessment for land use planning. *Land Use Policy*, *30*, 106–113.

Karafyllis, N. C. (2003). Renewable resources and the idea of nature – what has biotechnology got to do with it? *Journal of Agricultural and Environmental Ethics*, *16*(1), 3–28.

Karp, A., Hanley, S. J., Trybush, S. O., Macalpine, W., Pei, M., & Shield, I. (2011). Genetic improvement of willow for bioenergy and biofuels. *Journal of Integrative Plant Biology*, *53*(2), 151–65.

Karp, A., & Shield, I. (2008). Bioenergy from plants and the sustainable yield challenge. *The New Phytologist*, *179*(1), 15–32.

Kilpatrick, J., Heywood, C., Smith, C., Wilson, L., Procter, C., Spink, J., Tubby, I., Matthews, R., Mackie, E., Hogan, G. & Randle, T. (2008). *Addressing the land use issues for non-food crops , in response to increasing fuel and energy generation*. Hereford.

Kløcker Larsen, R., Jiwan, N., Rompas, A., Jenito, J., Osbeck, M., & Tarigan, A. (2014). Towards "hybrid accountability" in EU biofuels policy? Community grievances and competing water claims in the Central Kalimantan oil palm sector. *Geoforum*, *54*, 295–305.

Krimsky, S. (1995). The Cultural and Symbolic Dimensions of Agricultural Biotechnology. In T. B. Mepham, G. A. Tucker, & J. Wiseman (Eds.), *Issues in Agricultural Bioethics*. Nottingham: Nottingham University Press.

Krzywoszynska, A. (2012). "Waste? You mean by-products!" From bio-waste management to agro-ecology in Italian winemaking and beyond. *The Sociological Review*, *60*(2013), 47–65.

Kuchler, M., & Linnér, B.-O. (2012). Challenging the food vs. fuel dilemma: Genealogical analysis of the biofuel discourse pursued by international organizations. *Food Policy*, *37*(5), 581–588.

Kuhn, T. S. (1996). *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

Lakoff, G., & Johnson, M. (1980). *Metaphors We Live By*. Chicago: University of Chicago Press.

Lal, R. (2009). Soil quality impacts of residue removal for bioethanol production. *Soil and Tillage Research*, *102*(2), 233–241.

Lang, T., & Heasman, M. (2004). *Food Wars: The global battle for mouths, minds and markets*. London: Earthscan.

Larsen, S. U. (2009). Renewable Energy Act and energy crop production | AgroTech. Retrieved from http://agrotech.dk/en/what-is-new/renewable-energy-act-and-energy-crop-production [Accessed November 2011].

Larson, B. (2011). *Metaphors for Environmental Sustainability: Redefining our relationship with nature*. New Haven: Yale University Press.

Latour, B. (2004). A Collective of Humans and Nonhumans. In D. M. Kaplan (Ed.), *Readings in the Philosophy of Technology*. Lanham: Rowman and Littlefield Publishers.

Le Floch, S., Devanne, A., & Deffontaines, J.-P. (2005). La "fermeture du paysage": au-delà du phénomène, petite chronique d'une construction sociale. *L'Espace Géographique*, *34*, 49–64.

Lehrer, N. (2010). (Bio)fueling farm policy: the biofuels boom and the 2008 farm bill. *Agriculture and Human Values*, *27*(4), 427–444.

Leopold, A. (1949). *A Sand County Almanac*. Oxford: Oxford University Press.

Lepart, J., Marty, P., & Rousset, O. (2000). Les conceptions normatives du paysage . Le cas des Grands. *Nature Sciences Sociétés*, *8*(4), 16–25.

Levidow, L. (2008). European quality agriculture as an alternative bio-economy. Retrieved from http://technology.open.ac.uk/cts/docs/LL_Quality%20Agriculture_08.pdf [Accessed May 2013].

Levidow, L. (2013). EU criteria for sustainable biofuels: Accounting for carbon, depoliticising plunder. *Geoforum*, *44*, 211–223.

Levidow, L., Birch, K., & Papaioannou, T. (2013). Divergent Paradigms of European Agro-Food Innovation: The Knowledge-Based Bio-Economy (KBBE) as an R&D Agenda. *Science, Technology & Human Values*, *38*, 94–125.

Levidow, L., & Boschert, K. (2008). Coexistence or contradiction? GM crops versus alternative agricultures in Europe. *Geoforum*, *39*(1), 174–190.

Levidow, L., & Papaioannou, T. (2013). State imaginaries of the public good: shaping UK innovation priorities for bioenergy. *Environmental Science & Policy*, *30*, 36–49.

Levidow, L., & Papaioannou, T. (2014). UK biofuel policy: envisaging sustainable biofuels, shaping institutions and futures. *Environment and Planning A*, *46*(2), 280–298.

Levidow, L., & Paul, H. (2008). *Land-use, Bioenergy and Agro-biotechnology*. *WBGU*. Berlin.

Levitt, M. (2004). Complementarity rather than integration. *Medicine, Health Care, and Philosophy*, *7*(1), 81–3..

Lewis, C. W. (1981). Biomass through the ages. *Biomass*, *1*, 5–15.

Lovett, A. A., Sünnenberg, G. M., Richter, G. M., Dailey, a. G., Riche, A. B., & Karp, A. (2009). Land Use Implications of Increased Biomass Production Identified by GIS-Based Suitability and Yield Mapping for Miscanthus in England. *BioEnergy Research*, *2*(1-2), 17–28.

Lowe, P., Woods, A., Liddon, A., & Phillipson, J. (2009). Strategic land use for ecosystem services. In M. Winter & M. Lobley (Eds.), *What is Land For? The food, fuel and climate change debate*. London: Earthscan.

MacKenzie, D., & Wajcman, J. (1999). Introductory essay : the social shaping of technology. In D. MacKenzie & J., Wajcman (Eds.) *The Social Shaping of Technology* (pp. 3–27). London: Open University Press.

MacMillan, T., & Dowler, E. (2012). Just and Sustainable? Examining the Rhetoric and Potential Realities of UK Food Security. *Journal of Agricultural and Environmental Ethics*, *25,* 181–204.

Madsen, B. L. (1989). Vandløbene og deres omgivelser. *Geografisk Tidsskrift*, *89*, 39–43.

Maegaard, P. (n.d.). *Danish Renewable Energy Policy*. Copenhagen.

Mangoyana, R. B., & Smith, T. F. (2011). Decentralised bioenergy systems: A review of opportunities and threats. *Energy Policy*, *39*(3), 1286–1295.

Mårald, E. (2013). The Ambiguous Legacy of Agrarianism. *Philosophy of Technology*, *26*, 305–308.

Mariola, M. J. (2005). Losing ground : Farmland preservation , economic utilitarianism, and the erosion of the agrarian ideal. *Agriculture and Human Values, 22,* 209–223.

Marsden, T. (2003). *The condition of rural sustainability*. Assen: Wageningen Academic Publishers.

Marsden, T., & Sonnino, R. (2008). Rural development and the regional state: Denying multifunctional agriculture in the UK. *Journal of Rural Studies*, *24*(4), 422–431.

Martin, J. (2011). Perspective: Don't foul the water. *Nature*, *474*(7352), S17–S17.

McDonald, R. I., Fargione, J., Kiesecker, J., Miller, W. M., & Powell, J. (2009). Energy sprawl or energy efficiency: climate policy impacts on natural habitat for the United States of America. *PloS One*, *4*(8), e6802.

McMichael, P. (2009). The Agrofuels Project at Large. *Critical Sociology*, *35*(6), 825–839.

McMichael, P. (2010). Agrofuels in the food regime. *Journal of Peasant Studies*, *37*(4), 609–629.

Melillo, J. M., Reilly, J. M., Kicklighter, D. W., Gurgel, A. C., Cronin, T. C., Paltsev, S., Benjamin S. Felzer, B.S., Wang, X., Sokolov, A.P. and Schlosser, C. A. (2009). Indirect emissions from biofuels: how important? *Science*, *326*, 1397-1399.

Mepham, B. (2008). *Bioethics: An introduction for the biosciences*. Oxford: Oxford University Press.

Mepham, B., Tucker, G. A., & Wiseman, J. (Eds.). (1995). *Issues in Agricultural Bioethics*. Wiltshire: Redwood Books.

Miljøministeriet Naturstyrelsen. (n.d.). Statistik. Retrieved from http://naturstyrelsen.dk/naturbeskyttelse/naturprojekter/hvorfor-laver-vi-naturprojekter/statistik/ [Accessed June 2013].

Ministeriet for Fødervarer Landbrug og Fiskeri. (2008a). *Jorden - en knap ressource*. Copenhagen.

Ministeriet for Fødervarer Landbrug og Fiskeri. (2008b). *Landbrug og Klima*. Copenhagen.

Ministeriet for Fødevarer Landbrug of Fiskeri. (2013). Regeringen samler kræfterne om bioøkonomien. Retrieved from http://fvm.dk/nyheder/nyhed/nyhed/regeringen-samler-kraefterne-om-biooekonomien/?no_cache=1&cHash=95b93b17fd15e34bc48253cbef8e0628 [Accessed May 2014].

Ministry of Agriculture Fisheries and Food. (1988). *Land Classification of England and Wales.* London.

Ministry of Environment and Energy. (1996). *Energy 21 - the Danish government's action plan for energy*. Copenhagen.

Ministry of Food Agriculture and Fisheries. (2008). *Fuelling Future Energy Needs – The Agricultural Contribution*. Copenhagen.

Ministry of Food Agriculture and Fisheries. (2010). *Green energy, the agricultural contribution: Perennial energy crops*. Copenhagen.

Mitchell, D. (2008). *A Note on Rising Food Prices*. Washington D.C.

Mol, A. P. J. (2007). Boundless biofuels: between environmental sustainability and vulnerability. *European Society for Rural Sociology*, *47*(4), 297-315.

Mol, A. P. J. (2010). Environmental authorities and biofuel controversies. *Environmental Politics*, *19*(1), 61–79.

Molewijk, B. (2004). Integrated empirical ethics: in search for clarifying identities. *Medicine, Health Care, and Philosophy*, *7*(1), 85–7.

Monbiot, G. (2005). Worse than fossil fuel. *Monbiot.com*. Retrieved from http://www.monbiot.com/2005/12/06/worse-than-fossil-fuel/ [Accessed November 2014].

Mortimer, N. D. (2011). *Life Cycle Assessment of Refined Vegetable Oil and Biodiesel from Jatropha Grown in Dakatcha Woodlands of Kenya*. Northumberland.

Mudge, S. M. (2008). Is the use of biofuels environmentally sound or ethical? *Journal of Environmental Monitoring*, *10*, 701–702.

Murdoch, J., Marsden, T., & Banks, J. (2000). Quality, nature, and embeddedness: Some theoretical considerations in the context of the food sector. *Economic Geography*, *76*(2), 107–125.

Murphy, E., & Dingwall, R. (2003). *Qualitative Methods and Health Policy Research*. New Jersey: Transaction Publishers.

Nalepa, R. A., & Bauer, D. M. (2012). Marginal lands: the role of remote sensing in constructing landscapes for agrofuel development. *Journal of Peasant Studies*, *39*(2), 403–422.

Natural England. (2009). *Energy Crops Scheme Establishment Grants Handbook*. London.

Nerlich, B. (2007). Media , Metaphors and Modelling : How the UK Newspapers Reported the Epidemiological Modelling Controversy during the 2001 Foot and Mouth Outbreak. *Science, Technology & Human Values*, *32*(4), 432–457.

NESTA. (2011). *Financing Industrial Biotechnology in the UK*. London.

NOAH (Friends of the Earth Denmark). (2010). *Mad og brændstof til europa*. Copenhagen.

Nordgren, A. (2011). Ethical Issues in Mitigation of Climate Change: The Option of Reduced Meat Production and Consumption. *Journal of Agricultural and Environmental Ethics*, *25*(4), 563–584.

Nordjyllands Amt, Ringkøbgin Amt, Viborg Amt, & Aarhus Amt. (2006). *Fosfor- risikoområder Handlingsplan for Limfjorden*. Aarhus.

Nuffield Council on Bioethics. (2011). *Biofuels : ethical issues*. London.

Nygård, B., & Storstad, O. (1998). De-globalization of Food Markets? Consumer Perceptions of Safe Food: The Case of Norway. *Sociologia Ruralis*, *38*(1), 35–53.

Ofgem. (2011). Renewables Obligation: Sustainability Criteria for Solid and Gaseous Biomass for Generators (greater than 50 kW). Retrieved from http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=329&refer=Sustainability/Environment/RenewablObl/FuelledStations [Accessed February 2012].

Oliver, P. E., & Johnston, H. (2000). What a good idea! Frames and ideologies in social movement research. Mobilization: An International Quarterly 5 (1), 37-54.

ORC. (2010). *Agroforestry : Reconciling Production with Protection of the Environment A Synopsis of Research Literature*. Newbury.

Oxfam International. (2008). *Another Inconvenient Truth How biofuel policies are deepening poverty and accelerating climate change*. Oxford.

Palmer, J. (2010). Stopping the unstoppable? A discursive-institutionalist analysis of renewable transport fuel policy. *Environment and Planning C: Government and Policy*, *28*(6), 992–1010.

Palmer, J. R. (2014). Biofuels and the politics of land-use change : tracing the interactions of discourse and place in European policy making. *Environment and Planning A*, *46*, 337–352.

Partzsch, L. (2011). The legitimacy of biofuel certification. *Agriculture and Human Values*, *28*(3), 413–425.

Payne, G., & Williams, M. (2005). Generalization in Qualitative Research. *Sociology*, *39*(2), 295–314.

Pedroli, B., Elbersen, B., Frederiksen, P., Grandin, U., Heikkila, R., Krogh, P. H., Izakovičová, Z., Johansen, A., Meiresonne, L. & Spijker, J. (2013). Is energy cropping in Europe compatible with biodiversity? - Opportunities and threats to biodiversity from land-based production of biomass for bioenergy purposes. *Biomass and Bioenergy*, *55*, 73–86.

Perrow, C. (1999). *Normal Accidents*. New Jersey: Princeton University Press.

Perry, M., & Rosillo-Calle, F. (2009). *Sustainable International BioEnergy Trade: Securing Supply and Demand*. *Energy*. London.

Peterson, G. M., & Galbraith, J. K. (1932). The Concept of Marginal Land. *American Journal of Agricultural Economics*, *14*(2), 295–310.

Pilgrim, S., & Harvey, M. (2010). Battles over Biofuels in Europe : NGOs and the Politics of Markets. *Sociological Research Online*, *15*(3), 4.

Potter, C. (2009). Agricultural stewardship, climate change and the public good debate. In M. Winter & M. Lobley (Eds.), *What is Land For? The food, fuel and climate change debate*. London: Earthscan.

Potter, C., & Tilzey, M. (2005). Agricultural policy discourses in the European post-Fordist transition: neoliberalism, neomercantilism and multifuntionality. *Progress in Human Geography*, *581*, 3–18.

Potter, V. R. (1971). *Bioethics: Bridge to the future*. Englewood Cliffs, N.J.: Prentice-Hall Inc.

Radder, H. (1998). The Politics of STS. *Social Studies of Science*, *28*(2), 325–331.

Raffensperger, C., Campbell, M., & Thompson, P. B. (1998). Author meets critics. Considering The Spirit of the Soil by Paul B. Thompson. *Agriculture and Human Values*, *15*, 161–176.

Raman, S., & Mohr, A. (2013). Biofuels and the role of space in sustainable innovation journeys. *Journal of Cleaner Production*, *65*, 224-233.

Rathmann, R., Szklo, A., & Schaeffer, R. (2010). Land use competition for production of food and liquid biofuels: An analysis of the arguments in the current debate. *Renewable Energy*, *35*(1), 14–22.

Rechberger, P., & Lotjonen, T. (2009). *Energy from field energy crops – a handbook for energy producers*. Helsinki.

Reenberg, A., & Jensen, K. M. (1989). Marginaljord i Norden - problem eller mulighed? *Geografisk Tidsskrift*, *89*, 1–3.

Renting, H., Marsden, T. K., & Banks, J. (2003). Understanding alternative food networks: exploring the role of short food supply chains in rural development. *Environment and Planning A*, *35*(3), 393–411.

RFA. (2008). *The Gallagher Review of the indirect effects of biofuels production*. Sussex.

Ribeiro, B. E. (2013). Beyond commonplace biofuels: Social aspects of ethanol. *Energy Policy*, *57*, 355–362.

Richards, B. K., Stoof, C. R., Cary, I. J., & Woodbury, P. B. (2014). Reporting on Marginal Lands for Bioenergy Feedstock Production: a Modest Proposal. *BioEnergy Research*, *7,* 1060-1062.

Richardson, B. (2012). From a fossil fuel to a bio-based economy: the politics of industrial biotechnology. *Environment and Planning C: Government and Policy*, *30*, 282–296.

Rødsrud, G., Lersch, M., & Sjöde, A. (2012). History and future of world's most advanced biorefinery in operation. *Biomass and Bioenergy*, *46*, 46-59.

Rolston III, H. (1997). Nature for real: is nature a social construct? In T. D. J. Chapell (Ed.), *The Philosophy of the Environment*. Edinburgh: Edinburgh University Press.

Rothenborg, M. (2013). Landbrug: Vi skal ikke være. *Politiken*. Retrieved from http://politiken.dk/klima/ECE2047088/staten-vil-koebe-de-vaerste-marker-fri/ [Accessed March 2014].

Rothenborg, M., & Korsgaard, K. (2013). Staten vil købe de værste marker fri. *Politiken*. Retrieved from http://politiken.dk/klima/ECE2047088/staten-vil-koebe-de-vaerste-marker-fri/ [Accessed March 2014].

Roulston, K. (2001). Data analysis and "theorizing as ideology." *Qualitative Research*, *1*, 279–302.

Roundtable on Sustainable Biofuels. (2010). *RSB Principles & Criteria for Sustainable Biofuel Production* (Vol. 001). Geneva.

Royal Commission on Environmental Pollution. (2004). *Biomass as a renewable energy source*. *Fuel and Energy Abstracts* (Vol. 43). London.

Royal Society. (2008). *Sustainable biofuels : propects and challenges*. London.

RSPB. (n.d.). *A cool approach to biofuels*. Bedfordshire.

Sage, R., Cunningham, M., & Boatman, N. (2006). Birds in willow short-rotation coppice compared to other arable crops in central England and a review of bird census data from energy crops in the UK. *Ibis*, *148*, 184–197.

Sanderson, K. (2011). Lignocellulose: A chewy problem. *Nature*, *474*(7352), S12–4.

Sarewitz, D. (2004). How science makes environmental controversies worse. *Environmental Science & Policy*, *7*(5), 385–403.

Sarewitz, D., & Nelson, R. (2008). Three rules for technological fixes. *Nature*, *456*(7224), 871–872.

Schmid, O., Padel, S., & Levidow, L. (2012). The Bio-Economy Concept and Knowledge Base in a Public Goods and Farmer Perspective. *Bio-Based and Applied Economics*, *1*(1), 47–63.

Schubert, R., Schellnhuber, H. J., Buchmann, N., Epiney, A., Grieshammer, R., Kulessa, M., Messner, D., Rahmstorf, S. and Schmid, J. (2008). *Future Bioenergy and Sustainable Land Use*. London.

Scopolleti, M. ., Curras, G., & Bonnes, M. (2012). Natural landscapes. In Clayton, S. (Ed.), *Oxford handbook of environmental conservation psychology*. Oxford: Oxford University Press.

Scott, D. (2011). The technological fix criticisms and the agricultural biotechnology debate. *Journal of Agricultural and Environmental Ethics*, *24*, 207–226.

Searchinger, T., Heimlich, R., Houghton, R. a, Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D. and Yu, T.-H. (2008). Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science*, *319*(5867), 1238–40.

SEERAD. (2006). Scottish Executive Environment and Rural Affairs Department: Business Plan, 2006/2007. Retrieved from http://www.scotland.gov.uk/Publications/2006/08/11083400/2 [Accessed February 2012].

Service, R. F. (2007). Biofuel Researchers Prepare To Reap a New Harvest. *Science*, 315, 1488–1490.

Sherrington, C., Bartley, J., & Moran, D. (2008). Farm-level constraints on the domestic supply of perennial energy crops in the UK. *Energy Policy*, *36*(7), 2504–2512.

Silverman, D. (1997). The logic of qualitative research. In G. Miller & R. Dingwall (Eds.), *Context and Method in Qualitative Research*. London: Sage.

Sims, R. E. H., Mabee, W., Saddler, J. N., & Taylor, M. (2010). An overview of second generation biofuel technologies. *Bioresource Technology*, 101, 1570–1580.

Singleton, V. (1998). The Politic(ian)s of SSK : A Reply to Radder. *Social Studies of Science*, *28*(2), 332–338.

Slade, R., Bauen, A., & Gross, R. (2010). *The UK bio-energy resource base to 2050 : Estimates , assumptions, and uncertainties*. London.

Smil, V. (2001). *Enriching the earth: Fritz Haber, Carl Bosch, and the transformation of world food production*. Boston: MIT Press.

Smith, J. (2010). *Biofuels and the globalisation of risk*. London: Zed Books.

Soby, S. D. (2012). The End of the Green Revolution. *Journal of Agricultural and Environmental Ethics*, *26*(3), 537-546.

Sodano, V. (2009). Food security, human rights and gender equality. In K. Millar, P. Hobson West, & B. Nerlich (Eds.), *Ethical Futures: bioscience and food horizons* Wageningen: Wageningen Academic Publishers.

Sonnino, R., & Marsden, T. (2006). Beyond the divide: rethinking relationships between alternative and conventional food networks in Europe. *Journal of Economic Geography*, *6*(2), 181–199.

Sorrell, S., Speirs, J., Bentley, R., Brandt, A., and Miller, R. (2009). *Global oil depletion: An assessment of the evidence for a near-term peak in global oil production*. *Energy Policy*, 38, 5290–5295.

Stanhill, G. (1990). The Comparative Productivity of Organic Agriculture. *Agriculture, Ecosystems and Environment*, *30*(2459), 1–26.

StatBank Denmark. (2011). Statistics Denmark. Retrieved from http://www.statistikbanken.dk/statbank5a/default.asp?w=1344 [Accessed March 2013].

Strong, D. (1995). *Crazy Mountains: Learning from Mountains to Weigh Technology*. Albany: State University of New York Press.

Sugrue, A. (2008). *Bioenergy production on marginal and degraded land : the potential social impacts*. Paris.

Suschems, Europa Bio, & Sixth Framework Programme. (2009). *Industrial Biotechnology in Denmark*. Copenhagen.

Swift, J. (1962). *Gulliver's travels and other writings*. New York: Bantam Books.

Swinbank, A. (2009). *EU Support for Biofuels and Bioenergy , Environmental Sustainability Criteria , and Trade Policy*. Geneva.

Swingland, I. R. (2001). Definition of biodiversity. In *Encyclopaedia of Biodiversity*. Imprint Academic Press.

Tait, J. (2011). The ethics of biofuels. *GCB Bioenergy*, *3*(3), 271–275.

Taylor, G. (2008). Biofuels and the biorefinery concept. *Energy Policy*, *36*(12), 4406–4409.

The Gaia Foundation, Biofuelwatch, the African Biodiversity Network, Salva La Selva, Watch Indonesia, & EcoNexus. (2008). *Agrofuels and the Myth of Marginal Lands*. London.

The Guardian. (2013a). Burning food crops to produce biofuels is a crime against humanity. Retrieved from http://www.theguardian.com/global-development/poverty-matters/2013/nov/26/burning-food-crops-biofuels-crime-humanity?INTCMP=ILCNETTXT3487 [Accessed January 2014].

The Guardian. (2013b). Food-based biofuels allowance to rise by 50% under EU plans. *The Guardian*. Retrieved from http://www.theguardian.com/environment/2013/nov/29/food-based-biofuels-rise-european-union-crops [Accessed January 2014].

Thompson, P. B. (1995). *The Spirit of the Soil*. London: Routledge.

Thompson, P. B. (2008a). Agrarian philosophy and ecological ethics. *Science and Engineering Ethics*, *14*(4), 527–44.

Thompson, P. B. (2008b). Agricultural Biofuels : Two Ethical Issues. In *NABC Report 20*.

Thompson, P. B. (2008c). The Agricultural Ethics of Biofuels: A First Look. *Journal of Agricultural and Environmental Ethics*, *21*(2), 183–198.

Thompson, P. B. (2010). *The agrarian vision: sustainability and environmental ethics*. Kentucky: The University of Kentucky.

Thompson, P. B. (2012a). Agriculture, food and society - Philosophy to nanotechnology. In *Western Canadian Dairy Seminar*. Red Deer: Western Canadian Dairy Seminar. Retrieved from http://www.wcds.ca/proc/2012/ [Accessed February 2014].

Thompson, P. B. (2012b). The agricultural ethics of biofuels: climate ethics and mitigation arguments. *Poiesis Prax*, 8(4), 169–189.

Thompson, P. B. (2012c). The Agricultural Ethics of Biofuels: The Food vs. Fuel Debate. *Agriculture*, *2*(4), 339–358.

Thompson, P. B. (2013). Agrarian Philosophy of Technology: A Response to Critics. *Philosophy of Technology*, *26*, 317–320.

Thompson, P. B. (2013). Agricultural Ethics. In *International Encyclopaedia of Ethics*. Wiley Online Library. doi: 1002/9781444367072.wbiee218

Thompson, P. B. (2014). Agricultural ethics: then and now. *Agriculture and Human Values*, doi:10.1007/s10460-014-9519-1

Thompson, P. B., & Otieno Ouko, J. (2008). The ethics of agricultural intensification: An interdisciplinary and international conversation. In P. Thompson (Ed.) *The ethics of intensification: Agricultural development and cultural change*. Springer.

Timilsina, G. (2012). Biofuels: the food versus fuel debate. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, *7*(36), 2–6.

Trewavas, A. J. (2001). The population/biodiversity paradox. Agricultural efficiency to save wilderness. *Plant Physiology*, *125*(1), 174–9.

Tscharntke, T., Klein, A. M., Kruess, A., Steffan-Dewenter, I., & Thies, C. (2005). Landscape perspectives on agricultural intensification and biodiversity - ecosystem service management. *Ecology Letters*, *8*(8), 857–874.

Turley, D., Taylor, M., Laybourn, R., Hughes, J., Kilpatrick, J., Procter, C., Wilson, L. & Edgington, P (2010). *Assessment of the availability of marginal and idle land for bioenergy crop production* (Vol. 5). London.

Tværministeriel arbejdsgruppe. (2013). *Virkemiddel- katalog: Potentialer og omkostninger for klimatiltag*. Copenhagen.

Valentine, J., Clifton-Brown, J., Hastings, A., Robson, P., Allison, G., & Smith, P. (2012). Food vs. fuel: the use of land for lignocellulosic "next generation" energy crops that minimize competition with primary food production. *GCB Bioenergy*, *4*(1), 1–19.

Van der Scheer, L., & Widdershoven, G. (2004). Integrated empirical ethics: loss of normativity? *Medicine, Health Care, and Philosophy*, *7*(1), 71–9.

Van Eijck, J., & Romijn, H. (2008). Prospects for Jatropha biofuels in Tanzania: An analysis with Strategic Niche Management. *Energy Policy*, *36*(1), 311–325.

Van Huylenbroeck, G. Durand, G. (2003). Introduction. In G. van Huylenbroeck, G. Durand (Ed.), *Multifunctional Agriculture: A new paradigm for European agriculture and rural development*. Alderton: Ashgate Publishing Limited.

Vanloqueren, G., & Baret, P. V. (2009). How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations. *Research Policy*, *38*, 971–983.

Vinck, D. (2003). Socio-technical complexity: Redesigning a shielding wall. In *Everyday Engineering: An ethnography of design and innovation*. Cambridge, M.A.: The MIT Press.

Vogel, S. (1996). *Against Nature: the Concept of Nature in Critical Theory*. Albany: State University of New York Press.

Voytenko, Y., & Peck, P. (2011). Organisational frameworks for straw-based energy systems in Sweden and Denmark. *Biomass and Bioenergy*, 38, 34-48.

Walker, M. U. (1993). *Keeping moral space open. New images of ethics consulting*. London.

Wassenaar, T., & Simon, K. (2008). Biofuels: One of many claims on resources. *Science*, *321*, 199–201.

Weinberg, A. M. (1967). *Reflections on Big Science*. Worcester: MIT Press.

Wenner, C. (2012). The biofuels industry does not deserve to be demonised. *The Guardian*. London. Retrieved from http://www.theguardian.com/environment/2012/oct/16/biofuels-industry-demonised [Accessed September 2014].

Wetzstein, M., & Wetzstein, H. (2011). Four myths surrounding U.S. biofuels. *Energy Policy*, *39*(7), 4308–4312.

White, L. (1967). The Historical Roots of Our Environmental Crisis. *Science*, *155*(3767), 1203–1207.

Wilhjelm-udvalget. (2001). *En rig natur i et rigt samfund*. Copenhagen. Retrieved from http://www.sns.dk/udgivelser/2002/87-7279-378-3/pdf/helepubl.pdf [Accessed June 2011].

Williams, M. (2000). Interpretivism and Generalisation. *Sociology*, *34*(2), 209–224.

Wilson, G. A. (2007). *Multifunctional agriculture: a transition theory perspective*. Wallingford: CABI.

Winner, L. (1985). Do artifacts have politics? In D. MacKenzie & J. Wajcman (Eds.), *The Social Shaping of Technology*. Maidenhead: Open University Press.

Winner, L. (2004). Technology as Forms of Life. In D. M. Kaplan (Ed.), *Readings in the Philosophy of Technology*. Oxford: Rowman & Littlefield.

Winstone, R., Bolton, P., & Gore, D. (2007). *Energy Security*. London.

Winter, M., & Lobley, M. (2009). Introduction. In M. Winter & M. Lobley (Eds.), *What is land for? The food, fuel and climate change debate*. London: Earthscan.

Woolgar, S., & Lezaun, J. (2013). The wrong bin bag: A turn to ontology in science and technology studies? *Social Studies of Science*, *43*(3), 321–340.

WWF. (2008). *WWF Position Paper on Bioenergy*. London.

Wynne, B. (1996). SSK 's Identity Parade : Signing-Up, Off-and-On. *Social Studies of Science*, *26*(2), 357–391.

Wynne, B. (1998). Reply to Radder. *Social Studies of Science*, *28*(2), 338–344.

Young, A. (1999). Is there really spare land? A critique of estimates of available cultivable land in developing countries. *Environment, Development and Sustainability*, *1*, 3–18.

Zhang, B., Bi, J., Fan, Z., Yuan, Z., & Ge, J. (2008). Eco-efficiency analysis of industrial system in China: a data envelopment analysis approach. *Ecological Economics*, *68*, 306–316.

Zhang, Y.-H. P. (2013). Next generation biorefineries will solve the food, biofuels and environmental trilemma in the energy-food-water nexus. *Energy Science and Engineering,* 1(1), 27-41.

Zimdahl, R. L. (2000). Teaching agricultural ethics. *Journal of Agricultural and Environmental Ethics*, *13*, 229–247.

Zwart, H. (2000). A short history of food ethics. *Journal of Agricultural and Environmental Ethics*, *12*, 113–126.

Zwart, H. (2009). Biotechnology and naturalness in the genomics era: plotting a timetable for the biotechnology debate. *Journal of Agricultural and Environmental Ethics*, *22*(6), 505–529.

Appendix 1 Danish documents analysed

Category	**Document**
NGO	Action Aid (2010) Om biobrændstof og sult. Action Aid, Copenhagen.
	Bestmann, L.S. (2009) Energipil og betydende faktorer for optimale dyrkningssteder. University of Copenhagen, Copenhagen. `
	Danmarks Naturfredningsforenings (2010) Fremtidens energiforsyning I Danmark. Danmarks Naturfredningsforenings, Copenhagen.
	Danmarks Naturfredningsforenings (2009) Fremtidens landbrug i balance med natur og miljø. Danmarks Naturfredningsforenings, Copenhagen.
	IDA. (2009). IDAs Klimaplan 2050. IDA, Copenhagen.
	NOAH (2010) Mad og brændstof til Europa. NOAH, Copenhagen.
	Jørgensen, L.B. (2010) Biomasse og Bioenergy. Det Okologiske Råd, Copenhagen.
Academic and consultancy	Astrup, T., Tonini, D., Hamelin, L. and Wenzel, H. (2011) Environmental assessment of renewable energy scenarios toward 2050. CEESA, Aalborg.
	Callensen, I., Gronheit, P.E., Østergård, H.O. (2010) Optimisation of bioenergy yield from cultivated land in Denmark. *Biomass and Bioenergy*. 34: 1348-1362.
	CEESA (2011) Coherent energy and environmental systems analysis. CEESA, Aalborg.
	Gylling, M, Jørgensen, U, Bentsen, N.S., Kristensen, I.T., Dalgaard, T., Felby, C. and Kvist Johannsen. V. (2012) + 10 Mio. Tons Planen. Copenhagen University, Copenhagen.
	Gylling, M., Abildtrup, J., Nielsen, K.V., Petersen, S.M. and Varming, S. (2001) Langsigtede biomasseressourcer til energiformål - mængder, omkostninger og markedets betingelse. Ministeriet for Fødevarer, Landbrug og Fiskeri, Copenhagen.

	Hauggaard-Nielsen, H., Jensen, E.S., Carter, M.S., Johansen, A. and Ambus, P. (2009) Strip intercropping strategy for biomass to energy production while on the same time maintaining soil fertility. BioConsens, Roskilde.
	ICROFS (n.d.) Biomass and bioenergy production in organic agriculture. BioConsens, Roskilde.
	Jørgensen, U., Dalgaard, T. and Kristensen, E.S. (2005) Biomass energy in organic farming – the potential role of perennial energy crops. *Biomass and Bioenergy*. 28: 237-248.
Government	Ministeriet for Fødevarer, Landbrug of Fiskeri (2008a) Jorden – en knap ressource. Ministeriet for Fødevarer, Landbrug of Fiskeri, Copenhagen.
	Ministeriet for Fødevarer, Landbrug of Fiskeri (2008b) Landbrug og Klima. Ministeriet for Fødevarer, Landbrug of Fiskeri, Copenhagen.
	Ministry of Food, Agriculture and Fisheries (2008c) Land, a scarce resource. Danish Ministry of Food, Agriculture and Fisheries, Copenhagen.
	Ministry of Food, Agriculture and Fisheries (2008d) Fuelling future energy needs: the agricultural contribution. Ministry of Food, Agriculture and Fisheries, Copenhagen.
	Ministry of Food, Agriculture and Fisheries (2010a) Green energy: the agricultural perspective. Perennial energy crops. Ministry of Food, Agriculture and Fisheries, Copenhagen.
	Ministry of Food, Agriculture and Fisheries (2010b) Green energy: the agricultural contribution. Climate perspectives. Ministry of Food, Agriculture and Fisheries, Copenhagen.
	Ministry of Food, Agriculture and Fisheries (2010c) Green energy: the agricultural contribution. Second generation biofuels. Ministry of Food, Agriculture and Fisheries, Copenhagen.

Appendix 2 UK documents analysed

Academic and consultancy	AEA (2008) UK and global bioenergy resource – Final Report. AEA, Oxfordshire
	Andersen, R.S., Towers, W. and Smith, P. (2005) Assessing the potential for biomass energy to contribute to Scotland's renewable energy needs. *Biomass and Bioenergy***.** 29: 73-82
	Aylott, M.J., Casella, E., Tubby, I., Street, N.R., Smith, P. and Taylor, G. (2007) Yield rotation and spatial supply of bioenergy poplar and willow short-rotation coppice in the UK. *New Phytologist*. 178: 358-370
	Bauen, A.W., Dunnett, A.J., Richter, G.M., Dailey, A.G., Aylott, M., Casella, E. and Taylor, G. (2010) *Bioresource Technology.* 101: 8132-8143.
	Booth, E., Walker, R., Bell, J., McCracken, C., Curry, J., Knight, B., Smith, J., Biddle, A. (2009) An analysis of the potential impact on UK agriculture and the environment of meeting renewable feedstock demands. DECC and NNFCC.
	Copeland, J. and Turley, D. (2008) National and regional supply and demand for agricultural straw in Great Britain. NNFCC, York.
	Haughton, A.J., Bond, A.J., Lovett A.A., Dockerty, T., Sunnenberg, G., Clark, S.J., Bohan, D.A., Sage, R.S., Mallott, M.D., Mallott, V.E., Cunningham, M.D., Riche, A.B., Shield, I.F., Finch, F.W., Turner, M.T., Karp, A. (2009) A novel, integrated approach to assessing social, economic and environmental implications of changing rural land-use: A case study of perennial energy crops. *Journal of Applied Ecology.* 46: 315-322.
	Kilpatrick, J., Heywood, C., Smith, C., Wilson, L., Procter, C., Spink, J., Tubby, I., Matthews, R., Mackie, E., Hogan, G. & Randle, T. (2008). *Addressing the land use issues for non-food crops , in response to increasing fuel and energy generation*. Hereford.
	Lovett, A., Sunnenberg, G.M., Richter, G.M., Dailey, A.G., Riche, A.B. and Karp, A. (2009) *Land use implications of increased biomass production identified by GIS-based sustainability and yield mapping for miscanthus in England.* 2: 17-28.

	Rowe, R.L., Street, N.R., Taylor, G. (2009) Identifying potential environmental impacts of large scale deployment of dedicated perennial energy crops in the UK. *Renewable and Sustainable Energy Reviews*. 13: 271-290.
	Slade, R., Bauen, A. and Gross, R. (2010) *The UK bioenergy resource base to 2050: estimates and assumptions, and uncertainties.* Imperial Centre for Energy Policy and Technology.
	Turley, D., Taylor, M., Laybourn, R., Hughes, J., Kilpatrick, J., Procter, C., Wilson, L. and Edgington, P. (2010) Assessment of the availability of marginal or idle land for bioenergy crop production in England and Wales. Food and Environment Research Agency.
	Committee on Climate Change (2011) Global and UK Bioenergy Supply Scenarios. Committee on Climate Change, London.
Government	DTI, DEFRA (2004) A Strategy for Non-Food Crops and Uses: Creating value from renewable materials. DTI, London.
	DTI, DfT, DEFRA (2007) UK Biomass Strategy. DECC, London.
	DfT, DECC, DEFRA (2012) UK Bioenergy Strategy. DECC, London.
	Forestry Commission Scotland (2007) Biomass Action Plan for Scotland. Scottish Executive, Edinburgh.
	HM Government (2009) The UK Renewable Energy Strategy. HM Government, Surrey.
	Renewable Fuels Agency (2008) The Gallagher review of the indirect effects of biofuels production. Renewable Fuels Agency, London.
	SEERAD (2006) Review of greenhouse gas life cycle emissions, air pollution impacts and economics of biomass production and consumption in Scotland. Scottish Executive, Edinburgh.
	Action Aid (2010) Meals per gallon: The impact of industrial biofuels on people and global hunger. Action Aid, London

NGO	Biofuelwatch (2009) Biomass and Biofuels in the Renewable Energy Directive. Biofuelwatch, Edinburgh.
	Centre for Alternative Technology (2010) Zero carbon Britain 2030: A new energy strategy. The second report of the zero carbon Britain project. Centre for Alternative Technology, Llwyngwern.
	Christian Aid (2009) Growing pains: the possibilities and problems of biofuels. Christian Aid, London.
	Biofuelwatch, Carbon Trade Watch, Corporate Europe Observatory, Econexus, Ecoropa, Grupo de Reflexion Rural, Munlochy Vigil, NOAH (Friends of the Earth Denmark), Rettet Den Regenwald, Watch Indonesia (2007) Agrofuels: Towards a reality check in nine key areas. Biofuelwatch, Edinburgh.
	Friends of the Earth Europe (n.d.) Agrofuels: Fuelling or fooling Europe? Friends of the Earth Europe.
	Nuffield Council on Bioethics (2011) Biofuels: Ethical Issues. Nuffield Council on Bioethics, London.
	Royal Commission on Environmental Pollution (2004) Biomass as a renewable energy source. Royal Commission on Environmental Pollution, London.
	Royal Society (2008) Sustainable biofuels: Prospects and Challenges. Royal Society, London.
	RSPB (2011) Bioenergy: A burning issue. RSPB, Sandy.
	RSPB (n.d.) A cool approach to biofuels. RSPB, Sandy.
	WWF (2008) WWF Position Paper on Bioenergy. WWF, London.
	Drax (2011a) Biomass: The fourth energy source. Drax, Selby.
Industry	Drax (2011b) Sustainability policy for biomass. Drax, Selby.
	REA (2010) Renewable Energy Industry Roadmap UK. REA, London.

Appendix 3 Interview questions

(Questions in bold are main questions, questions not in bold are sub-questions that may have already been covered by main questions).

Introduction and broad why, where, how questions.

- **Could you tell me a bit about your background and your involvement in the biomass energy sector?**
- **What do you think of the use of biomass in the energy sector?**
- **What do you see as the most important reasons for using it?**
- **What types of energy production should biomass be prioritised in? For example, heat, power, transport etc.**
- **What in your view are the "best" types of biomass to use in energy production? Why?**

  What is your view of the use of perennial energy crops and crop residues in energy production?
  How should perennial energy crops and crop residues be prioritised in relation to other sources of biomass, like wood, waste etc?
- **What kind of contribution should biomass from agriculture make to the biomass energy system in comparison to other sources of biomass, such as forestry and waste?**
- **What do you see as the most important challenges facing the use of biomass in energy?**

Where

- **There are differing opinions about the proportion of biomass that should be produced at home and abroad, where do you think biomass should come from?**
- **Figure 1** (p.16) **shows a map of land use cover in the UK in 2006/Figure 3** (p.18) **shows a map of land use cover in Denmark in 2006, Figure 2** (p.17) **is the legend. What types of land do you think perennial energy crops should be grown on in the UK/Denmark?**

  In the literature it is often suggested that perennial energy crops should be grown on marginal land in the UK/Denmark. What do you think of this idea?
  How would you define marginal land?
  In the literature it is suggested that perennial energy crops should be grown on idle land in the UK/Denmark. What do you think of this idea?
  Do you think grassland should be used?
  Should contaminated land be used?
  Is it acceptable for perennial energy crops to displace *any* food production?
  What are the biggest concerns with regard to displaced food production, eg. UK/Danish food security, balance of trade, indirect effects abroad?
- **Figure 3** (p.18) **shows a chart of current use of agricultural land in the UK. Figure 4** (p.19) **shows a chart including the government's target of 350,000ha of perennial energy crops in**

the UK, grown instead of cereals. What do you think of the government target for perennial energy crop production?

- **Looking at figures 3 and 4, you can see that oilseed rape for food use – human and animal consumption, is differentiated from oilseed rape for non-food use – biodiesel production. Do you think the distinction made between food and fuel crops is an important one?**
- **Studies have shown that using better land for perennial energy crops leads to higher yields, but the use of better land is more likely to conflict with food production. How do you think the need to increase yields and minimize conflicts with food production should be balanced?**
- **Land is often seen as a scarce resource globally and in the UK/Denmark. It's sometimes also framed as an under-utilised resource. What's your view on this?**

How

(If not covered in the introduction) What do you see as the most significant environmental challenges facing perennial energy crop production and the most significant environmental benefits?

- **It has been suggested that if increased production of perennial energy crops puts pressure on the supply of other agricultural products then yields will need to increase to make up the shortfall. This has been called "sustainable intensification". What is your view of this idea?**
- **What challenges do you think face the use of straw in the energy sector?**
  - How important do you think the loss of soil nutrients and soil carbon would be, particularly to the organic sector?
  - And the need to replace these through artificial fertiliser that takes a lot of energy and GHG emissions to produce?
  - What about conflicts with other agricultural sectors such as livestock sector?

(Include question like "Agriculture is talked about as an industrial sector of the economy and also as an activity that has a wider meaning or significance for society. Do you have any views on this distinction?")