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SUPPLY CHAIN INTEGRATION IN THE UK BIOENERGY INDUSTRY

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Thesis Summary

This study is an investigation on supply chain integration in bioenergy. It takes a different approach from many contemporary studies found in the literature because most research in bioenergy treats technological performance, characteristics of feedstock, impact on energy consumption in relation to the carbon footprint as distinct and separate entities. None of these examples consider bioenergy from supply chain integration and thus, a business performance perspective. The study proposes that bioenergy is defined from the biomass-to-bioenergy, which is from the point of origin to the point of conversion, and that it is a developing industry. It was found that stakeholders play a prominent role throughout the various phases from planning approval to project implementation and are also involved during operational phases of a bioenergy business. In the study this is referred to as stakeholder integration. During handover phases process integration dominates operational activities within the bioenergy firm. By dividing characteristics in a bioenergy business as stakeholder and process integration it is possible to identify constructs that are applicable to bioenergy. These were investigated through secondary research as well as primary research approaches. Inherent within the configuration of bioenergy supply chains are issues and challenges that were different from established energy systems and factors peculiar to conventional supply chain approaches. The research finds bioenergy supply chains tend to be horizontally integrated from B2C, and as yet lack vertical integration, B2B found in mature supply chains. Contributions resulting from this factor, coupled with the research approaches, particularly by using qualitative methods extended knowledge and practice in operations management research as well identifying best practice in a novel and emergent industry.

Keywords: Bioenergy, Supply Chain integration, Process and Stakeholder Factors

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List of Abbreviations

ACRONYM	**DESCRIPTION OF MEANING**
AD	Anaerobic Digestion
AONB	Area of Outstanding Natural Beauty
ADBA	Anaerobic Digestion and Bioresources Association
CD	Competitive Dialogue
CHP	**Combined Heat and Power** CHP generates electricity whilst also capturing usable heat that is produced in this process.
C&I	Commercial and Industrial Waste
CSW	Commercial Solid Waste
CV	Calorific Value
CVP	Low Carbon Vehicle Partnership
DECC	Department of Climate Change
DEFRA	Department of Food and Rural Affairs
DNO	Distribution Network Operator
DUoS	Distribution Use of System Contract
EU	European Union
EUA	Energy and Utilities Alliance Network
FiT	Feed-in-Tariff
GW/KM^2	GigaWatt per Kilometer area squared
GVA	Gross Value Added
H&S	Health and Safety
ktoe	' toe ' means Tons of Oil Equivalent ktoe means 1000 toe. 1 toe = 41.84 gigajoule
KM	Kilometer
KW	Kilowatt
KW/KM^2	Kilowatt per kilometre area squared
LEC	Levied Exemption Certificates
LHV	Lower Heat Value
MW	Mega Watt
MW/h	Megawatt per hour
MSW	Municipal Solid Waste
Mj/Kg	Mega joule per kilogram
NCV	Net Calorific Value
NFFO	Non Fossil Fuel Obligation
NGV	Natural Gas Vehicle
Odt	Oven Dried Tonnes
ONS	Office of National Statistics
PFI	Private Finance Initiative
p/kWh	Pence per kilowatt hour
REA	**Renewable Energy Association** The REA was established in 2001, as a not-for-profit trade association, which represents British renewable energy producers and promotes use of renewable energy in the UK. It has 950 members from the UK renewable energy sector.

REC	Renewable Energy Certificate
RHI	Renewable Heat Incentive
ROC	Renewable Obligation Certificate
R&D	Research and Development
RPI	Retail Price Index
UK	United Kingdom
WID	Waste Incineration Directive

Tables and Figures

Chapter One: Introduction and Rationale: A Study of Supply Chain Integration in Bioenergy: Concept and Constructs.

1.0: Chapter Overview.

The purpose of this chapter is to explain the motivation behind the study in the context of supply chain integration and the challenges that this presents for new and emergent sectors such as those found in bioenergy. Organisation of this introductory chapter will present factors that are driving the need to implement alternative energy systems, which in turn, provides the scope as to why these factors have determined the need to undertake a study in this area. For clarification, the study considers factors that integrate biomass to bioenergy supply chains, that is, from the point of origin to the point of conversion. The context will follow a systematic format by presenting the main determinants of bioenergy and its significance as a field of study which qualifies the gap in current knowledge from this particular perspective and secondly, this chapter presents the aim and research questions that will evolve throughout the thesis in order to address questions from secondary and primary research approaches.

1.1: The Problem Statement: Why it is Important to Study Supply Chain Integration in Bioenergy.

How is the bioenergy supply chain organised? To date there has not been a study that defines bioenergy organisations from supply chain process and stakeholder perspectives. Bioenergy firms operating in the UK are in a sense, disparate organisations because the supply chain linkages are uneven and lumpy due to lack of infrastructure (Adams et al., 2011). Not only are there inconsistencies in regulations across North West Europe but there are also inconsistencies in regulations that govern supply in UK bioenergy firms (Bauen et al., 2009; Jablonski et al., 2008; Perry and Rosillo-Calle, 2008).

National and international governments drive the agenda for reducing dependence on fossil fuels for energy production, namely the Brundtland Report published in 1987 outlined the need for adopting sustainable practice in all aspects of everyday life from social, environmental and economic perspectives; Kyoto Protocol, United Nations Framework Convention on Climate Change that came into force 16th February 2005 required nations to provide specific targets on greenhouse gas reduction followed by the Stern Report (2006) placed emphasis on climate change through dependence on fossil fuels. However, what operates at a strategic level can prove particularly challenging to implement.

Driving the agenda for renewable energy in the UK is a challenging task because firstly, there is a gap between strategic intent and policy implementation and secondly, technological, environmental and economic characteristics are treated as separate constituents rather than as a whole entity within a supply chain. Therefore, not only is there a need to understand what factors comprise a bioenergy supply chain there is also a need to provide appropriate building blocks that fledgling bioenergy businesses can adopt.

Conventional energy supply chains are vertically integrated where every area from exploration to distribution has its distinct supply chain (Hilson, 2000). This presents disadvantages in relation to inflexibility and increased risk due to lack of information and knowledge flows across different areas of the supply chain (Alajoutsijärvi et al., 2012). Much is already known in the way conventional energy systems operate in the UK but due to the novelty of the renewable energy sector, there is a lack of knowledge in the viability and performance of bioenergy businesses over the long-term.

Bioenergy is an emerging sector, borne out of the recycling and re-use of waste (biomass) and the need to produce energy from renewable sources. However, the question of whether such a nascent sector can function and perform independently of supplier agreements is one that requires a holistic approach. Biomass increases complexity of the supply chain due to the distribution versus value and volume of energy output. Such requirements implicate a need for a large transportation capacity (Lam et al., 2010). This is constrained by the characteristics of the biomass itself and dismisses bioenergy production from an economic argument. Biomass has low-energy density per unit of volume but high land-use (energy per unit area). Therefore bioenergy infrastructure costs are higher than the value of the energy output (Lam et al., 2013). Costs of transportation of biomass over long distances outweigh both economic and environmental benefits of its ‘green’ energy use (Krotscheck et al., 2000).

There are however, advantages that are not financial but refer to security of energy supply. This, in turn, reduces risk of dependence on oil from unstable, national regimes (Barton et al., 2004). Location of biomass tends to be in rural areas such as farms and forests, hence low energy density and distributed nature of resources, which requires a large capacity for transport, particularly road transport (Lam et al., 2010). There is no contribution in the literature that uses a supply chain approach to bioenergy (Čuček et al., 2012). The majority of definitions for bioenergy involve life-cycle analysis and carbon footprint approaches. Such methodologies do not provide supply chain integration and therefore do not identify business success factors for bioenergy. Čuček et al., (2012) perceive the bioenergy footprint as two distinct layers of upstream, biomass production and distribution, and downstream characteristics of energy production and consumption purely in terms of costs relating to the carbon footprint in bioenergy. They acknowledge that:

'The bioenergy supply chain model, which consists of mass balances, production and conversion constraints, cost functions, profit objective function and carbon footprint calculation', (Čuček et al., 2012, p. 136).

Concern over security of supply drives the agenda for alternative energy production. The EU target of 10% energy from biofuels by 2020 is five years away (at the time of writing 2015) (Akgul et al., 2012). Biofuel production is dominated by first generation technology. This is shown in table 1.1.1: European Biofuel Technology Platforms.

Table 1.1.1: European Biofuel Technology Platforms.

Generation Platform	**Description**
1st Generation	Source of carbon is derived from sugar, liquid or starch directly extracted from the plant. 1st generation technology is viewed as being in direct competition for food and crop production
2nd Generation	Source derived from cellulose, hermicellulose, liguia or pectin. This includes agriculture, forestry wastes and residues that is purpose grown (i.e. non-food stock) such as short-rotation coppice, energy grasses such as miscanthus.
3rd Generation	Source is derived from algae where the sugar is extracted from the algae to produce biofuels. This is not considered to be pure 3rd Generation.

Source: Adapted from www.biofuelstp.eu/advancedbiofuels.htm#generations

Whilst this study is not an analysis of the characteristics of biomass feedstock, it is worth considering factors pertaining to its influence on the supply chain. Both first and second-generation bioenergy technologies are commercially available, but the technology supporting third generation feedstock is not. Akgul et al., (2012, p. 57) define the bioenergy supply chain as:

> *'... a multi-echelon network consisting of biomass cultivation sites, ethanol production facilities and demand centres'.*

This places dependence on transport from feedstock to conversion facility. Gold et al. (2011) identify only upstream characteristics in biofuel production of harvesting, collection and transport. Such models for calculating the costs of these operations are based purely on economic models (Zamboni et al., 2009; Morrow et al., 2006). Spatial models based on location data include economic and environmental performance attributes. Environmental factors in practice mean volume of gas emissions from ethanol supply chains, which are biased towards upstream factors and not integration of the whole process upstream to downstream factors in bioenergy supply chains. Further upstream models such as Yu et al. (2009) consider discrete event simulation for biomass to bioenergy for first generation biofuel production.

Approaches in second-generation biofuel production use mixed integer linear programming to compare the cost of production with value of biofuel (Eksioglu et al., 2009). Geographical Information Systems (GIS) use spatial models (Leduc et al., 2010; Parker et al., 2010) but Bai et al. (2011) integrates transport in the biofuel supply chain. In consideration of emergent supply chains such as bioenergy identification of key operational factors form important factors in the understanding and definition of bioenergy supply chain integration. Inclusion of logistics' operations moves towards development of stakeholder relationships rather than just focusing on supply chain processes. Whether choice of feedstock is central to how a bioenergy supply chain integrates is questionable because the literature does not single out a particular feedstock as being more effective than the other. However, what tends to happen is these particular companies have sensed an opportunity to develop bioenergy production as a spin out from their core activity. The case studies presented in this thesis bear this out in chapter six. The literature supports the view that most feedstock is expected to come from crop residues, (second generation bioenergy technology platforms). Such demand imposes challenges on resources and ability to supply. This permeates throughout the biofuel supply chain, invoking the fuel versus food debate and socio-economic impact in biomass and biofuel production (Chen et al., 2010). Support services for biomass means that decisions over location will regionalise bioenergy production due to the need to reduce transport costs and negative environmental impact (Bai et al., 2012; Kang et al., 2010). The design of the biofuel supply chain has to be cost effective and commercially viable. However, SCI in bioenergy is challenged because upstream supply chain attributes are considered whereas downstream factors are not, partly because they are more difficult to measure, but mainly because bioenergy itself is a nascent sector and there are few established firms beyond first generation technology platforms.

Bioenergy supply chain integration in the literature is biased towards integration of upstream factors such as feedstock prices, transport, processing costs and location decisions (Bai et al., 2012). Such factors are significant in SCI as risk in price of feedstock may fluctuate if competing with other bioenergy firms and non-energy users. A decrease in the price of feedstock may result from either high demand or centralization of the bio-refinery process (McNew and Griffith, 2005). High capital costs to establish a bioenergy plant and inflexibility of agricultural land use lends itself to longer-term contracts, thus incentivising farmers to supply conversion facilities (Larsen et al., 2008). These approaches err towards economic models as Bai et al. (2012) discuss application of different economic models to measure optimal feasibility and robustness in the biofuel supply chain. They identify that bioenergy firms tend to be local and regional rather than globally based as a sector. Simulation models used in conventional manufacturing applied to predict growth of bioenergy businesses are not as effective as GIS location models as these ascertain optimal supply chain and logistics design (Parker et al., 2008; Eathington and Swenson, 2007). As Bai et al. (2012) identify from the literature most studies to date have not captured supply chain performance in bioenergy, namely, the behaviour between buyers and sellers. Thus procurement and the characteristics of the contract is central to a bioenergy supply chain and integration but not strictly within a transaction economic cost model framework

'These existing economic models, unfortunately rely heavily on aggregated historical data, but did not explicitly capture the mechanism behind the new biofuel industry and existing food markets or the competitive behaviours of farmers, so they can hardly provide useful insights', (Bai et al., 2012, p. 1624).

Furthermore most models fail to address integration between process upstream and downstream in the supply chain and, more importantly, fail to consider stakeholder integration, which is a key factor in bioenergy supply chain integration.

The growing importance of biomass as an alternative fuel source is frequently cited in the literature. Examples of biomass are wood, forestry residues, wheat straws, oilseed straw and cotton stalks as well as bio-waste from food production (Lam et al., 2010). Biomass is defined as a 'distributed resource' that is locally sourced and dependent on extensive infrastructure networks for harvesting, transportation, storage and processing (Lam et al., 2010, p. 782). Such operational attributes include a number of associated constraints that challenge the development of bioenergy supply chains. Constraints in use of biomass comprise local conditions of existing infrastructure, location factors. This is compounded by the low energy per unit volume that outweighs cost recovery from bioenergy production. Rather than economic models to justify development of bioenergy, actors consider instead carbon footprint (CFP) to measure the performance of bioenergy, which only measures carbon emissions and not the business success of the supply chain. This means that CFP approaches do not take account of integration of process and stakeholders attributes. The literature acknowledges that renewable energy is not carbon neutral; therefore the low value for feedstock determines location of all areas from farm to conversion facility to be locally situated:

> *'The typical locations of biomass sources (farms, forests etc.), the relatively low energy density, and the distributed nature of the resources require extensive infrastructures and huge transport capacities for implementing biomass supply networks',* (Lam et al., 2012, p. 782).

Transport in this instance means collection and transporting biomass to conversion site. Viable supply chains in bioenergy involve integration with compatible industries such as food manufacturing for example (Junginer et al., 2001). However, such approaches refer to upstream factors (Lam et al., 2012; Dunnett and Shah, 2007).

Bioenergy supply chain feasibility is constrained by cost irrespective of how actors view the need for renewable energy. Its costs are higher than fossil fuels, which place bioenergy production at a disadvantage (Krotscheck et al., 2000). Another argument is where costs offset the reduction of risk in locally sourced energy supplies (Klemẽs and Lam, 2009). Lam et al. (2012) proposes Porter's model by developing regional energy clusters where concentration of similar industries is beneficial to economic development.

The literature scopes contemporary views on bioenergy production and establishes the context of the research problem. There is evidence to support that the bioenergy supply chain is defined from the point of origin (feedstock production) to the point of conversion (energy production) and shaping this definition is the level of stakeholder and process interventions that serve to ensure the viability and robustness of bioenergy businesses.

1.2: Research Aim and Research Questions.

There is evidence of a gap in the research that supply chain integration in bioenergy has not been explored from both process and stakeholder integration perspectives. This in turn helps form the overall aim of the research.

1.2.1: Research Aim.

The aim of the study is to identify factors that enhance integration in bioenergy supply chains.

1.2.2: Research Questions.

1. What is meant by supply chain integration in bioenergy as a concept and set of constructs?
2. What are the issues and challenges arising from supply chain integration in bioenergy?
3. What are the integration factors that would help improve the performance of bioenergy supply chains?

The overall aim and research questions are addressed using both secondary and primary research approaches. The study was conducted from beginning 2009 to mid-2015.

1.3: Organisation of Chapters: How Supply Chain Integration in Bioenergy will be Studied and Presented.

In order to satisfy the research aim and answer the research questions, the subsequent chapters will consider each question as the study evolves from predominantly secondary research approaches to primary research. In addressing the first and second research questions, secondary research is deployed through a review and analysis of the contemporary literature. This chapter is divided into two parts, the first presents supply chain integration definitions and characteristics, and the second part of the literature review, analyses bioenergy research approaches that are identified from supply chain integration constructs provided in the first part of the literature survey.

By reviewing the literature, it is possible to design appropriate methods deployed in the study and provided in chapter three. This chapter considers how the issues and challenges of supply chain integration may be better understood by providing the primary research tools for evidencing supply chain integration factors in bioenergy organisations. The method used in the study is wholly qualitative and inductive based on findings from survey questionnaires, semi-structured interviews and case studies.

Chapter four presents findings from a pilot study. Not only did the pilot study test the research design but also, provided a better understanding of the research rationale which helped enhance the development and approach in the main study. The pilot study was conducted during 2010-2012 and main study fieldwork was undertaken from 2012-2015. Predominantly, primary research is provided in the pilot study in chapter four, the findings are compared using evidence from the literature. From focusing on fieldwork on a UK-wide basis in the pilot study, the main study focused on bioenergy supply chain integration in the West Midlands region.

An overview of the area is presented in chapter five and is based on secondary research approaches. The advantages of narrowing the field into a manageable and accessible area assisted the study in defining a more robust view of supply chain integration constructs and factors that encourage the development of bioenergy businesses.

Chapter five provides data on the availability of biomass and business case for the development of an alternative energy industry. The main findings of the study are presented in chapter six that provides data from survey questionnaires and case studies of bioenergy companies based in the West Midlands Region. Results from two surveys are presented, the first is a questionnaire aimed at stakeholders and operators in bioenergy businesses from the Region and the second questionnaire targeted researchers in bioenergy. The purpose of the researcher questionnaire was first to confirm the shift towards expansion in the higher education sector emanating from chapter five (An Overview of the West Midlands and Bioenergy Potential Capacity) and whether such research can determine policy and direction of the bioenergy industry.

Case studies presented in the latter part of chapter six present views from rural and urban locations, stakeholder and operators in development of bioenergy. The output of chapter six provides on the one hand confirmation of issues and challenges from primary research and begins to address the final research question in how the contribution from the study improves the effectiveness of bioenergy through supply chain integration. Analysis of the main survey results is given in chapter seven which identifies key factors that integrate the bioenergy supply chain from stakeholder and process perspectives.

Evidence is taken from the primary research findings presented in chapter six and compared with evidence from the literature in chapter two. It is this chapter that addresses the overall aim of the research and confirms supply chain integration factors taken from the evidence and contributes to expanding knowledge in understanding of supply chains in emergent and immature industries, namely bioenergy in this case. This leads into the final chapter, (chapter eight) which summarises the contribution to existing knowledge from the original theoretical prepositions provided in chapter two and how to develop best practice procedures for bioenergy businesses. The final chapter also provides an evaluation of the approaches made in this study and proposes future research in this evolving and novel field.

Chapter Two: Review of the Literature: Supply Chain Integration Constructs and Challenges - Part I.

2.0: Overview of the Chapter, Purpose and Approach.

This chapter provides an analysis of key concepts and constructs in supply chain integration by first defining the concept of the supply chain and how it has evolved from a generic viewpoint, followed by how the supply chain literature has determined linkages within bioenergy firms. In this context, the literature review addresses the first research question in relation to defining the constructs of bioenergy supply chains and the latter part of the chapter analyses the issues and challenges in determining bioenergy supply chain integration, which in effect addresses the second research question. The definition of a 'construct' in bioenergy refers to the so-called pillars of sustainability. These are economic, environmental, technical and social and are cited in the bioenergy literature.

Secondary research approaches dominate this chapter in parts one and two of the literature review. Apart from academic literature in part I, data is also obtained from European and National Government and their respective agencies. Regarding the issue of confidentiality at this stage, all data, whether sourced from academic and practitioner resources are from published sources and are cited accordingly. The second part of the literature review presents an analysis of methods that have been applied to bioenergy research. A similar overview is provided at the start of part II in order to give a brief summary of context, purpose and organization.

2.1: Method and Purpose of Doing a Literature Review.

This chapter follows on from the previous chapter to explore and analyse the main characteristics of supply chain integration in bioenergy. First, why conduct an investigation from secondary research approaches? Fink (2005, p. 5) defines a literature review as a:

'...systematic, explicit, and reproducible design for identifying, evaluating synthesising the existing body of completed and recorded work by researchers, scholars, and practitioners'.

Thus, the review of the literature is systematic and deductive approach, which is in this context, is to identify rules inherent in the definition of supply chains. From this, it is possible to determine the constructs that integrate the bioenergy supply chain. Fink's definition provides an insight as to why perform such an investigation from work that is already known to interested parties. The main reason for conducting this initial investigation is to define the concept, form the basis of understanding the concept and constructs that underpin the topic being studied and help clarify meaning. A literature review helps us make sense of 'real-world' constructs in a robust and systematic way. Sources of data came from the academic literature, namely journal articles that focused on generic supply chain literature; industrial and governmental policy documents in addition to reports that define the scope of bioenergy and agenda for its development and implementation.

2.2: Definitions and Concept of Supply Chain Integration.

The concept of supply chain integration stems from business processes that aid organizational performance in a typical supply chain. This comprises raw material suppliers to end-user firms, inter-linked by a series of transactional operations between them. Such transactions are determined by either long or short-term agreements between supplier and buyer firms, which add complexity depending on the extent of horizontal and vertical integration of each individual firm in the supply chain. According to Lambert and Cooper (2000: p. 65):

'It is not a chain of businesses with one-to-one business to business relationships, but a network of multiple relations and relationships'.

This means that activities between linked firms perform more efficiently where business processes and operations are co-ordinated end-to-end across the supply chain.

The concept of, 'supply chain management' first appeared during the 1980s, and dominated by manufacturing processes that were determined by buyer-supplier relationships. The definition of supply chain management from the Global Supply Chain Forum (GSCF) in 1986 provides the conventional view of supply chain management:

'…the integration of key business processes from end user through to original suppliers that provides products, services, and information that add value for customers and other stakeholders'. (GSCF cited in Lambert and Cooper, 2000, p. 66).

Additional operations such as transporting products between suppliers and customers were not seen to add value but are critical to supply chain management and its integration. The former Council for Logistics Management (CLM), 1986 endorses this view by defining logistics as:

'The process of planning, implementing and controlling the efficient cost-effective flow and storage of raw materials, in-process inventory, finished goods, and related information flow from point-of-origin to point of consumption for the purpose of conforming to customer requirements', (Council for Supply Chain Management Professionals, CSCMP since January 2005).

There have been other definitions for supply chain management depending on particular viewpoints. For example Ellram (1990, p. 2) defines SCM in a linear supplier to end-user context:

'…integrative philosophy to manage the total flow of a distribution channel from supplier to the ultimate user'.

This does not take into account multi-channel distribution and hierarchical relationships between tier 1 and tier 2 suppliers and customers. Harland (1996, p. 64) replaces the term, 'management' with network, defining SCM as the:

'…management of a network of interconnected businesses involved in the ultimate provision of product and service packages required by end customers'.

Harland's definition implies integration rather than management of the supply chain, suggesting that it comprises a complex network of not just processes but also relationships between firms. In support of this view Christopher (1998) considers the term, ‘chain’ representative of a network of organizations, which includes numerous suppliers and their customers including vertical integration from supplier to supplier and horizontal integration between suppliers to customer. Christopher’s approach takes the concept of the ‘supply chain’ further by adding the dimension of a ‘demand chain’. Interaction of the main decision makers involves functional areas of the supply chain such as logistics, marketing, distribution and purchasing (Halldorsson et al., 2007).

Supply chain management is under constant scrutiny and change according to Halldorsson et al. (2007). Increasingly, firms have to develop ways of adding value to their products without increasing costs. This results in higher levels of complexity and diversity of managerial decision-making operations. Collaboration and integration in the supply chain is imperative if firms are to be competitive. The supply chain comprises organizations, the flow of goods and information between raw material suppliers to end-users. Integration of core and non-core functions across the supply chain on the one hand adds value but on the other, also places emphasis on the need for effective co-ordination of information and product flow between firms. Raw material suppliers at one end of a supply chain (upstream) and customers at the other end, (downstream) have to be able to co-ordinate activities horizontally across tiers and vertically within the same tier. The first step is to identify members and distinguish between primary and secondary member firms. Primary members are firms that operate within the first tier whereas secondary members are situated within tier 2 (Lambert and Cooper, 2000). Product and information flow provides for better visibility and co-ordination (Davenport, 1993). However, it is apparent that not all members have equal parity across the supply chain. Distinction between secondary members and non-members of the supply chain challenge visibility for information and product flows. Non-core functions such as logistics and marketing have an important role to ensure that information pulls the product from manufacturing to customers and logistics providers are responsible for ensuring just-in-time delivery of product, but this is dependent upon the quality of information they receive (Lambert and Cooper, 2000). It is usual practice for companies to outsource their non-core activities in order to focus on core activities. This adds layers complexity and places more importance on effective communications between parties in the supply chain. Traditional historical forecasting methods would push rather than pull products through the supply chain and result in excessive inventory carrying costs, discounting unwanted and surplus inventory. Effective supply chain integration pulls from the customer and is responsive to market changes. Product and information flows from end-to-end of the supply chain are complex and challenging but it is evident that long-term supplier relationships lead to improvement of competitive capabilities amongst member firms (Flynn et al., 2010; Kim, 2009). Thus it is important to explore the scope of factors that integrate rather than investigate what is loosely defined as 'management' in a supply chain. For general purposes the standard literature helps us to understand the definition and therefore, mechanisms of a supply chain and if these align with bioenergy businesses. From the 'generic' supply chain literature there could be similarities but it is worth exploring further through stakeholder and process characteristics.

2.3: Stakeholder Integration Characteristics in Bioenergy Supply Chains.

This section of the literature review identifies the scope of stakeholder integration in terms of relationship management, trust, collaboration and partnership attributes. Gold (2010a) confirms how important the framework for stakeholder relationships are to a bioenergy supply chain. By the same token benefits can also adversely outweigh positive aspects fostered from stakeholder processes. This contradicts much of the contemporary literature, which refers to stakeholder challenges and risk as being beneficial to policy and implementation of a bioenergy facility. The literature is limited identifying what it means by challenges and risk to the bioenergy supply chain. Furthermore, what factor in a 'typical' bioenergy supply chain can be characterized as the main attribute and which stakeholder factors are sub-ordinate to the main attribute? In addition, what is the order of linkages between each attribute? One main factor that links process integration with stakeholder integration is the contract (McCormick and Kåberger, 2007). The literature supports robust agreements between firms in supply chain bioenergy production and distribution, as without these, bioenergy is not viable (Roos et al., 1999). Factors defining relationship management in SCI and more importantly bioenergy supply chain management are challenging to define, because the literature suggests that supply chain practice is not global but locally orientated. According to Mirata et al. (2005, pp. 989-990) stakeholder relationships are central to bioenergy systems:

'As local development concerns a large number of stakeholders, it is crucial to develop a common understanding regarding targeted dynamics, develop shared objectives and goals, and assure commitment among regional parties'.

What tends to happen in reality is location and construction phases are put out to tender which also incorporates competition from international as well as national firms. Commercial viability of bioenergy plays a central role in the long-term deployment of bioenergy facilities as Mangoyana and Smith (2011, p. 1286) identify:

'Commercial viability remains a primary concern for the sustainability of decentralized bioenergy systems. There are, however, opportunities for compounding benefits through integrating small-scale bioenergy systems with other production decentralized systems'.

Dissemination of EU targets through national governments to lower energy production from fossil fuel and increase energy production from renewable energy supply drives policy creates a climate that is risk adverse and such conditions mitigate against innovation in bioenergy (McCormick and Kåberger, 2005). In practice, this means that firms seek assurance to develop from firms with a previous known record of success (Mirata et al., 2005). Management of relationships is therefore not grown from spontaneous inter-firm linkages that have developed over years of trading, but can be pre-selected by initial stakeholders. This finding, however, is not untypical of building supplier alliances from given selection criteria (Pätäri, 2010). On the face of it, local bioenergy firms tend to be tied into long-term agreements with either national, or international contractors for a prescribed period of time. Contractual agreements ranging 10 to 25 years are not unusual in the bioenergy industry (Krah et al., 2015). This is not as straightforward as it appears. Long-term contracts can induce risk and how strategic relationships are managed is important as Chen and Paulraj (2004, p. 119) find:

'…the challenge of designing and managing a network of interdependent relationships developed and fostered through strategic collaboration'.

Some of the bioenergy literature considers stakeholder relationships within corporate social responsibility and marketing paradigms (Pätäri et al., 2014). Again, this study argues that this does not provide the constructs of how stakeholder relationships benefit a viable bioenergy supply chain and how such linkages relate to process integration within a bioenergy business. For clarification, the definition of a stakeholder is:

'…any identifiable group or individual who can affect the achievement of an organization's objectives or who is affected by the achievement of an organization's objectives', (Freeman and Reed, 1983, p. 91).

This is an apt definition and the study would not proffer an argument against their definition, which is about the governance rather than the ownership of the supply chain (Cannon et al., 2000; Jones et al., 1997). What characteristics constitute the stakeholder relationship? Gold (2011a) considers stakeholder relationships on two distinct levels, firstly, stakeholder collaboration and secondly, financial viability. Supply chain governance is different from supply chain ownership in the conventional supply chain literature, in that governance relates to reciprocal relationships of:

'*formal contacts promote relational governance in exchange setting and relational governance enables the refinement of contracts and promotes stability in inter-organization exchanges',* (Poppo and Zenger, 2002, p. 713)

For such formal relationships to work within the stakeholder process, it is assumed that long-term agreements facilitate supply chain co-ordination (Spekman et al., 1998; Krause and Ellram, 1997). In the context of the focal firm, long-term agreements exist only between tier one suppliers and customers. Stakeholders are important to the decision-making process in bioenergy businesses (Gold, 2011a). The process of governance in bioenergy helps reduce the level of risk and disruption in the supply chain:

'High numbers of supply chain members and high degrees of interdependencies within bioenergy production systems make it indispensible to involve all supply chain actors but also other affected stakeholders into decision-making processes in order to prevent disruptions', (Gold, 2011a, p. 447*).*

Decision-making responsibilities amongst stakeholders also depend on the configuration of the bioenergy supply chain. Van der Horst (2008) finds two types of supply chain model in bioenergy:

1. Farm-led model where farmers supply the feedstock operate bioenergy production among themselves and is localised (Heinimö et al, 2008);
2. Manufacturer-led model where selected technology determines the supply chain.

In latter approach, technology-driven bioenergy systems rely more on robust contractual agreements for example contracts between feedstock suppliers (Madlener and Bachhiesal, 2007 and Sims and Venturi 2004). Having a contract in place, particularly a long-term contract for feedstock protects against decreases in prices (Leduc et al., 2009; Rauch, 2007). Long-term agreements can incur a trade-off between fixing prices in long-term contracts against the need for flexibility in seeking new opportunities (McCormick and Kåberger, 2007). The contract is a prerequisite to trust according to McCormick and Kåberger (2007, p. 446) who state:

'*Contracts between farmers and local energy companies, conceivably involving Local Government are needed to create a climate of confidence and promote diffusion of energy crops'.*

There is a tension between regional and national policy to lower carbon emissions and utilization of conventional energy systems and how this can be practicably implemented as a viable business. The stakeholder process is a complex one which, on one hand, is tasked with key decisions in choice of feedstock, location and complementary technologies and compliance versus the physical process of day-to-day operations of a bioenergy plant. The integration of the stakeholder side and the process side can prove challenging to a bioenergy business. The next section examines process integration in bioenergy supply chains from operational and technology aspects and considers how the characteristics of process integration complements stakeholder integration.

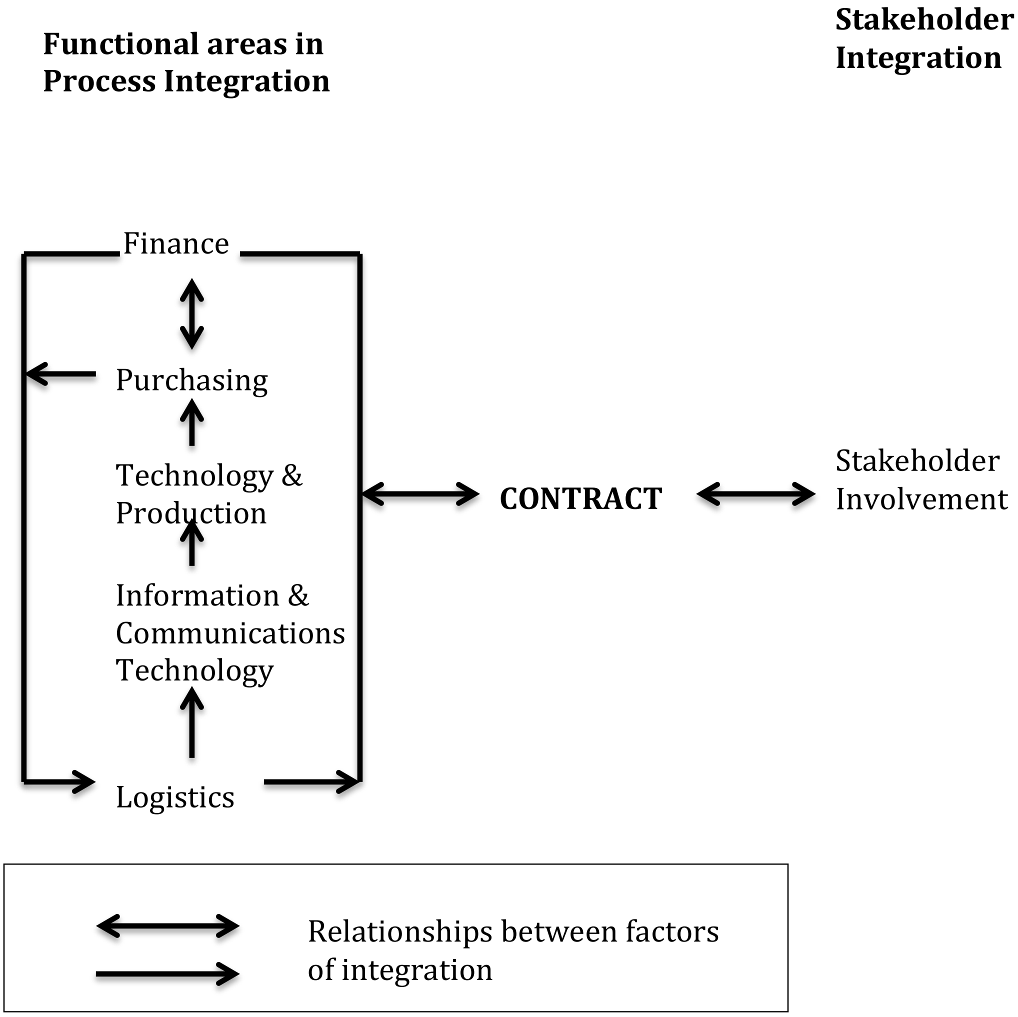
2.4: Process Integration in Bioenergy Supply Chains.

Process integration is governed by national guidelines and standards (Perry and Rosillo-Calle, 2008). This means that technological and operational factors associated with the day-to-day operations is driven by national energy policy (van Dam et al. 2010). For the purpose of this study process integration in a bioenergy supply chain is not defined as discrete operations that aid energy production but is defined as functional attributes of bioenergy production such as finance, communications, marketing, procurement and logistics operations, as well as plant technology and maintenance. By defining process integration in this way assures that this aspect of the bioenergy supply chain is seen in a wholly 'integrated' sense and not as individual supply chain processes. Jablonski et al. (2008) confirm this view by consideration of the whole bioenergy supply chain as technical, economic and social attributes. Technical potential is the volume of bio-heat and power that can supply the market; economic potential is the extent of financial viability of bioenergy production and social potential accounts for implementation of bioenergy policy (Jablonski et al., 2008, p. 637). However, it is worth considering each operational process in relation to the role it plays within the supply chain. For the purpose of this study operations are:

- Finance and purchasing,
- Information Communication Technology,
- Technology and Production Processes,
- Logistics Systems and,
- Marketing.

A more succinct view of process integration in bioenergy is illustrated in Figure 2.4.1: Process Integration Constructs in Bioenergy (p. 30).

Figure 2.4.1: Process Integration Characteristics in Bioenergy.



2.4.1: Financial and Purchasing Factors in Bioenergy.

Finance in bioenergy serves two purposes. First in the form of EU and UK Government funding incentives and secondly, costs relating to the day-to-day purchasing operations at firm level. In the first instance, UK renewable energy policy has served to incentivize implementation of bioenergy, which is demonstrated in table 2.4.1: Financial Incentives in Bioenergy Schemes in the UK (pp. 31-33). The Office for Renewable Energy Deployment (ORED), co-ordinates actions on behalf of the

UK Government to encourage achievement of 2020 renewable energy targets that is in response to actions taken from the Kyoto Protocol (1998).

Table 2.4.1: Financial Incentives to Support Bioenergy Schemes in the UK.

Scheme	**Purpose**	**Funding Amount £**
Renewables Obligation introduced during 2002.	UK Electricity providers to produce a certain proportion of energy from renewable sources.	Energy providers are paid in terms of Renewable Obligation Certificates, (ROCs) at a value of £46 per ROC, which is the long-term buy-on value of KWh units of electricity produced from renewables.
Renewable Transport Fuels Obligation (RTFO) 2007 amended during Dec. 2011 to implement elements of EU Renewable Energy Directive (RED) 2009/28/EC and amended again in 2013 to implement article 7a-e of EU Fuel Quality Directive 2009/30/EC.	RTFO encourages production of biofuels for transport which does not have negative impact on the environment.	UK Government provided £10 million in 2011 and a further £7.5 million in 2013 in order to provide financial support in converting 7500 buses in 25 local transport authorities outside London to reduce harmful substances from petrol and diesel emissions.
Feed-In-Tariffs (FiT Schemes) 01.04.10.	FiT supports organisations to generate low carbon energy using small-scale 5MW or less total installed capacity systems (i.e. 50 KW or less).	Large schemes gain either £10 KWh for new and £15 KWh for existing schemes (=>250,000 domestic customers) Small schemes paid £25 KWh for new or £30 KWh for existing schemes (<250,000 domestic customers).

Table 2.4.1: Financial Incentives to Support Bioenergy Schemes in the UK, (continued).

Energy Aid Payment Scheme.	EU incentive that encourages farmers to set aside land for energy crops. It is managed through the Rural Payments Agency.	For example, Scottish Government provides a flat rate of 45€ for either bio-fuels or biomass feedstock.
Entry Level Environmental Stewardship Scheme started in September 2012 and closed in September 2013.	To encourage good environmental practice across farm businesses.	£30 per hectare using a points-based system. Money is paid annually.
Bioenergy Infrastructure Scheme since 06.06.2008 (DEFRA).	To encourage production of biomass from short rotation coppice, miscanthus, reed canary grass, rye grass, straw and prairie cord grass; wood fuel from forestry.	Total of £3.5 funding made available from the UK government across England and Wales to increase renewable energy generation. Out of the £3.5 million individuals may apply up to £200,000 grant per group/business.
Renewable Heat Incentive.	Long-term financial support for users to utilise renewable energy to heat their buildings. Domestic RHI introduced in 09.04.14 Non-Domestic RHI introduced November 2011 to provide payments, which are determined by technology.	Air-source heat pumps 7.3p/KWh. Ground-source & water heat pumps 18.8p/KWh Biomass only boilers & thermal pellet stoves 12.2p/KWh. Solar thermal panels 19.2p/KWh.
Energy Company Obligation (ECO) became ECO_2 01.04.15 until 31.03.17.	Initiated from the Energy Act 2011. Suppliers are allocated a proportion of overall renewable energy targets. This obligates large energy companies to deliver energy in more efficient and sustainable ways.	

Table 2.4.1: Financial Incentives to Support Bioenergy Schemes in the UK, (continued).

Renewable Energy Guarantees of Origin (REGO) 05.12.10.	EU member states are required to establish and maintain renewable obligation and increase contribution of renewable energy	1 REGO is issued for MWh of eligible renewable output.
Non-Fossil Fuel Obligation, (NFFO), Electricity Act 1989.	Permit electricity producers to purchase a portion of energy from renewable sources. Initially NFFO was designed to support nuclear energy and stimulated growth in hydro, forestry, waste and sewage gas.	Price has fallen since 1990. Average price of power is 2.71p/KWh.
Climate Change Levy.	Environmental tax to encourage businesses to operate in a more environmentally-friendly way by providing exemption at main rates or carbon price rates.	As at 06.04.15: Electricity 0.559p/KWh Gas 0.195p/KWh.
Carbon Trust Incentive in partnership with Siemens.	Install biomass heating systems – equipment gran.t	£550 million in energy efficiency financing.
DECC Office for Renewable Energy Deployment (ORED) 2011-2015.	Co-ordinate action for achieving 2020 renewable energy targets, works through the Environment Agency to provide a support service	£200 million to facilitate a network of partnerships
Energy Crops Scheme.	Encourage growth of short rotation coppice and miscanthus for feedstock production. Producers can claim 50% of eligible costs.	In England a total of £1,811.50 was made from energy crops (i.e. short rotation coppice and miscanthus).

Sources: www.gov.uk, carbontrust; webarchive.nationalarchives.gov.uk; www.adlib.ac.uk; www.uea.ac.uk; www.tyndall.ac.uk/sites/default/files/wpy8.pdf.

The main Governmental agencies for co-ordinating and awarding funding for bioenergy production according to the table are National Government, Carbon Trust, Ofgem and Rural Payments Agency. The Department for Energy and Climate Change introduced the Office for Renewable Energy Deployment (ORED). Financial incentives in the UK are categorised into four main groups:

1. Incentives for feedstock production,
2. Incentives for renewable energy production,
3. Incentives for selected renewable energy technologies and,
4. Incentives for bio-fuel production in transport.

This study will only investigate financial opportunities in the first three categories and not the fourth category, bio-fuel production in transport. Aside from incentives for bio-fuels, national governments restrict initial choice of bioenergy technology and feedstock production by providing more funding for particular technology and feedstock than in others. In the first category of national financial incentives, (feedstock production), much of the funding targets agricultural and forestry producers through the Energy Crops Scheme that supports short crop rotation coppice and miscanthus grass (£1,811,50 in England during 2014); and Energy Aid Payments Scheme for farmers to set aside land for energy crops paying up to £30 per hectare. The second group of incentives relate to choice of technology. Similar to the key findings of incentives for feedstock, there are also differences in levels of Government funding for technological choice of bioenergy schemes. Bearing in mind that financial incentives for feedstock do not include non-agricultural biomass and excludes feedstock from other potential sources that are viable. For example municipal waste and sewage slurry from water treatment works. There is approximately 31 billion tonnes of municipal solid waste (MSW) produced in the UK (DEFRA, 2012). Out of the total volume of MSW, only 16.1% is used for bioenergy production. The gate fee is currently £54 per tonne, which applies to facilities built before 2000 and £73 per tonne for bioenergy conversion facilities built after 2000, (at the time of writing August 2015). Therefore, if 31 billion tonnes of MSW were converted into bioenergy based on pre-2000 conversion facilities, the income from this would amount to £1,674 billion. Whilst this is only speculation based around 2012 MSW figures, it stresses the point that a potential source of feedstock is not being fully exploited. The same can be seen in domestic sewage waste. Waste water treatment accounts for 11 billion litres of wastewater. This excludes non-domestic wastewater (6,273,037 litres) according to DEFRA (2015). Again, the point being made is that this is another potential resource that does not incur risk in supply of feedstock and yet financial incentives from national government are not forthcoming to develop decentralised energy systems, particularly for bioenergy, (Carbon Trust, 2013; Wolfe, 2008; Woodman and Baker, 2008). Decentralised energy systems refer to energy produced from both conventional sources as well as renewable sources. Such systems can serve cities and whole communities. The main impediment to their introduction is lack of infrastructure from local government:

'The major obstacle to mass take-up of decentralised energy is institutional - the lack of experience and expertise in the public sector', (Carbon Trust, 2013).

This is an important consideration in supply chain integration within bioenergy because bioenergy supply chains are regionally based. Therefore it makes sense to evolve a structure that assists supply chain integration from both a process and stakeholder perspective that devolves energy supply in a decentralised system.

The second and third category of financial incentives given in table 2.4.1 shows funding for renewable energy production. There is a distinction between incentives for renewable energy production and incentives for selected technologies in renewable energy production. Carbon Trust Incentive (in partnership with Siemans), provide a £550 million equipment grant to install biomass heating systems. This is the largest financial incentive for production systems compared to other financial incentives in this category within the UK. Renewable Energy Guarantees of Origin (REGO) and Renewable Energy Obligation Certificates implement the Feed-in-Tariff, (FiT) rates in renewable energy production. This is divided according to the proportion of renewable energy produced by providers and whether such production facilities are either dedicated plants or co-generation indicated in table 2.4.1. The UK's electricity and gas regulator (Ofgem) publish rates for renewable energy production, which is provided in table 2.4.1.2: FiT Rates for Renewable Energy in the UK.

Table 2.4.1.2: FiT Rates for Renewable Energy in the UK since 2010.

Renewable Energy Installed Capacity by Technology	**2010**	**1st April 2015-1st March 2016**	**Difference between 2010 rates and current rates**
AD ≤ 250 KW	13.66 p/k/Wh	10.13 p/k/Wh	3.53 p/k/Wh
AD 250 KW - 500 KW	13.66 p/k/Wh	9.36 p/k/Wh	4.3 p/k/Wh
AD > 500 KW	10.66 p/k/Wh	8.68 p/k/Wh	1.98 p/k/Wh
CHP	11.84 p/k/Wh	13.45 p/k/Wh	1.61 p/k/Wh
Co-generation ≤ 50KW	19.66 p/k/Wh commissioned before 14th July 2009 under the Renewable Obligations Order.		

Since 2010 FiT rates have decreased for anaerobic digestion ≤ 250 kW, (13.66 p/kWh) compared to current FiT rates from 1st April 2015 to 31st March 2016 at 10.13 p/kWh, a reduction of 3.53 p/kWh. Similar FiT reductions for AD installations with a total installed capacity from 250 kW up to 500 kW as in 2010 FiT rates were 13.66 p/kWh and currently they are 9.36 p/kWh, a reduction of 4.3 p/kWh. In the case of AD facilities with an installed capacity >500 kW, FiT rates were 10.66 p/kWh in 2010 but now are set at 8.68 p/kWh, giving a reduction of FiT rates of 1.98 p/kWh. The largest reduction is for AD facilities producing between 250 kW to 500 kW/h of renewable energy. However, Combined heat and power (CHP) FiT rates have been increased from 11.84 p/kWh in 2010 to 13.45 p/kWh in 2013, an increase of 1.61 p/kWh. Co-generation where fossil fuels are used in combination with feedstock from renewable sources is set at 10.66 p/kW. This is for eligible installations with a net capacity of ≤ 50 kW, that have been commissioned in or before 14th July 2009 and accredited under the Renewables Obligation Order, 2002, (Ofgem.gov.uk). The Renewable Heat Incentive (RHI) applies to both non-domestic and domestic renewable energy production. This incentive likewise differs for types of technology used to generate bioenergy as biomass only boilers and biomass pellet stoves are provided 12.2 p/kWh compared with solar thermal panels at 19.2 p/kWh, a difference of 7 p/kWh (www.ofgem.gov.uk). The incentive in this group is the Climate Change Levy and ECO_2, which is not a financial incentive but acts as a key driver to encourage businesses to change the way in which they consume and produce energy, thus not necessarily bioenergy production.

Despite financial incentives from the national government, there is not evidence to support how such schemes add value to the long-term viability in bioenergy businesses (Adams et al., 2011). In reality Adams et al. (2011) find that many bioenergy schemes do not survive beyond the initial pump priming stage. This may mean and as this research will demonstrate that lack of business planning during the early stages will have a negative impact on the long-term sustainability of a bioenergy business and its supply chain. This is certainly demonstrated by changes made to government incentive payments for technological and feedstock decisions in Table 2.4.1. Management for the viability of a bioenergy business needs to ensure that robust financial agreements are in place through effective supplier selection that lower contractual risk from suppliers (Çebi and Bayraktar, 2003). Supplier selection is central to the decision-making process because selection of appropriate suppliers helps reduce purchasing costs and improves competitiveness (Ghodsypour and O'Brien, 2001; Jacobsson and Johnson, 2000). Furthermore effective supplier selection integrates the supply chain as a whole entity (Weber et al., 2000). The main challenge in supply of feedstock according to Scott et al. (2013) for bioenergy conversion is the low value afforded to feedstock. Competition from alternate uses is more attractive. For example, woody material is also sourced by the construction and paper industry (Perlack et al., 2005). There is a lack of evidence in the contemporary literature, which fails to identify the importance of contractual agreements in bioenergy (Scott et al., 2013). However, the research finds evidence from non-academic sources that provide a framework for supplier agreements in biomass. The Scottish Government has designed a template for a contract in biomass supply. Its criteria involves a number of characteristics based on eight main criteria:

1. Name of the parties that the contract is between,
2. Quality specifications of biomass,
3. Cost of biomass £ per m^3 or £ per tonne of biomass,
4. Type of biomass,
5. Delivery volume,
6. Delivery dates and times,
7. Duration of Contract and,
8. Penalties incurred should either party be in breach of the terms of the contract (www.scot.gov).

The cost of woody biomass such as woodchip at 30% moisture content is £110 per tonne and cost of wood pellets is higher at £210 per tonne. However, use of wood in other sectors provides a significantly higher value per tonne, and also represents greater environmental performance in being utilised as a building material compared to other construction materials. More importantly wood material is more energy efficient where used for construction than its use in bioenergy conversion. Sathre and Gustavsson (2009) give figures of the value of wood in construction between 11,100€ to 23,300€ per wooden frame. Part of the challenge in lowering risk in supply of woody biomass is due to the fact that there is limited energy and carbon taxes, 'to internalise the external costs' (Sathre and Gustavasson, 2009, p. 255). Such lack of infrastructure and robustness in the supply chain provides challenges to logistics operations, which are outsourced to third party companies (Scott et al. 2013). It is typical that main transport providers engage in long-term agreements with conversion facility. As an example Stobart have signed a 15- year index-linked contractual agreement with Tilbury Green Power Ltd (renewableenergyfocus.com). This is to transport 2 million tonnes per annum to the site. This is by no means a small venture but a considerable investment on the part of the Stobart Biomass Group, which must mean that robust contractual arrangements have been agreed. Leaving aside logistics provision until further on in this chapter, the next section in process integration is the involvement of information and communication technology, (ICT).

2.4.2: Information and Communication Technology (ICT) in Bioenergy.

Information and communications technology in bioenergy is a complex one and it is worth deconstructing this into three sub-groups of, decision-making, production automation and social communications. Generally, decision-making operations in bioenergy utilises ICT mainly for selecting choices of location, technology and biomass. This is distinct from automation processes in production and use of social media for marketing and communications.

Location decisions are determined by GIS applications informed via social, economic, technical and topographical data (Scott et al., 2014). Despite geospatial analysis tools, the literature presents rather a confusing array of different approaches applied to assess bioenergy systems and the appropriateness of location as determined by GIS support systems. Mitchell (2000) identifies a minimum of 28 computer models that determine bioenergy from diverse perspectives of material sorting, location, energy consumption of either transportation or production of feedstock, which again varies with the characteristics of different of feedstock types. It must be noted that such issues have arisen due to the novelty of this sector, which lacks an integrated approach from its onset.

It can be assumed that the role of ICT in bioenergy is central to integration as Stallo et al. (2010, p. 175 and p. 179) state:

> *'ICTs have a significant role … ICTs can be applied in two possible ways to produce renewable energy and to support current renewable energy production processes'.*

Without integration of ICT there is a lack of visibility in supply chain operations. Unfortunately, the literature is particularly limited in this area because rather than discuss ICTs as an integrated characteristic, which helps create a viable bioenergy business and supply chain. Instead the literature refers to ICT as a decision support tool that predominately relates to location, technology and feedstock decisions (Taticchi et al., 2013, Linton et al., 2007) and automation of production and purchasing functions (Stallo et al., 2010). Additionally, this excludes the use of ICT as a marketing tool, which again is an important function of process integration in relation to procurement and generating potential business opportunities.

This study attempts to address this gap by considering the application of ICTs in bioenergy in relation to the contract. Figure 2.4.2: Relationship between ICT and the Contract in Bioenergy Supply Chain Integration, (p. 31) shows direct and indirect relationships between ICT and its attributes that lead to establishment of the contract. The contract is a central construct in process integration with ICT as one of the main attributes. Production and logistics are functional areas, which are also defined as main attributes but are closely linked with ICT both in automation of processes and information tools. Sub-attributes identified in the figure as decision making and marketing form part of the constructs with ICT. The third role in marketing and personal communication deals with maintaining supply chain relationships, for example, the day-to-day communications between firms. In order to do this there has to be a common language and terms of reference. There is evidence in the renewable energy literature that considers ontological perspectives of bioenergy (Solanki and Skarka, 2013). Application of semantic web-based applications have the potential to link into decision support systems whilst at the same time evolving a given bioenergy supply chain. Ayoub et al. (2006, p. 710) define a decision support system (DSS) as:

'…computer technology systems that can be used to support complex decision making and problem solving'.

To date, this has not been evident in large-scale commercial bioenergy ventures in the UK. The second aspect of ICT in a bioenergy supply chain is in automation of operations. Such knowledge exists in the conventional supply chain literature but not in bioenergy applications. Information Technology helps automate processes such as scheduling production, procurement, production operations, storage and logistics such as vehicle routing (Ikonen et al., 2013). This in turn, helps reduce waste and costs due to optimization of product and information flow. However, in bioenergy, infrastructure for transportation does not present many examples in the literature.

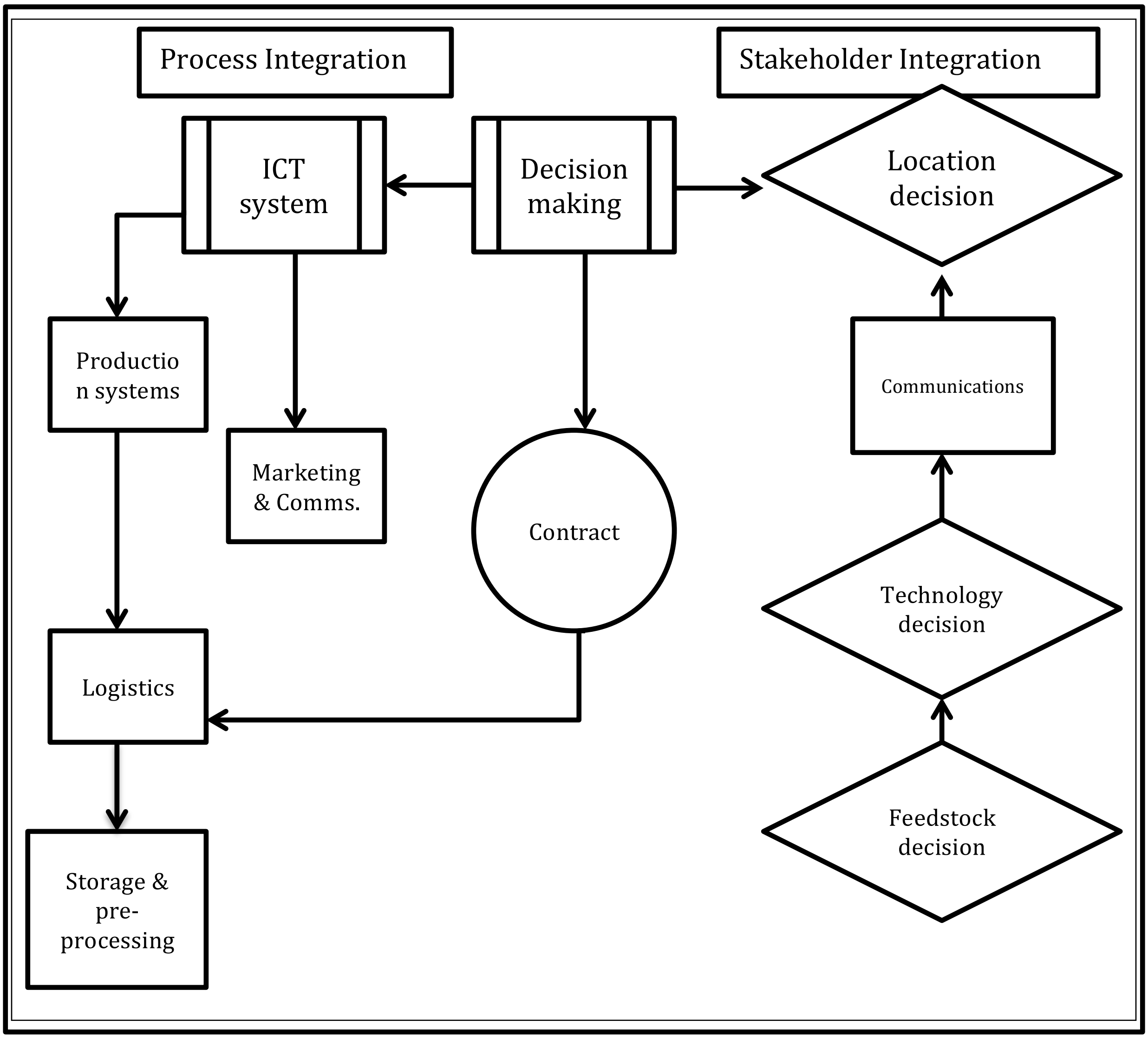
As Bonilla and Whittaker (2009, p. 6), state:
'…importance of transport network and mode, infrastructure needs traffic are rarely looked at in analysis of large scale biomass deployment'.

The term Information and Communication Technology implies a system which in this case is bioenergy production and information integration. Mostly, the literature considers the characteristics of biomass rather than in terms of inbound and outbound logistics as part of an integral system within the bioenergy supply chain. Emphasis in logistics for bioenergy is based around the features of biomass, volume and distance and mode of transport constraints. Uslu et al. (2008, p. 1206) on pre-treatment of biomass state:

'The pre-treatment step has a significant influence on the performance of bioenergy chains, especially on logistics'.

Suurs (2002) considers inbound attributes for long-haul transport for large-scale bioenergy schemes but not how bi-products from waste, post-conversion are deployed that would be typical of outbound logistics. Other authors consider the amount of energy expended during pre-production and production phases, which includes transportation of biomass, (Rogers and Brammer, 2009). In respect of ICTs in bioenergy, production systems are technologically driven and dependent upon a number of factors.

Figure 2.4.2: Relationship between ICT and the Contract in Bioenergy Supply Chain Integration.



Key:

□ Process

◇ Decision

◫ Pre-defined process

→ Links between functions

The first relates to the level of stakeholder support such as the provision of subsidies that serve to encourage technological innovation (Thornley and Cooper, 2008). This in itself proves risky to bioenergy companies because of the fluctuating changes in financial incentives. For example, at the time of writing (June 2015) the Secretary for State for Energy and Climate Change announced the ending of subsidies for on-shore wind with effect from 1st April 2016 (www.gov.uk/government/speeches/statement-on-ending-subsidies).

Bramsiepe et al. (2012) likewise confirms the risk of bioenergy firms depending on Government subsidies:

'A major hurdle for the new process technologies especially short-lived products is the high risk related to new process hardware. In future equipment manufacturers will provide a leasing and rental park for process equipment modules to enable manufacturers to take this hurdle', (Bramsiepe et al., 2012, p. 34).

Ability to control processes is central to effective information systems in process integration because of the need to be able to respond to actions for all aspects of plant operations (Bramsiepe et al., 2012).

The final perspective of ICT in bioenergy in this section is that of marketing and communications. Market leaders in promoting the potential of bioenergy are according to McCormick (2010), Brazil, Sweden, Germany, USA and China. On the other hand, marketing and communications from the EU with the exception of Germany is thwarted by Directives that serve to mitigate against the deployment of bioenergy (McCormick and Tåberger, 2007). Potential procurement opportunities originate from marketing and communication activities. Links with external parties provide potential contractual opportunities as Kokkenenk et al. (2013, p. 15) find:

'...also significance of networking is becoming more evident in bioenergy production solutions'.

The literature is limited in this area but nevertheless it is an important area because without understanding the role of the market in bioenergy how can optimal decisions in bioenergy evolve?

Bioenergy market participation is defined by Galik (2015, p. 15) as:

'the direct generation of earnings from bioenergy from bioenergy market activities'.

This, in turn can lead to a successful business opportunity and contract between parties (Galik, 2015). Effective deployment of marketing and communications approaches can determine technological, location and feedstock decisions over other choices, and ultimately, contractual agreements between parties. Publicity is important in communicating to all parties including the general public the role that bioenergy will play in the wider community as Domac et al. (2005) confirm.

Process integration includes logistics and production that have a close relationship with procurement operations in terms of managing relationships between the supply side of a bioenergy business and the demand aspects of a bioenergy business. The next section of this chapter analyses the determinants of procurement through logistics and production systems. Logistics is responsible for delivering supply of biomass and production systems for meeting demand for heat and power, thus technological characteristics in process integration.

2.4.3: Production and Logistics: Its Role within the Bioenergy Contract

The role of production rather than technology is proposed in this section together with logistics because of evidence in the literature to support upstream supply chain processes in relation to biomass-to-bioenergy. Firstly, technology refers to individual equipment and outputs as Trømborg et al. (2007) find in assessing outputs of a range of technologies in bioenergy conversion. Here, technology refers to as category of equipment, raw material, capital, maintenance costs and raw material processing costs. On the other hand, production involves supply chain operations from both a stakeholder and process perspective. Examples in the literature include Voivontas et al. (2001) on the development of a decision support tool that incorporates technology, location and feedstock decisions:

'The method, finally, aims at the evaluation of the biomass potential that can be economically exploited for power production through optimization of power plants,

distribution taking into account the geographic spread of available biomass and the plant characteristics', (Voivantas et al., 2001, p. 102).

Likewise in Forsberg (2000) applies life cycle inventory (LCI), which incorporates ISO 14000 standard to measure the impact renewable energy production, thus distinguishing parameters for which producers of renewable energy systems must comply. This includes growing, harvesting, transport and combustion up to delivery of regional electricity. Contractual pre-requisites are of course, determined by types of feedstock. Wood and forest residues are governed by the EU Timber Regulation, (since 2012), and Forest Law Enforcement, Governance and Trade Action Plan (FLEGT since 2003). These are regulations that ensure that timber is not illegally sourced. The interface between feedstock production, transport and conversion demands different operational processes and also different units of measurement. In agricultural operations machinery is calculated by running hours rather than time and distance travelled from one location to another. Conventional logistics systems support total distribution costs but in bioenergy it is more complex because the costs include agricultural units of measurement such as harvesting, chipping, baling etc., as well as volume, distance, fuel costs for example (Van Belle et al., 2003). Tatsiopoulos and Tolis (2003) provide details of cycle time for cotton-stalk biomass and compare this with conventional supply chain and logistics' methods and determine two types of scenario:

1. Centralized system: where feedstock is a bi-product of waste from other production systems and,
2. Decentralized systems where facilities are transported to a central depot.

Centralized systems deploy contractual agreements and good relations with farmers and third party transporters (Tatsiopoulos and Tolis, (2003). However, decentralized systems are more dependent on transport provision. Costs here are higher due to distances travelled and empty running on the return journey. Increasing local biomass activity, (tonne/ha) allows for effective economies of scale over the entire bioenergy system (Hamelinck et al., 2005). The most expensive transport system is where pre-processing is undertaken on site of feedstock producers in examples cited in Van Belle et al. (2003), unless costs are divided amongst the feedstock producer, logistics company and conversion facility to reduce overall costs. Management of bioenergy supply chain relationships are central according to Gold (2011a, p. 440):

> *'In addition to structure and design of bio-energy supply chains, management of relationships interlinking the supply chain actors and successful involvement beyond the supply itself are of outstanding importance'.*

This supports the view that both stakeholder interaction and process integration are intrinsic to each other. It is the level of decision and intervention from stakeholder actors that may determine the main components of the biomass-to-bioenergy supply chain as feedstock decisions, transport decision and technology decision, and the same stakeholder actors may also influence distribution.

2.5: The Constructs of the Contract and its Role in Bioenergy Supply Chain Integration, (SCI).

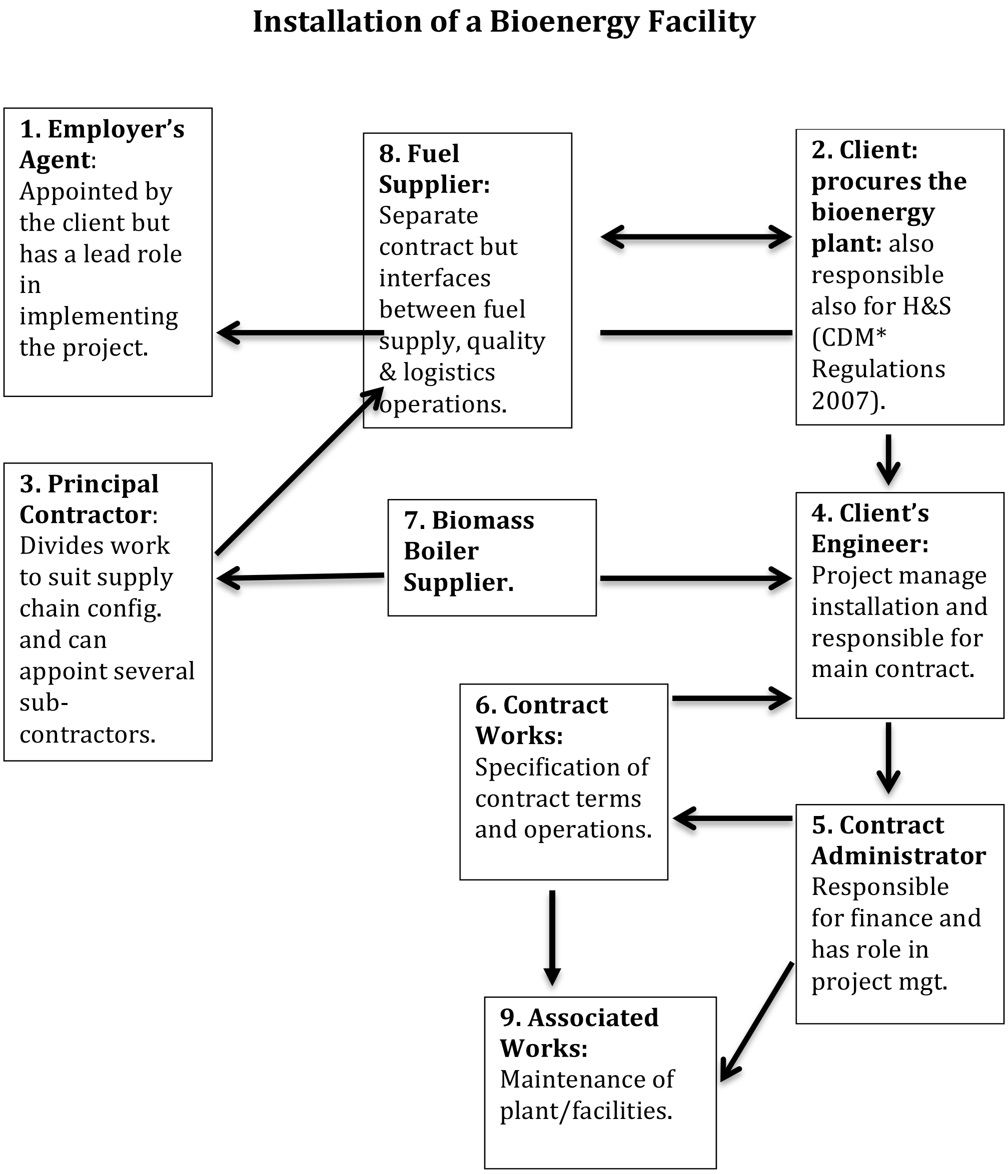
This is an interesting area of study as there is a deficit in the academic literature because there is no agreed definition of a bioenergy contract which also, includes the constructs of a bioenergy supply chain, McCormick and Tåberger (2007) and as Roos et al. (1999) find, bioenergy is yet to define itself. Nevertheless, the same body of literature frequently cites advantages of robust agreements between parties in order to reduce risk between demand and supply of bioenergy amongst the various actors. Bioenergy installations are being developed outside mainstream construction, building and engineering services. Ironically and particularly pertinent of wood and timber biomass, it is largely unregulated, (at the time of writing, August 2015). Therefore there is a lack of standardization in terms of agreement between parties. The UK Carbon Trust provides a reasonable and rational template with which to develop a bioenergy facility through types of agreement and procurement arrangement, (see figure 2.5.1: Actors in the Bioenergy Contract, (p. 47 and table 2.5.1: Bioenergy Contract Options: Advantages and Disadvantages, p. 48). Windisch et al. (2010, p. 856) also attempt to analyse the costs of procurement in a bioenergy supply chain and conclude that supply approaches:

> *'…can improve efficiency and profitability of forestry in the fast growing field of forest fuel procurement'.*

Figure 2.5.1 demonstrates the range of iterations in procuring a bioenergy facility and it is evident that this in itself is at risk of losing integral visibility and robustness across the supply chain, due to the number of contractors and sub-contractors between the main client as Hoggett (2013, p. 165) confirms:

'The interconnected nature of these actors and phases across the supply chain means that failure in one part can jeopardise many other areas'.

Figure 2.5.1: Actors in the Bioenergy Contract



*** CDM:** Construction Design Management Regulations

Table 2.5.1: Bioenergy Contract Options: Advantages and Disadvantages.

Contract Types	Advantages	Disadvantages
Option 1: In-house design, installation and commissioning	Lowest cost as project is managed by client. Direct link to contractors, Client retains control of design.	Client manages all problems and costs.
Option 2: In-house design with third party installation and commissioning	Client manages all interfaces. Issues and delays do not all fall on client. Client retains control.	Pricing of risk and management falls on Main Contractor, which adds to initial costs.
Option 3: Third party design, installation, (Turnkey * approach)	Contractor manages all facets of bioenergy project with limited involvement of client. Greater cost certainty as main contractor must price risk and provide a turnkey price	Contractor must accept and manage risk, which adds to initial costs.
Option 4: Third party installation, commissioning (Turnkey approach) with separate operating contract	Similar to Option 3 but Client hands over plant operations to a third party. Third party manages all the risks.	High costs
Option 5: Third party design, installation, commissioning and operation with agreement to supply Energy Service Co. (ESCO model).	Third party manages risks. Core business invests in project.	High costs and risk where core business is in control.

Source: Adapted from Carbon Trust Biomass Installation Contracting Guide, n.d. pp. 12-13

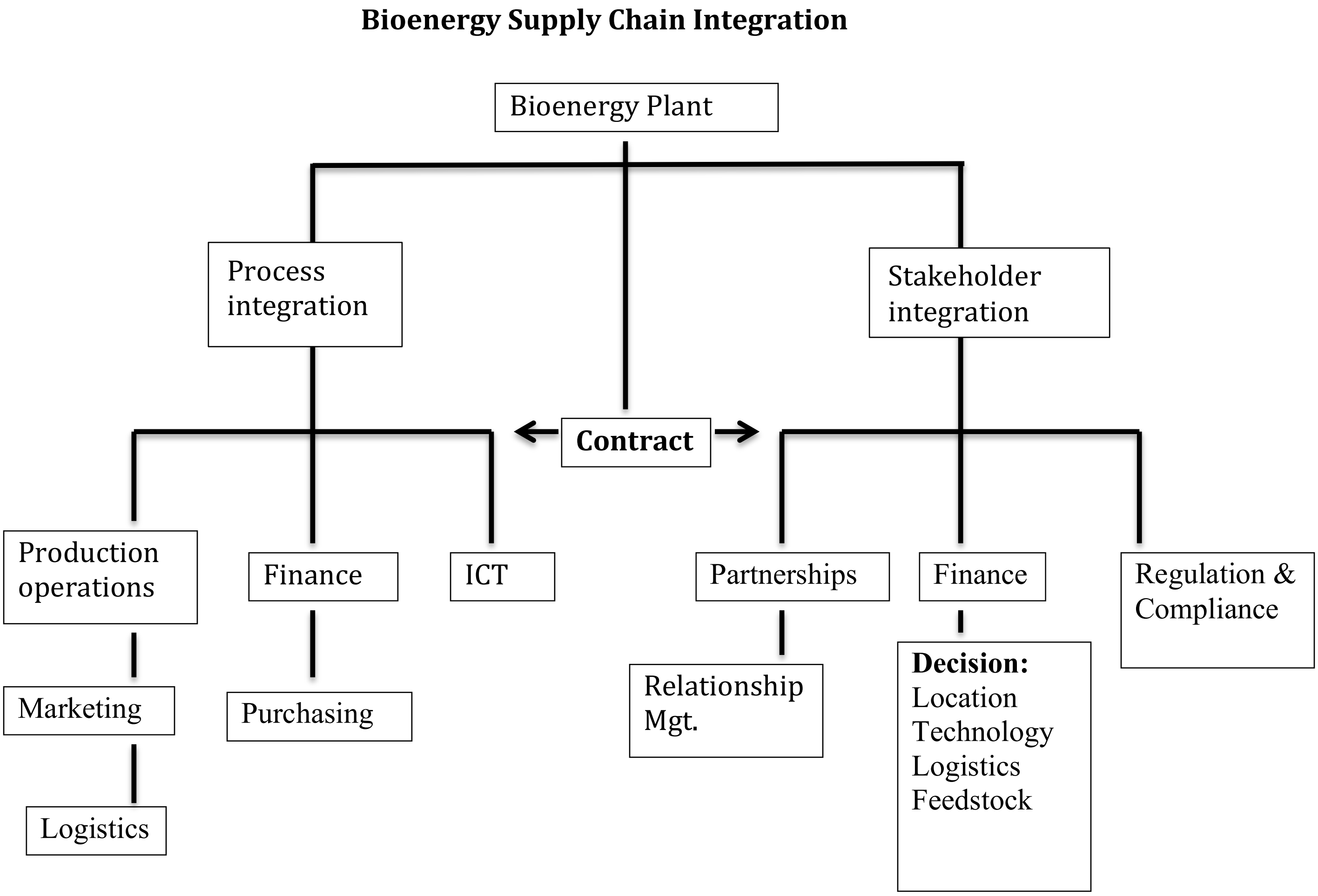
Table 2.5.1 shows the inclusion of turnkey procurement approaches in options 3-5. A Turnkey means literally ‘turning the key’ and is defined as a business arrangement where the project is delivered in a completed state (www.rics.org). All relevant parties in the contract enter into a contract with one party, which is usually between the Client and Developer to complete the project before ‘turning the key’ over to the client once the project is completed. This type of arrangement is used for construction of both small-scale single facilities to large-scale developments. Whereas, conventional ‘lump-sum’ contracts is where the client agrees to pay contractor to complete a project specification but the client has the opportunity to make decisions and changes throughout the life-time of the project. In a turnkey contract, the client is left out of the building phase as the developer makes all decisions. Piterou et al. (2008) find inflexibility to intervene in turnkey contracts because, firstly there is a lack of control and monitoring of contractors during the installation phases, which leads on to the second point in that technological choice can become out of date at the time of handing over to the client. Malik, (2008) also considers contractual criteria and conditions for viable bioenergy businesses and considers advantages compared to the disadvantages of turnkey contracts. One of the main advantages of this type of contract is the fact that it is in the developer's interests to complete the project to the agreed costs and on time. On the other side of the coin, turnkey contracts coupled with restraints on financial opportunities, restrict the level of innovation and new technologies in bioenergy production as Malik, (2008, p. 660) states:

> *'With debt finance, risk of multiple contracts is unlikely be acceptable to lenders unless the technology is mature and proven, the project management has a sound track record and a UK cost record is established'.*

The findings from the contemporary literature conclude that the contract is central to all phases of the biomass-to-bioenergy supply chain and that its constructs include mitigation of risk in terms of financial and technological decisions. Environmental and social constraints on the other hand, feature as part of the contractual agreement but they do not have the same level of importance as financial and technical components.

From this point on, it is possible to develop a research model from the constructs identified in the literature. Figure 2.5.2: Stakeholder and process characteristics in the bioenergy supply chain show the relationship between attributes that link into a contractual agreement.

Figure 2.5.2: Stakeholder and Process Characteristics in the Bioenergy Supply Chain.



This model devised by the researcher and is simplified for clarity. It is based upon findings from the literature in part I. However, the model requires validation through theoretical and primary research. It is assumed that bioenergy supply chain integration is determined by the contract. Hence, the contract is featured as pivotal to supply chain integration between stakeholder and process characteristics in figure 2.5.2. Functional areas sit within process integration constructs, but stakeholder constructs appear more intangible because they are determined by policy and level of intervention at the planning and feasibility phase. The extent to which stakeholders influence bioenergy businesses are evidenced in the second and third research questions. However, part II of the literature review explores theoretical constructs and approaches in bioenergy research in order to validate the rigour of the research aim and questions and establish parameters from an academic perspective.

Chapter Two: Review of the Literature: Theoretical Constructs and Research Approaches in Supply Chain Integration in Bioenergy, Part II.

2.6: Overview of Part II: Theory and Bioenergy Research Approaches in the Literature.

The second part of the literature review considers theoretical perspectives from the supply chain literature and operations research literature. It is evident that theoretical approaches in supply chain integration have evolved from the operations management paradigm. Like part one of the literature review, investigative approaches and analysis is based wholly on secondary sources of data. In part one data resources were sourced from both academic and industry-based literature. For part II, resources came from academic texts from searches on Emerald, Wiley, and Science Direct for example. The output of part II is first to confirm evidence of supply chain integration constructs proposed in chapter one and identified in part one of the literature review, and second to justify why this study applied qualitative research methods as opposed to deductive and quantitative research approaches. Findings arising from the latter part of this chapter will clarify the framework for chapter three, methods used in the study and contribute towards understanding the scope of emergent supply chains in an emergent sector.

2.7: Theoretical Constructs in Bioenergy Supply Chain Integration.

Within operations management research, environmental issues are still in their infancy (Angell and Klassen, 1999). This provides considerable opportunities for developing research and appropriate methodological approaches in this paradigm. The World Commission on Environmental Development (1987) called for integration of environmental practices in plant location and manufacturing processes. Gupta and Sharma (1996) identify the relevance of environmental management in key decision-making and strategic management processes. The wider issues in operations management relate to the ‘green’ supply chain literature that includes relationship management with suppliers and transport providers in order to decrease the carbon footprint and lower operating costs (Sarkis, 1995; Shrivastava, 1995 and Post, 1991). Performance measurement of environmental practices (Ettlie, 1993 and Klassen,

1993) have led to disparate and disjointed research because to date there is no framework and clear constructs that both shape and define supply chain integration in the environmental and ecological literature (Angell and Klassen, 1999). Historically, environmental management was confined to legal and corporate functions governing environmental legislation. Research focused on efficiency improvements and cost reduction whilst adding environmental constraints to core manufacturing outputs. Such a restricted operational strategy ignored both process and stakeholder phenomena across the supply chain from an environmental perspective (Wheelwright and Hayes (1985). Application of phenomenological approaches not only helps make sense of the present situation but also drives future research (Morgan and Kreuger, 1997; Calder, 1997). Building and reinforcing rules around a topic that relies on different theoretical constructs can be explored from a logical and systematic perspective. There are two camps in supply chain management; some view this area as a process, which borrows theories from other paradigms (Stock, 1997), whereas other authors, give credence to supply chain management as a discipline in its own right (Cooper et al., 1997; Chen et al., 2004; Carter and Rogers, 2008). Supply chain integration like theoretical constructs from the supply chain management literature is likewise continually evolving. Integration means that the supply chain should not be considered as either parts or entities but as an integral whole (Flynn et al. 2010). Supply chain integration definitions place emphasis on collaboration between firms as Flynn et al, (2010, p. 59) state:

'…the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra and inter-organization processes'.

This view supports mutual trust between firms in contrast with arms-length agreements and also adds another benefit of lessening risk to supply raw materials. The aim of managing the supply chain is to secure competitive advantage and achieve higher levels of business performance. Integration in the end-to-end supply chain ensures that all linkages across supply chain operations are optimised. Supply chain integration can be broken down into a range of different inter-related attributes of cost, quality, flexibility and time performance (Kim, 2009). However, these attributes are considered internal characteristics of supply chain integration. External characteristics relate to integration between suppliers and customers (Fuente et al., 2008; Nurmilaakso, 2008; Swink et al., 2007; Cagliano, 2006; Narasimhan, 1997). Supply chain integration according to Kim (2009), *'plays a role as strategic levers that supply chain management practices can be used to enhance the chances of firm success'* (Kim, 2009, p. 329). This involves two roles, firstly to ensure effective management of the supply chain in order to promote optimal performance and secondly, to embed infrastructure for effective business practice and operations. There are theoretical arguments on the role of SCI in relation to business performance (Vachon and Klassen, 2008). This concerns levels of integration amongst suppliers, cross-functional integration within the company and between suppliers and their customers. Diversification and agility in the supply chain are important to sustaining competitive performance (Hitt et al., 1997) and integration of cross-functional processes is a pre-requisite for consolidating supplier and customer relationships. The ability to meet market change is, '*paramount for many companies'* (Kim, 2009, p. 341). However, SCI is dependent on size of firm as this has a direct impact on its capacity to instigate improvement and change. Where a firm does not have the size and capacity, integration is challenging due to loss of bargaining power in smaller firms. This impacts on the firm's ability to negotiate longer term and more secure agreements. Important in SCI are those factors that concern relationships between firms based on partnerships and long-term agreements (Kim, 2009). From this perspective there is evidence to support SCI having a positive effect on operational performance (Wong et al., 2011). Some studies suggest that drivers for SCI are borne out of market volatility, but Wong et al. (2011) refer to this as environmental uncertainty, particularly in the case of interventions emanating from the European Union (EU). Further studies show that market forces moderate SCI (O'Leary-Kelly and Flores, 2002). Lack of theoretical evidence, which provides a framework for measuring risk instead, divides SCI between internal integration that are largely process driven and external drivers that are stakeholder driven. It is doubtful that by adding internal and external factors together will enable better supply chain integration across the whole supply chain. According to Wong et al. (2011) each division of integration helps improve supply chain performance. Dröge et al., (2004) state that internal integration determines product quality and cost. Supply chains can be either strengthened or weakened by lack of internal integration, which places emphasis on process integration. Operational factors dominate the literature in SCI as Pagell (2004) adds that poor internal integration results in waste and poor utilisation of resources against effective internal integration that encourages cohesion and effective co-ordination. Logistics has a key role in this respect because it has responsibility for delivery of product from suppliers to their customers; hence management of such relationships between third party providers and the customer is a crucial element to SCI. Relationship management does have its challenges as Wong et al. (2011, p. 606) state:

> *'Uncertainty can be defined as the inability to assign probabilities to future events, or difficulties to accurately predict the outcomes of decisions'.*

In the context of the supply chain this determines multiple channels of goods and information flows across the supply chain. Therefore there is a positive benefit from better supplier and customer integration leading to improvements in product development, marketing and procurement. The purpose of SCM is to enhance competitive performance by,

> '*…closely integrating internal functions within a company and directly linking them with external operations of suppliers, customers and other channel members'* (Kim, 2009, p. 328).

Supply chain integration challenges business organisations because to have true SCI, there must be actual linkages for all products and information. Expectations for improved costs, quality, and flexibility and time performance assume a cross-functional role within the firm, its external suppliers and customers. Therefore, it is reasonable to assume that effective SCI is where firms within a supply chain can demonstrate good practice. Here SCI provides the driver by which good practice can be cascaded into participating firms. Kim's (2009) paper argues that effective SCI encourages formal but long-term relationships between firms rather than arms-length and casual agreements. From this, it can be assumed that SCI acts as a lever for appropriate organisational infrastructure and, *'improvement of competitive capabilities'* (Kim 2009, p. 329). There are those that ascertain SCI does not have any theoretical foundation but many authors encourage a theoretical and systematic approach to understanding the concept of SCI. Competitivity in the supply chain considers the Resource Based View, (RBV) in Barney et al. (2001) which suggests that RBV helps develop organisational capabilities that in turn, improves performance. This theory is based on two concepts; the first being resources and capabilities of the firm and second, both tangible and intangible assets linked to that firm. However, the RBV approach does not link into the supply chain, rather it is internalised from the single organisation perspective. Kim (2009) links RBV with supply chain strategies that support business strategies within the firm. Improvement processes such as JIT, lean operations help develop a culture and infrastructure for improvement. The relationship between SCI and supply chain practice within RBV is complex due to the number of process and stakeholder functions within the firm. World-class manufacturing strategies are key drivers for better integration and performance as Kim, (2009, p. 330) states:

> *'By developing a high level of supply chain integration, manufacturers are able to identify and eliminate non-value adding activities and subsequently strengthen product quality and delivery reliability capabilities, thereby providing a foundation for sales growth'.*

1. Resource Based View allows firms to attain competitive advantage in two ways:
2. Visibility of information and operational knowledge permits SCI partners to respond to new demands and,
3. Firms where supply chains are integrated have potential to reduce net costs and therefore reduce total costs for their customers.

The interlocking effect of SCI places firms within the same supply chain in a position of leverage to compete, particularly in a volatile market place. Simchi-Levi et al. (2003) support the view that SCI asserts strength in strategic alliances, which leads to intensification of key practical resources such as adding value to products, improving market access to information networks, strengthening logistical operations for technological and financial gain. Supply chain management is under change and scrutiny because effective integration demonstrates capacity to produce and deliver products on time. Increasingly, firms have to develop ways of adding value to their product without necessarily increasing cost. This results in higher complexity and diversity of management decisions (Halldorsson et al., 2007). Collaboration and integration in the supply chain is imperative if firms are to be competitive. Three further theoretical approaches applied to SCI in addition to RBV according to Halldorsson et al., (2007) are:

> **Principal Agency Theory**, in this respect refers to factors arising out of economic activities between agents and the principal agents. Greater bargaining power is afforded to the principal agent:
>
> *'The contract between principal and agent governs the relationship between the two parties, and the aim of the theory is to design a contract that can mitigate potential agency problems'* (Halldorsson et al., 2007, p. 287).
>
> **Transaction Cost Analysis** offers a normative approach to determine the firm's boundaries and can be used to present efficiency as a motive for entering inter-organisational relationships and,
>
> **Network View**, is where a firm's performance is determined by how a particular firm performs with its partner organisations:
>
> *'…the firm's continuous interaction with other players becomes an important factor in the development of new resources'* (Halldorsson et al., 2007, p. 287),

Such theories alone do not explain SCM, SCI and logistics but nevertheless, they can be applied, as Fisher (1997) suggests theories are aligned to SCM according to the best 'fit'. The supply chain comprises flows of goods and information between organisations from raw material suppliers to end-users. The concept of a supply chain in this respect has been acknowledged for 35 years yet according to authors there are no socio-economic theoretical constructs that fully underpin and explain the rules of SCM. Mentzer et al. (2004) suggest a unified theory of logistics, which merges operations between organisations in the supply chain for product and information flows. However, the majority of viewpoints focus on marketing and purchasing, as Halldorsson et al., 2007 support the view that the supply chain integrates business processes internally to the business and externally across all organisations in the supply chain. Cooper and Ellram (1990, p. 2) define SCM as an, '*integrative philosophy to manage the total flow of a distribution channel from supplier to the* *ultimate user'*. Harland (1996, p. 64) replaces the term 'management' with *'network of inter-connected businesses',* and Christopher (1998) supports Harland's view of supply networks that includes numerous suppliers and customers but divides the supply chain into vertically integrated networks of supplier-to-supplier and horizontal integration of supplier to customer. Thus SCM and its physical structure are determined by relationships and interactions between decision makers in the firm (Halldorsson et al., 2007). This separates functional areas of SCI such as logistics, marketing, distribution and purchasing to non-functional areas such as development of collaboration and relationship management between organisations. SCM includes relational contracting theory and resource dependency theory. This implies that the supply chain is determined by a series of transactions, which comprises two dimensions. The first relates to the relationship between organisations, namely between suppliers and the second relates to relationships between suppliers and customers, but more importantly, the latter refers to factors that enable such supplier-customer agreements to develop. Table 2.7.1: Theoretical Framework to Bioenergy SCI, p. 59, highlights characteristics of theoretical approaches that apply to new product development. If bioenergy can be considered in this context, such theories could help explain the constructs of SCI in bioenergy.

Table 2.7.1: Theoretical Framework Applied to Bioenergy SCI: An Emergent Supply Chain.

Characteristic	Principal Agent Theory	Transactions Cost Analysis	Resource Based View	Network Theory
Behavioural Features	Potential conflict between supplier and buyer.	Trust resulting from controls in place	Trust between key suppliers, co-operative	Trust & information sharing, win-win situation.
Functional attributes	Degree of supplier involvement in bioenergy production	Number of tasks outsourced to suppliers	Mgt. of resources resulting from bioenergy processes	Number of other competitors for raw material/end product
Time Dimension	Contracts only drawn up when specifications are set	Short-term contracts for standard components but long-term contracts awarded to bioenergy dev.	New bioenergy business developed from core business activity	Short-term contracts for third parties, long-term contracts for key partners
Output	Formal contracts	Number of firms involved in business process	Development of new competencies	Relationship between customers and suppliers
Relationship Dimensions	Adversarial relationship	Arms-length for standard items but development of strategic partnerships for bioenergy development	Develop new competencies	Mutual information sharing between partners
Key Drivers	Alignment with contracts	Investment on specific assets	Development of new competencies	Personal contracts an development of trust between key parties

Source: Adapted from Halldorsson et al., 2007, p. 290.

Principal Agency Theory and Transaction Cost Analysis are underpinned by neo-classical economic theory. Both theories reinforce the make or buy decision within firms. This is limited in relation to bioenergy because in general they do not include human intervention and relational attributes that characterise the supply chain. With particular reference to bioenergy, such neo-classical economic theories do not include attributes that contribute to stakeholder relationships. Resource Based Theory and Network Theory are classified as descriptive theories and are applied to examine the processes and systems within companies. For example, how do inter-trading firms develop trust amongst each other? As Halldorsson et al., 2007, p. 291 state: '*Trust is the most important precondition in supply chain management',* and *'…we find that we cannot rely on one unified theory to explain inter-firm to explain inter-firm governance structure and management decisions in a supply chain, but have to apply complementary theories'* (Halldorsson et al., 2007, p.293).

Whilst supply chain management is well defined in the literature, the concept shares one major issue with how supply chain integration is also defined (Lambert and Cooper, 2000). End-to-end supply chains from raw material supplier to customer do not actually exist, but academics have sought to explain these phenomena through the predominance of the focal firm contracting with first tier customers and/or suppliers. The remaining tiers are the responsibility of their suppliers and not the focal firm, thus complete supply chain visibility cannot be assumed. Distribution of products is largely outsourced and is the responsibility of logistics providers, but these functions are not wholly integrated but rather seen as ad hoc arrangements in the conventional supply chain and logistics literature as Lambert and Cooper (2000, p. 71) state:

> *'Successful supply chain management requires a change from managing individual functions to integrating activities into key supply chain processes'.*

Supply chain processes traditionally comprise upstream and downstream activities, which can prove challenging in relation to inter-connected activities. If a supply chain is to be truly integrated there is a requirement for continuous information flows to create efficient product flow. According to the Global Supply Chain Forum the first phase towards SCI is management of relationships with customers (Customer Relationship Management, CRM), (cited in Lambert et al., 2000). CRM integrates with real-time information flow that in turn, relates to inventory management. It is demand driven, likewise energy is demand driven (Asif and Muneer, 2007). Conventional supply chains seek to pull rather than push from the customer and need to adjust their resources accordingly, therefore the procurement process is central to reducing risk of uncertainty between parties. Suppliers are categorised as either having long, or short-term relationships. Long-term contracts are those that attain strategic alliances and are generally perceived as a win-win situation. Short-term contracts on the other hand, are those considered to be bid-and-buy relationships at arms-length (Lambert and Cooper, 2000). Higher levels of business performance centre on a firm's ability to supply customers with what they require (Wu et al., 2004; Handfield and Nichols, 1999). This comprises two factors; firstly, the ability to produce what the customer wants and, secondly, the ability to deliver on time to the customer. Thus, SCI involves logistics' links between supplier and customer. Synergies between the main process in order fulfilment helps lower costs of inventory and operating costs and therefore reduces risk as Wu et al. (2004, p. 322) state:

'...greater degree of supply chain integration is strongly associated with higher levels of performance'.

Three main elements underpin SCI and associated levels of performance, which are supply chain structure, management components and the business process. Simchi-Levi et al. (2000) consider such definitions with SCM and define it as a set of approaches but key to is integration of all functions and processes, which integrate all activities with minimum of costs. Such process-orientated attributes ignore the importance of the role that relationships play in the supply chain that adds value (Wisner and Jan, 2000). Integration is seen as central to effective supply chain management, which stem from developing key relationships between the firm, its suppliers and customers (Power, 2005). Supply chain visibility depends on flow of information between firms sharing systems and, in addition this places emphasis on linkages with third party logistics providers. This adds complexity to the extended enterprise as Power (2005, p. 252) states:

'...a network of processes, relationships and technologies creating inter-dependence and shared destiny'.

Such findings are in concurrence with Handfield and Nichols (1999) who add that information integration results from increased levels of global competition creating more customer and demand-driven markets, which in turn, creates the need for new inter-organisational relationships. Information flows are dynamic due to requirement for Information Technology (IT) but their implementation is a two-fold condition of determining how companies inter-link and co-operate on an operational level but also on a behavioural level as Senge (1990, p. 71) finds:

'...situations where cause and effect are subtle, and effects over time of interventions are not obvious. Conventional forecasting, planning and analysis methods are not equipped to deal with dynamic complexity'.

Within manufacturing systems if information flows do not run in time with product flows the resultant Bullwhip or Forrester Effect result from dynamic changes that cannot be controlled (Chen et al., 2000). It is questionable however, whether energy systems have an issue with this problem, but the role of IT is central to ensuring the infrastructure for SCI (Bouffard and Kirschen, 2008). The role of the Internet and worldwide web help ease linkages between firms and may eliminate time delays in any supply chain network (Handfield and Nichols, 1999). Supply chain integration is not a new concept according to Bowersox and Calantone (1998) but this view is biased towards information sharing as Christopher (2000, p. 38) confirms:

'The use of information technology to share data between buyers and suppliers is in effect, creating a virtual supply chain. Virtual supply chains are information-based rather than inventory based'.

Information technologies may create a virtual supply chain but they require a robust physical infrastructure to ensure that goods are delivered to the right customers. Logistics is central to managing inventory and production flows. Location decisions are therefore crucial as the A. T. Kearney Report (2000) warns:

'Companies have failed to pay sufficient attention to areas such as transport and logistics, distribution and purchasing. The most serious problems companies face are the continuing internal functional focus, a failure to align their IT systems and organisations with supply chain needs, and the traditional nature of their relations with their external suppliers and customers'.

Both Handfield and Nichols (1999) and Tait (1998) support this view in that inter-firm alliances are the foundation for effective supply chain management and are afforded higher levels of performance and financial gain. Conventional SCI centres on the contract, which traditionally conforms arms-length agreements, not determined by local conditions that serve to strengthen relationships between suppliers and their customers (Dyer et al., 1998). Silo relationships compromise performance of SCI (Lambert and Cooper, 2000). Integration in the supply chain is distinct from functional and process linkages between firms and include both member and non-member inter-firm linkages. This implies that relationships between organisations are managed at strategic level with the focal company in control, co-ordinating information and product flows. This requires trust between parties according to Ballou et al. (2000, p. 16) who state:

> *'...a general expectancy held by a channel member that the word of the other can be relied upon. That is, one party has confidence in an exchange partner's reliability and integrity'.*

Trust is beneficial to both parties because it encourages co-operation and commitment. In SCI concentration of control occurs amongst a few players rather than sub-contractors and partners below tier one in the supply chain. This means that not all players receive the full benefits of being part of a network or alliance. There are winners and losers according to Fein and Jap (1999). Strategic planning in the supply chain should serve its customers profitably, which adds robustness to the relationship rather than wholly functional attributes. Reliance on third parties to perform distribution operations adds further complexity in supply chain relationships (Lummus et al., 1998). However, Power (2005) recommends development of competencies in management of SCI in order to integrate such third parties like logistics providers. Successful implementation of SCI is given in Akkermanns et al. (1999, p. 566) who state:

> *'...the operations management literature has shown very little empirical evidence of successful strategic moves towards supply chain management (and later)...we do not yet have casual relationships between the various factors driving effective supply chain management and inter-relations with performance improvements in areas like inventory management, supply chain costs and customer satisfaction'.*

End to end SCI is challenging due to the differences between upstream and downstream characteristics of the supply chain. Wu et al. (2004) address this in terms of linkages that are either vertically integrated, from business to business, or horizontally integrated, from supplier to customer. It is assumed that conventional energy supply chains are vertically integrated but this is not the case in bioenergy. Due to their regional and local structure, it can be assumed that such bioenergy businesses are horizontally integrated (Walsh and Todeva, 2005). However, it is important that bioenergy supply chain integration is stable as Wu et al. (2004) find that stability in the supply chain promotes long-term relationships and commitment amongst member firms and thereby create traded inter-dependencies (Goodman and Dion, 2001; Skarmeas and Katsikeas, 2001). One of the central characteristics is visibility and this is developed from partnership arrangements (Wu et al., 2004). This is distinct from functional attributes in SCI because partnerships depend on behavioural aspects of SCM such as communications and long-term commitment (Anderson and Narus, 1990). The ability of a company to get others within the supply chain to perform actions that they would not otherwise undertake is part of forming relationships across the supply chain (El-Ansary and Stern, 1972). Supply chain integration requires firms to trust one another and share sensitive information whilst at the same time provide opportunities for gaining competitive advantage (Wu et al., 2004: Moorman et al., 1993). Elements of continuity, communications, power and trust create normative commitment amongst supply chain partners as Wu et al., 2004, p. 331 conclude:

'It is believed that the partners will make more commitment if the manufacturers make visible transaction-specific investments. Thus consistent with norms of reciprocity and reciprocal action theory'.

Supply chain integration (SCI) is synonymous with supply chain management (SCM) (Näsland and Hulthen, 2012; Stock and Boyer, 2010; Pagell, 2004) and improved levels of business performance. This is perceived on two levels, the first being strategic and the second level being operational (Fröhlich and Westbrook, 2001; Mentzer et al., 2000). Globalization of supply chains has increased the need for short product life cycles and mass customization in relation to conventional manufacturing (Näsland and Hulthen, 2012). On another level, SCI permits collaboration amongst supply chain partners that in turn, leads to reduction of costs, stock-outs and lead time, (Giménez and Ventura, 2005). Integration permits better product information, and product flows that determines service effectiveness and cost efficiency (Richey et al., 2010). Despite such claims there is very little evidence in the literature beyond dyadic levels (Fawcett and Magnan, 2002), and scant evidence of upstream, between suppliers and downstream from supplier to customer of integration in practice

(Lambert et al., 1998). There are few studies that investigate co-ordination in the supply chain, for example Mejza and Wisner (2001). There is a lack of a clear definition and understanding of SCM (Mentzer et al., 2001; Skjoett and Larsen, 1999), results in a confusing terminology. Empirical evidence determines what factors to integrate because they have been deemed to be good practice, but due to limited data it is difficult to construct optimal SCI in bioenergy. Cooper et al. (1997) discuss visibility in the supply chain as end-to-end integration and Mentzer et al. (2001) attempt to construct a framework for SCI based on long-term business functions across the supply chain, which add value. Romano (2003, p. 122) clarifies this:

'*The concept of integration as a mechanism to support business processes across a supply network is closely related with the effort to overcome intra and inter-organizational boundaries'.*

The literature confirms this on a number of perspectives. Vickery et al. (2003) consider supplier integration in the same way as Lambert et al., (1998) as both vertical and horizontal integration. On the other hand Kim (2009) attempts to identify different organizational entities between suppliers and customers. However, it is Flynn et al. (2010, p. 58) who views the role of process integration on intangible benefits between suppliers and their customers:

'The degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra and inter-organizational processes, in order to achieve effective and efficient flows of products and services, information, money and decision to provide maximum value to the customer'.

This implies collaboration is one of the key factors in supply chain performance and integration (Holweg et al., 2008). The traditional concept of SCI considers transparency across the supply chain, which helps avoid functional silos according to Näsland and Hulthen, (2012), who explain this phenomena as forward and backward integration. Forward integration refers to integration between suppliers and their customers, whilst backward integration involves transactions amongst suppliers (Trent and Monczka, 1998). It is questionable whether full transparency exists amongst firms as Fawcett and Magnan (2002) confirm that backward integration only

goes between first tier suppliers. In addition, there is further evidence in the literature that integration is divided into four key stages as Stevens (1989) suggests:
Stage One: Functional dependence for compatible business processes and operations amongst organizations within the same supply chain,

Stage Two: Functional integration of inward goods flow,

Stage Three: Control systems, namely information flows and application of Information Technology systems and,

Stage Four: Distribution, the transportation of goods.

Stevens (1998) focuses only on functional and not relationships amongst supply chain partners. Further evidence in Fabbe-Costes and Jahre (2007) suggests that SCI means integration of operations but adds integration of actors, (structures and organizations) to the characteristics of supply chain integration without identifying constructs of intangible factors. Such attributes are more challenging to quantify because they depend on factors that are based on tacit knowledge and experience (Lambert et al. 1998). Physical process flows and value streams in the supply chain demonstrate the important role of partnership, but the constructs for information sharing and application of information systems remains limited both in the literature and application (Rodriques et al. 2004; Kemppainen and Vepsäläinen, 2003; Narasimhan and Kim, 2001).

Supply chain relationships vary from short-term, arms-length contractual arrangements to longer term, dyadic relationships (Lambert et al. 1998). The further away a firm is positioned in the supply chain from the focal firm and first tier, the shorter term the contract. Firms that move towards partnering arrangements are those that are closer to the focal company (Masella and Rangone, 2000). Collaboration is often seen as another term for integration (Bowersox, 1990) but this implies functional attributes rather than both tangible and intangible factors as Näsland and Hulthen (2012, p. 492) confirm:

'Strategic integration activities are long-term, collaborative, and encompass relationship building, just-in-time development and information sharing regarding costs and capability with customers and suppliers as companies consider their partners' processes as extensions of their own'.

Again this infers bias towards improving functional areas of the supply chain. Näsland and Hulthen (2012) do not find any empirical evidence from the literature of actual end-to-end supply chain integration, but instead, they find collaboration taking place between tier 1 and tier 2 suppliers, (triadic relationships). The most common form of SCI is via IT systems and performance measures. Barratt (2004) emphasises the importance of standards in collaborative planning. However, the literature does not provide any guidelines on what the processes ought to be integrated (Kemppainen and Vespäläinen, 2007). The means how to integrate a supply chain is dependent on information sharing but mainly through enterprise resource planning systems, (ERP) (Fawcett and Magnan, 2002). The literature indicates that levels of integration are limited beyond first tier level as Näsland and Hulthen (2012, p. 493) state:

' ...a truly integrated supply chain practice is rare to find'.

Their definition of SCI places up and downstream co-ordination of process and information flows between the focal company, key suppliers and key customers. Triadic networks add relationship and stakeholder integration within the supply chain and takes SCI beyond operations in dyadic and network alliances. However, as Das et al. (2006) find the notion of integration is challenged by complex relationships between vertical and horizontal layers of the supply chain. The literature supports the view that the extent of SCI depends on what perspective is considered. For example, SCI is perceived from information integration, financial integration, marketing, and performance integration perspectives (Gimenez et al., 2012). However, the literature has not considered both process and stakeholder integration in supply chain integration, but rather dyadic relationships and not triadic (Gimenez et al., 2012). Supply chain integration is a multi-dimensional concept, thus its definition is not well established as Gimenez et al. (2012, p. 585) state:

'...relational initiatives such as cross-functional involvement and joint problem solving that might lead to trust and satisfaction'.

The emphasis on *'might lead to'*, confirms that communications throughout all tiers of the supply chain is not widely practiced (Flynn et al., 2010; Bargchi et al., 2005). Supply chain integration and performance according to Bargchi et al. (2005) appears in most of the supply chain literature and is synonymous with level of communication between firms (Chen et al., 2004), that in turn, affects quality of relationships and purchasing decisions (Kaufman and Carter, 2006). Complexity according to Gimenez et al. (2012, pp. 588-589) is:

> *'…the process in which buyer-supplier relationship and define it as the complexity of the process in which buyers' orders are converted into the suppliers' manufacturing orders, resulting in the delivery of goods according to the buyers' expectations…links in the supply chain characterised by high complexity are more integrated than the ones characterised by low complexity'.*

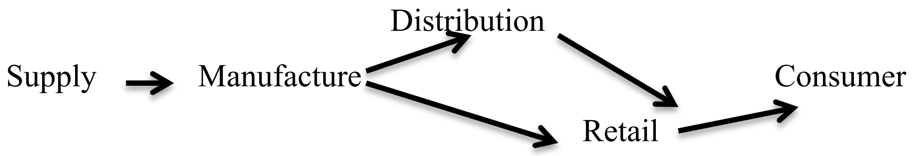
Dependency on co-operation and collaboration is also associated with supply chain complexity but is aligned with dyadic characteristics. Yet trust is a critical factor for SCI, which implies more than operational attributes (Johnson et al., 2004). There is also another dimension to consider in such complex supply chain relationships and this relates to environmental compliance, which is discussed in the next section. Supply chain integration constructs are not simply a means of configuring a supply chain so that it operates on both product and information flows but is cognizant of factors pertaining to trust that fosters long-term supply chain relationships. Furthermore, introduction of environmental performance attributes should encourage long-term rather than short-term supply chain relations.

Environmental and sustainable processes within production systems across the supply chain are increasing in both literature and practice. Beamon (1999, p. 332) states:

> *'…there must be a fundamental shift in the way production systems operate'.*

This is indicative of earlier legislation during the 1970s for waste disposal (end of product life) and pollution control, which focuses on the product life cycle. A traditional supply chain starts upstream with the supplier and ends downstream with the consumer shown in figure 2.7.1

Figure 2.7.1: Traditional Supply Chain Structure



Source: Beamon, 1999, p. 335.

The figure shows a highly simplified representation of how a conventional supply chain delivers its goods from raw material supplier to final customers. However, it is a comprised view because such configurations do not account for obsolete goods returning back through the supply chain when they are either no longer required, or have reached the end of their product life. This area of literature has grown since the 1990s due to the interest in closed-loop systems advocated by Dekker et al., (2004). However, it is ironic that to date there are no environmental measures with which to measure the performance of bioenergy and this compounds the need for SCI as Beamon (1996, p. 336) states:

> *'No longer is it acceptable or cost effective to consider only the local and immediate effects of products and processes; it is now imperative to analyse the entire life-cycle effects of all products and processes'*

The terms 'sustainability' and 'green supply chain management' (GSCM) are widely quoted in the literature but not well defined. Usually the terms refer to environmental issues within manufacturing and logistics processes, (Ahi and Searcy, 2013). Sustainability includes the triple bottom line of environmental, economic and social factors in the supply chain but there is an on-going debate in the literature that questions what 'sustainability' involves? More importantly, sustainability has to include integration of economic, social and environmental factors. Furthermore, green supply chain management (GSCM) neither includes SCI, nor does GSCM refer to bioenergy production within a supply chain context (Ahi and Searcy, 2013). Bioenergy is an emerging sector, borne out of the recycling and re-use of waste (biomass) and the need to produce energy from renewable sources. However, the question of whether such a nascent sector can function and perform independently of supplier agreements is one that requires a holistic approach.

2.8: A Review of Research Approaches in Bioenergy.

This section provides a critical review of research methods applied to a range of studies in bioenergy from both stakeholder and process integration perspectives. Table 2.8.1: Summary of Research Methods in Bioenergy, (pp. 71-80) identifies characteristics of a range of methods deployed and their application to particular areas of bioenergy and supply chain theories. The table is divided into six sections:

1. Economic Methods and Tools, (pp. 71-72),
2. Spatial Geographical Tools - these tools are not necessarily methods but are frequently applied to socio-economic research (p. 73),
3. Multi-criterion Decision Tools, (pp. 74-75),
4. Linear Programming, includes mixed integer programming methods (pp. 76-77),
5. Non-Linear Programming, (p. 78) and,
6. Genetic Algorithms, (pp. 79-80).

There is a distinction in bioenergy research between application of primary and secondary data sources arising from the methods in the literature (Levidow et al., 2014). There were a considerable number of examples that depended upon secondary data sources to consider strategic policy decisions at stakeholder level. Likewise it was found at process integration level there was a body of literature, which again, uses secondary sources of data to formulate and propose mathematical models of national government polices across countries (see for example, Sung, 2015). Other examples from the literature focus on the use of primary data gathering methods but only focus on the ‘bigger’ picture as opposed to specific areas of bioenergy supply chain integration (An et al., 2011; Appels et al., 2011; Konur, 2011). Supply chain management is not an entity in its own right and this is why it is a challenge to underpin SCM and SCI as a discrete paradigm with its own set of rules and theoretical foundation. A further observation in relation to the methods literature in bioenergy is that it tends to focus on upstream operations within the supply chain (for example see Gold and Seuring, 2011; Min and Zhou, 2002, who focus on critical success factors of supply chain processes). Similarly, this study follows the same course of investigation because without establishing the reasons why one bioenergy business is more viable than another, it would be more difficult to ascertain why renewable energy can be effectively distributed. Furthermore, downstream distribution is an area of research that would be best served as a topic in its own right.

Table 2.8.1: Summary of Research Methods in Bioenergy

Research method and main features	**Authors**	**Process integration**	**Stakeholder integration**	**Applications in bioenergy research**
Section One: Economic Methods and Tools				
LCA Inventory analysis to assess & evaluate environmental impact of supply chain factors in bioenergy	Huttunen et al. (2014); Rehl & Müller (2011); Righi et al. (2013); Macombe et al. (2013); Muench & Guenthen (2013).	●	●	Utilization of primary and secondary data sources Quantitative & qualitative data Inform decisions at stakeholder and process level.
LCI Deployed in conjunction with LCA Specific environmental impact assessment tool, can be used in conjunction with ISO 14040 assessments of production operations	Forsberg (2000); ISO 14040, (1993).	●		Primary data sets to measure the environmental performance of either a process or product.
FAPRI Partial equilibrium model used to predict baseline prices in U.S. and world agricultural commodity market	Okwo & Thomas (2014)		●	Large secondary data sources, economic policy model. This applies to economic feasibility in siting a renewable energy facility.
FASOM Similar to FABRI but applies to land-use and allocation and simulates land allocation with socio-economic data	Beach & McCarl (2010)		●	Large secondary data sources that integrates land allocation and location with socio-

				economic data to assess the economic feasibility of a decision to produce renewable crops, e.g. switchgrass. Also can be used in conjunction with food vs. fuel debate.
SCND location decision integrated with supply chain processes	Eskandapour et al. (2015).		●	Economic and social data collection from secondary sources excludes operational data from logistics and production operations.
EIO Economic input-output analysis model and can be used in conjunction with LCA.	Yazan et al. (2011); You et al. (2011, 2012).	●	●	Requires large data sets to calculate and analysis impact of input vs. output of processes, e.g. socio-economic impact of biomass-to-bioenergy production.

Glossary of terms in table section

LCA: Life Cycle Assessment
LCI: Life Cycle Inventory
FAPRI: Food and Agricultural Policy Research Institute Model
FASOM: Forest and Agricultural Sector Optimization Model
SCND: Supply Chain Network Decision
EIO: Economic Input-Output Model

Table 2.8.1: Summary of Research Methods in Bioenergy, (continued).

Research method and main features	Authors	Process integration	Stakeholder integration	Applications in bioenergy research
Section Two: Spatial Tools/Programs				
GIS Geographical database integrated with socio-economic data	Martinkus et al. (2014); Beccali et al. (2009); Lovett et al. (2009); Panichelli & Gnansounou (2008); Yue et al. (2014); Zhang et al. (2011)	●	●	Spatial analysis tool utilizing both secondary and primary data sources. Selection of location, feedstock decisions.

Glossary of terms in table section
GIS: Geographical Information Systems

Table 2.8.1: Summary of Research Methods in Bioenergy, (continued).

Research method and main features	Authors	Process integration	Stakeholder integration	Applications in bioenergy research
Section Three: Multi-Criteria Decision Making Tools				
MODA Belongs in same category as MCDA. Distinction between MADA & MODA is attributes in MADA are weighted utilizing fuzzy approaches, whereas in MODA, objective criteria are adapted to the individual user.	Visser (2013); Malzcewski (2006); Giove et al., (2009).	●	●	Decision making tool with fuzzy approach that has potential for location, technology and biomass selection.
AHP Multi-criteria decision making method, namely a fuzzy logic model to evaluate a decision uni-directional framework between a main attribute and sub-attributes.	Saaty, (2004); Suganthi (2015); Subramanian & Ramanathan (2012); Kurka (2013).	●	●	Primary and secondary data sources to measure (pair-wise comparison) attributes of a decision of a renewable energy from a range of perspectives, e.g. location, feedstock, supplier selection and logistics operations.
ANP Similar to AHP, ANP is a multi-criteria decision making method used to identify and measure relationships between factors, (attributes).	Saaty (2004); Yücenur et al. (2011); Scott et al. (2014); Atmaca & Basar, (2012); Iskin et al., (2012).	●	●	Primary and secondary data sources to model a matrix that measures the relationships between attributes, e.g. biomass selection, contract (L or S/T) and location decision.
MADA Form of multi-decision tool but attributes are attained to find best or preferential alternative in descending order.	De Meyer et al., (2014); Malczewski, (1999).		●	Secondary data to develop decision factors in conjunction with GIS so that there are

Used with GIS applications				spatial/location elements linked with socio-economic factors that determine stakeholder/policy decisions in bioenergy.

Glossary of terms in table section
AHP: Analytic Hierarchical Process
ANP: Analytic Network Process
MODA: Multi-objective Decision Analysis
MADA: Multi-Attribute Decision Analysis

Table 2.8.1: Summary of Research Methods in Bioenergy, (continued).

Research method and main features	Authors	Process integration	Stakeholder integration	Applications in bioenergy research
Section Four: Linear Programming				
LP Mathematical models that have linear objectives and constraints. Dijkstra algorithm utilizes LP to ascertain shortest path between two sites.	De Meyer et al. (2014); Cundiff et al., (1997).		●	Secondary data set to resolve logistical problems, namely shortest path problem. Can apply to decision making and fuzzy logic approaches for biomass-to-bioenergy locations.
MoMILP Stochastic model that is part of same group, which involves mixed integer linear programming methods that has been applied to consider costs in transportation of biomass to conversion site with number of constraints such as cost and time.	Zamboni et al. (2009,); Mele et al. (2009)	●	●	Deterministic method to optimize location decision. Uses secondary and primary data to consider risk factors in bioenergy production, e.g. feedstock supply, transport costs etc.
MISP Mathematical model with two elements *mixed integer* relates to discrete optimization and *stochastic programme* relates to continuous optimization**.**	Senn, (2005); De Meyer et al., (2014).	●	●	Secondary data to consider costs and size of facility and feedstock allocation, which allows forecast (stochastic constraints) of potential feedstock supply.

				Scenario planning in bioenergy.
REC Mixed integer linear tool developed to determine optimal location	Lam et al., (2010a, 2010b)		●	Large secondary data sets to identify environmental impact of biomass-to-bioenergy location

Glossary of terms in table section

MoMILP: Multi-objective Mixed Integer Linear Programming
LP: Linear Programming
MILP: Mixed Integer Linear Programming
MISP: Mixed Integer Stochastic Programming
REC: Regional Energy Cluster

Table 2.8.1: Summary of Research Methods in Bioenergy, (continued).

Research method and main features	Authors	Process integration	Stakeholder integration	Applications in bioenergy research
Section Five: Non Linear Programming				
NLP Mathematical model where some of the factors (constraints) are non-linear in sequence i.e. individual factors are not intrinsically linked but the series of factors are linked because they relate to a given procedure, e.g. time, costs, transport, etc.	Bai et al., (2011); Bruglieri & Liberti (2008); Lam al., (2008); Čuček et al., (2012a; 2012b).	●		Secondary data sets applied to develop NLP model to optimize up stream biomass-to-bioenergy. NLP also applied to modelling facility-location problem integrated with environmental constraints
SQP Non-linear function where method can measure a series of continuous, yet discrete constraints.	Gill et al., (1994); Rentizelas & Tatsiopoulos, (2010).		●	Large secondary data sets in attempt to forecast potential volume of biomas. Applicable to global sourcing of biomass.

Glossary of terms in table section

NLP: Non Linear Programming
SQP: Sequential Quadratic Programming

Table 2.8.1: Summary of Research Methods in Bioenergy, (continued).

Research method and main features	Authors	Process integration	Stakeholder integration	Applications in bioenergy research
Section Six: Genetic Algorithms				
GA Heuristic approach to seek optimal value of decision. It is an adaptive or generative method used for estimating different scenarios	De Meyer et al., (2014); Ceylan & Ozturk, (2004); Ayoub et al., (2007); Celli et al., (2008); Rentizelas et al., 2010, 2009; Venema, (2003).	●		Secondary data sources to model an algorithm that is loosely based on genetic changes in the 'real-world'. In bioenergy GA is applied to optimize upstream processes in the biomass supply chain. GA can be applied to fuzzy logic approaches.
PSO Stochastic algorithm based upon natural animal behaviour of swarming, flocking etc.	Izquierdo et al., (2008); López et al., (2008).	●		Secondary data sources, mainly literature search of PSO applications in biomass supply chains, consideration of transport costs and routing problem.
BHBF Heuristic approach using swarm algorithms that systematically works through a problem until it reaches a final outcome.	Vera et al., (2010); De Meyer et al., (2014).	●		Secondary data sources to model optimal location of a bioenergy facility, optimal sourcing of biomass

Glossary of terms in table section
GA: Genetic Algorithm
PSO: Particle Swarm Optimization
BHBF: Binary Honey Bee Foraging

2.8.1: Economic Methods in Bioenergy Research.

Economic methods, reside within Transactional Cost Economics and Resource Based View theoretical approaches. Systems to identify performance metrics dominate bioenergy supply chain studies. Economic Input-Output models, (Choi et al., 2010) and LCA/I methods depend on distinct parameters (Baral and Bakshi, 2010). Firstly such rigid rules restrict supply chain integration processes and identification of their characteristics and, secondly understanding the level of importance between each supply chain attribute. Haimes et al. (2005) discuss application of EIO models in conjunction with case study research approaches, which confirms their limitations in the context of identifying a set of essentially 'unknown' heuristics. To add rigour to the application of EIO methods, the literature finds the method used with mixed integer programming, namely Mo-MILP (You et al., 2012). This adds considerable complexity to what are in essence small-scale, rural agricultural businesses. Life cycle assessment and life cycle inventory assessment methods likewise feature largely in the bioenergy literature as Suh et al. (2004 in Baral and Bakshi, 2010, p. 1809) state:

'Most life cycle assessments rely on data of relevant unit processes in the life cycle'.

However, these too are developed in conjunction with other research methods such as discrete event simulation (Awudu and Zhang, 2012) and depend upon quantitative as opposed to a balance of quantitative and qualitative data as Valente et al. (2011, p. 434) find:

'Regarding the methodology, the life cycle assessment is an established tool designed to assess a product in quantitative terms'.

Furthermore, they acknowledge the restriction of LCA methods in supply chain research as:

'Further analyses are necessary for assessing the impact of bioenergy production from the terminal to the end users', (Valente et al., 2011, p. 435).

This is confirmed by Dressler et al. (2012) who find that LCA follows a set of rigid parameters established by the ISO 14040/44 framework, which exclude supply chain processes (von Blotnittz and Curran, 2007). Associated with economic approaches in bioenergy supply chain research is the supply chain network design, which is a method that again requires large data sets and also utilizes other research tools to quantify particular findings. For example, Kim et al. (2011) applied SCND to MILP models to simulate the performance of different bioenergy conversion technologies. Included in bioenergy SCI is technological integration but it is assumed in this research that technology is not the only factor that integrates the supply chain. Economic performance assessment methods are restricted in their application. Furthermore, they require complex approaches that do not add to the knowledge in this area. Life cycle assessment methods in particular, focus on carbon emissions from upstream activities in a biomass-to-bioenergy supply chain as Daystar et al. (2014, p. 431) confirm:

'Yield and productivity are more important to be delivered at cost and net GHG emissions in a feedstock scenario than the transport distance, harvest time and degradation upon storage'.

From both a stakeholder and process integration perspective, it is the latter from this quotation that is of considerable importance to the viability of a bioenergy business. The National Government and EU have strict guidelines on carbon emissions and environmental integrity of which firms must comply such as the EU Directive 2012/27/EU and the UK Government's Climate Change Act (2007).

2.8.2: Geographic Spatial Programs.

Principal Agency Theory, (PAT) and Multi-Attribute Utility Theory underpin decision support systems. Geographic Information Systems' (GIS) tools have been incorporated into this chapter because they are well documented in the bioenergy literature. They are not methods as such, but geographical programs that utilize socio-economic data to assist decision-location-feedstock problems in the biomass-to-bioenergy supply chain. Examples are seen in ascertaining scenarios involving feedstock from different sources and determination of conversion technology and location. As An et al. (2011, p. 3769) confirms:

'GIS is very useful in dealing with dispersed biomass locations'.

Application of GIS programs used in conjunction with genetic algorithms find optimal transport routes for globally sourced biomass (Rentizelas et al., 2009). On the one hand application of GIS helps identify an optimal biomass supply chain from location and routing perspective but excludes technical constraints:

'One of the main technical challenges of the multi-biomass approach is the ability of available energy conversion technology to use fuel mix comprised of several biomass types with varying fuel characteristics'.
(Rentizelas et al., 2009, p. 890).

Whilst many research methods include socio-economic factors they have limitations in that such approaches exclude the integration of operational processes and stakeholder integration characteristics suggested in the research model of this study. This challenge is that it should not be assumed that there is a direct relationship between single processes and stakeholder interventions, but that integration of attributes in bioenergy exists on a number of levels.

2.8.3: Linear Programming and Mixed-Integer Programming Methods.

As with GIS tools, linear programming is based on multi-criteria referencing methods developed in Multi-Attribute Utility Theory. Linear programming (LP) is a mathematical model applied to simulate a linear relationship between variables in order to find an optimal solution. It also is referred to as integer and mixed integer programming because the constraints, which are assumed, 'linear' are based along time, cost and climatic variations for example. In bioenergy systems, linear programming methods have been applied to assess the viability of feedstock from production to conversion (Nienow et al., 2000). Here it is assumed there is a direct relationship between feedstock producers and conversion plants but, include transport as a third party and, thus adding a degree of uncertainty. Further examples of LP in the literature can be found in Cundiff et al. (1997) who investigate uncertainty in seasonal variation of feedstock supply. Whilst this is a robust method, it has advantages in delivering outputs such as cost and time features it does not analyse the complexities of the bioenergy supply chain, particularly in respect of the importance of stakeholder and process integration factors. Furthermore, as with most quantitative methods, LP requires large data sets in order to perform computer simulation modelling (De Meyer et al, 2014). Therefore, LP is not an appropriate technique for this study, which considers the factors of supply chain integration in bioenergy through the case studies. Whilst it can be argued that LP is frequently applied to case studies in bioenergy (van Dyken et al., 2010). The linear relationship from the literature is restricted to upstream biomass-to-bioenergy parameters and LP is not an appropriate tool with which to measure levels of relationship emanating from contractual agreements in bioenergy businesses.

2.8.4: Non-Linear Programming.

Non-linear programming (NLP) is a generalization of LP rules that includes ‘fuzzy’, heuristic constraints that assumes a linear relationship between phenomena (Kuhn, in Giogi and Kjeldsen, 2014). In biomass-to-bioenergy supply chains the NLP literature considers the same problem in multiple sources of feedstock and procurement constraints, which again is underpinned by Multi-Attribute Utility Theory in this context. This is similar to queries set in enterprise resource planning systems (ERP). Shabani and Sowlati (2013) apply different planning horizons to model effective optimal procurement outcomes for different types of feedstock. However, they find limitations to the model because it is restricted to monthly planning horizons due to gaps present in their data:

‘Since in many cases it would not be possible to have precise data due to uncertainty in the system, it would be useful to develop a model which captures uncertainty and would be robust for all possible realizations of stochastic parameters’, (Shabini and Sowlati, 2013, p. 360).

The paper describes the development of a NLP program comprising 260 variables, of which there were 76 binary variables and 187 continuous variables measured against 333 constraints. Within this study, the majority of bioenergy cases are small MW plants that comprise local and regional supply chains, which do not necessarily have complex ERP programs. NLP applications in practice would appeal to global sourcing of feedstock to multiple locations from an operational perspective.

2.8.5: Genetic Algorithms.

Genetic algorithms (GA) including swarm algorithms are computer programs that mimic 'real-life' problems, (PSO and BHBF in Table 2.8.1, pp. 71-80). They are often adapted for decision support systems as cited in the bioenergy literature (Ceylan et al., 2014). However, such algorithms do not fall into a specific theoretical category but instead support Control Theory and Network Theory (Bo-Hu et al. 2010; Kannan et al., 2009). The GA method deploys data collection from a number of secondary sources to establish a best-worst case scenario and modelled from several 'discrete' but unitary perspectives. This is particularly pertinent in the planning stages of bioenergy systems (Ayoub et al. 2007). Stakeholder integration relationships would benefit from applying such methods because GA techniques help inform decisions (Ayoub et al. 2007). As a decision support tool, GA incorporates fuzzy logic that evaluates technical and economic feasibility of bioenergy firms. This is applied by undertaking repeated runs without interruption but has disadvantages, because the system requires continual upgrading (Ayoub et al., 2009).

Fuzzy logic methodologies utilize Multi-Criterion Decision Analysis (MCDA), namely Multi Utility Application Theory (MAUT). Such applications are frequently cited in the literature and suggest a trend towards Analytical Network Processing and Analytical Hierarchical Processing (ANP/AHP) methodologies in bioenergy research.

2.8.6: Multi-Criterion Decision Tools and Fuzzy Logic Methodologies.

Bioenergy systems are complex and it cannot be assumed there are direct linear relationships between attributes (Karakezi, 2001). Multi Criteria Decision Analysis has the capacity to incorporate dynamic systems such as those of bioenergy supply chains (Buchholz et al., 2007). Integration of phenomena between stakeholder and process in the bioenergy supply chain is complex and challenging (Wolfslehner et al. 2005), because of the difficulty in measuring the impact of stakeholder and policy performance with scientific and technical data from operational attributes. Farley et al. (2005) suggest that this constraint can be overcome by a systems rather than a reductionist approach where each constituent part is identified and studied in order to fully understand the system as a whole (Buchholz et al. 2007). Adopting this approach in the study means that a bioenergy supply chain must be investigated from three underpinning perspectives, which is also evidenced in the literature. Volk et al. (2004) consider technical attributes in bioenergy and Heller et al. (2003, 2004) consider feedstock constraints to measure performance of bioenergy systems. Both feedstock production and selected technologies are part of the bioenergy supply chain from a process integration perspective and must be considered as such where it comes to ascertaining optimization of the supply chain. Joyce (2003, p. 340) appreciates the tension between stakeholder policy and application of scientific rigour in assessing bioenergy systems:

> *'…the challenge is to do planning and decision making while balancing three tensions, (1) maintaining scientific credibility, (2) assuring practical saliency and, (3) legitimizing the process to multiple participants'.*

Advantages in MCDA include the range of economic, social and environmental factors because bioenergy systems are iterative which means they can adapt operational tasks resulting from stakeholder decisions. Thus MCDA is able to incorporate relational values across several phenomena rather than measure them as discrete entities in a linear manner (Mendoza and Prabhu, 2003). Key to MDCA methodologies is assigning a decision hierarchy that is both realistic and relevant to bioenergy supply chain optimization. Scott et al. (2012) review decision support systems in the bioenergy literature and discuss challenges in developing a robust approach that manage 'fuzzy' logic relationships across the bioenergy supply chain. Torjai et al. (2015) argue extensively on the challenges in bioenergy research in identification of key performance indicators that optimize bioenergy functions and supply chain effectiveness:

'...and a general lack of agreement on a reasonably practical set of metrics to be measured, (as well as on the applied terminology', (Torjai et al., 2015, p. 326.)

Decision criteria falls into two approaches, the first being cost-determined models proposed by Sharma et al. (2013) and the second set of methods centre on mathematical modelling referred to in this chapter (De Meyer et al., 2014). However, none of the approaches account for recent research on application of case study data, particularly from a bioenergy viewpoint. Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP) both developed by Saaty during the 1970s is a multi-attribute decision making method. Saaty (2004) defines the Analytic Hierarchy Process as:

'... a 'theory of relative measurement with absolute scales of both tangible and intangible criteria based on the judgement of knowledgeable and expert people' Saaty (2004, p. 1).

The Analytical Network Process is defined as:

'*…is a generalization of the Analytic Hierarchy Process (AHP) by considerting the dependence between elements of the hierarchy'* (Saaty, 2004, p.2).

Saaty (2004) rightly identifies ANP as a robust method with which to identify levels of dependence between factors in a hierarchical matrix. This compliments contemporary approaches in MCDA and decision support systems. Each attribute is assigned sub-attributes that are connected with other attributes and sub-attributes within a matrix structure. Secondly, ANP incorporates both qualitative and quantitative data. Forming a reliable but rigorous method that enables data from tangible and intangible sources is critical to understanding contractual agreements central to the bioenergy supply chain from stakeholder interventions to integration of processes is central to this study. As Sipahi and Timor (2010, p. 794) find:

'The ANP method is better to provide a flexible model to solve real-world situations'.

According to Dey (2006), ANP is being increasingly used in the energy industry to develop decision support systems and therefore, frequently cited in the bioenergy literature. Despite such methods identified in table 2.8.1 and trends towards fuzzy logic methodologies, their application does not fulfil sufficient and robust answers to the research questions,

'What is meant by supply chain integration in bioenergy as a concept and set of constructs?' and,

'What are the issues and challenges arising from supply chain integration in bioenergy?'

The real challenge in bioenergy research emanating from evidence in the literature is that it does not clarify bioenergy as a business that is novel and therefore is a lack of maturity in the supply chain. Chapter one referred to mature supply chains as both vertically integrated (B2B) and horizontally integrated (B2C). Evidence from the literature concludes that bioenergy supply chain integration is horizontally integrated (B2C) but lacks conventional supply attributes of B2B that are vertically integrated. In bioenergy, supply chain integration comprises stakeholder and process characteristics and this determines the research approach applied to the fieldwork. Functional attributes are namely process integration factors. On the other hand, regulation and policy-driven that are mainly stakeholder attributes. How such characteristics interact and at what impact they have in ensuring effective supply chain integration performance will be determined by the final research question:

'What are the integration factors that would help improve the performance of bioenergy supply chains?'

The next chapter provides an analysis of the methods deployed in the study from a philosophical perspective and presentation of qualitative research approaches.

Chapter Three: Methodological Approaches in Bioenergy Supply Chain Integration.

3.0: Overview of Chapter, Context and Contribution.

The purpose of a methods chapter is to clarify the research framework based on primary as opposed to secondary research. The chapter is divided into five sections of which section 3.2 provides an analysis of research philosophies taken from operations management research approaches. The following section (section 3.3) investigated methods that have been applied to bioenergy research and by critiquing such methods the section concludes with selection of research methods that were deemed appropriate for this study from a pragmatist perspective. Towards the latter part of the chapter, section 3.4 explains methods used in the scoping study and main study. The chapter concludes with section 3.5, which evaluates methods deployed in the primary research.

Methods were wholly qualitative and used survey questionnaires in both a scoping study and in the main study. A review of the literature initially helped develop a framework for the research and content for semi-structured interviews. These in turn, formed the structure and organisation of questionnaires used in this study. The interviews were organised through site visits to bioenergy facilities, meetings, and telephone interviews. Initial fact finding with bioenergy practitioners helped develop the questionnaire used in an initial fact finding survey, namely a scoping study. Following on from this, findings and analysis from the scoping study helped develop two further questionnaires used in the main study. The purpose of two questionnaires in the main study was two-fold. The first questionnaire targeted academics and researchers' working in bioenergy and, the second questionnaire was aimed at personnel employed in bioenergy businesses. The combined results are presented in chapter five of this study and analysis of main study findings in chapter six. In addition to the findings from questionnaires, case studies were developed through networking activities on the part of the researcher.

The main contributions arising from the methods chapter are firstly, validation and confirmation of supply chain integration constructs that were identified through the literature review and secondly, development of pragmatist and accessible methods to better understand the characteristics of an emergent sector.

As this study applied a pragmatist approach because it became evident from the literature review and scoping study that bioenergy is an emergent industry and, in addition, investigating bioenergy from a supply chain integration perspective is also novel. In this respect, Grounded Theory permitted the researcher to develop theoretical constructs from qualitative research methods in a systematic way as established by Glaser and Strauss (2012).

3.1: Introduction.

It can be assumed that supply chain integration in bioenergy from a contractual perspective involves a number of physical (process integration) and stakeholder constructs given in chapters one and two of this study. Theoretically, supply chain management as a concept relies on elements that are both qualitative and quantitative principles found in the operations management literature. Traditionally, operations management drew its foundations from deductive and thus positivist research approaches. More recently, contemporary operations management literature includes qualitative and therefore inductive and phenomenological methods (Mangan et al., 2004).

It could also be argued that abductionist research approaches apply to this topic of research in order to investigate interactions between the main actors of university-public authority-industry stakeholders as Brekke et al. (2014) provide where the main actors are responsible for all the decision-making elements of a given project.

Abductionism was first introduced by Pierce during 1931 and is neither based on deductive nor inductive approaches given in the operations management literature.

Kjellberg (2001, p. 62) states that abductionism is:

'... the process that involves a successful reinterpretation of both theory and empirical observation'.

This is important to developing systematic approaches to case study research and thus qualitative methods. However, this study found a mis-match between the main stakeholder actors and, in particular, those from university institutions where there was a gap between new development and commercial practice. Pace of development and engagement between actors restricted the application of abductionist approaches as Brekke et al. (2014, p. 10) in their research find:

'We especially wanted to provide insights into how the construction industry can engage in better networking interactions to create innovations. None of these desires were fulfilled, for one simple reason. There was not a lot of innovation going on, and few participating companies'.

Such sentiments are confirmed in this study where commercial practice in bioenergy centred on contractual interactions between stakeholder and operator actors rather than application of risky technologies being developed within the university sector.

This research therefore adopts a problem-centred and thus a pragmatic approach to understand challenges in bioenergy supply chain integration. Pragmatism in research is concerned with the 'what' and 'how' of a given research problem (Creswell, 2005). A pragmatist researcher therefore does not follow one philosophical system but instead pursues the research problem through a mixed-methods approach (Somekh and Lewin 2005; Tashakkori and Teddlie, 2003). The research question is central and is applied to all approaches in order to help understand the problem (Creswell, 2003), and is therefore central to data collection and analysis of findings (Mackenzie and Knipe, 2006). Such questions involve given philosophical perspectives in order to build and defend a particular theoretical position. In order to present a systematic approach there has to be a clearly defined framework. This was done by first exploring the operations management literature in the section following on from this and thereby defining the approach and qualifying the main arguments for application of both theoretical and thus philosophical perspectives in justifying why it is apt to underpin this study with Grounded Theory and pragmatism (Bryant, 2009).

3.2: Philosophical Perspectives in Operations Management Research, (OMR): Development and Adaptation of OMR in Bioenergy Supply Chain Integration.

Building and reinforcing rules around a topic that relies on different theoretical constructs can be explored from a logical and systematic perspective. There are two camps in supply chain management; some view this area as a process, which borrows theories from other paradigms (Stock, 1997), whereas other authors, give credence to supply chain management as a discipline in its own right (Cooper et al. 1997; Chen et al., 2004; Carter and Rogers, 2008). The main issue in this research is that both supply chain management and bioenergy are relatively new disciplines with bioenergy being the most novel of the two (Angell and Klassen, 1999). From this stance, underpinning philosophical approaches in supply chain integration in bioenergy can be explained from the operations literature. Meredith (1998) supports the view that operations management research can adopt qualitative approaches and move away from its traditional paradigm in rationalistic research methods that are based around mathematical modelling in optimization and simulation. Field and case study methods include principles founded in operational research (Meredith, 1989). Objectivity centred on quantitative studies taken from a positivist rationalist approach does not provide sufficient evidence of a 'real-world' view of phenomena. In an earlier paper Meredith (1998) supports the view that empirical studies that deploy field and case studies explore alternative paradigms, which in turn, helps develop knowledge and understanding of the real world. If this study were to assume a rationalist as opposed to a phenomenological approach, it could be argued that the view is biased towards the researcher rather than the phenomena being studied (Guba, 1990; Klein and Lyytinen, 1985). Contrary to this, it is well documented in the literature that supply chain management research utilizes statistical survey and therefore quantitative methods such as multivariate analysis (Hair et al. 2006). Such positivist and quantitative methods depend wholly on large data sets in order to test reliability and validity of a 'cause and effect' relationship between two variables. Therefore it has to be assumed that the results from such studies are pre-determined and are limited to either a positive or negative correlation. Research into new and novel areas cannot be pre-determined as new factors have yet to be identified and explained. This results from empirical evidence-based observation in the field and comparative analysis from similar cases. The case studies explored and analysed in this research utilize multiple approaches for data collection based on observation, survey questionnaires that result from using both qualitative and quantitative methods for data collection and analysis (Yin, 1994; Eisenhardt, 1989; Benbasat et al., 1987). Triangulation of methods referred to as 'perceptual triangulation' (Bonoma, 1985, p. 203) can be challenging to undertake but quantitative approaches can rationalise and validate the results.

Direct observation in case study and field research requires the researcher to observe a number of similar cases in order to identify, collate and measure data for replication. Meredith (1998) warns of single case studies as,

'...not an attempt to increase the sample size but rather like follow-on experiments or surveys to extend the study to new populations' (Meredith, 1998, p. 443).

In operations research there are advantages as well as disadvantages from following either a quantitative, (rationalist) or a qualitative approach (phenomenological). Table 3.2: Advantages and Disadvantages of Rationalist and Case Study Methods, (p. 85) highlight the main challenges and attributes from both philosophical perspectives and address underpinning theoretical constructs in relation to such approaches.

One of the main advantages of a rationalist approach in operations research is the ability to test the reliability of data. However, such methods are limited because they lack the ability to interpret 'real-world' phenomena. Observation of phenomena can identify new variables and relationships between them that had not been previously conceived go beyond anticipated and expected results according to McCutcheon and Meredith (1993). Qualitative research is subject to more explanation and interpretation of what phenomena can mean (Kaplan, 1964). This begs the question of how does a researcher conclude the most appropriate meaning of phenomena? Hudson and Ozanne (1988) draw a distinction between explanation and understanding. Interpretation of results is an on-going process rather than an end in itself. Hence, a further advantage of phenomenological philosophical perspectives in bioenergy supply chain research because the more this subject is studied from different perspectives and researchers, the more understanding of the nature and characteristics of this sector can be clarified from both theoretical and practical viewpoints. Richardt and Cook (1979, pp. 13, 22, 23) find that triangulation of research methods:

'Quantitative understanding presupposes qualitative knowing'.

Research has no value if the initial concept is superficial; interpretation and communication of concepts are ineffective. Case study research deals with relational inference rather than measurable variables. Through observation of processes that help deduce rational explanations as to how they are caused. It can be argued that case study approaches are conducted using rigorous data collection methods as well as observation in the field, (Gerwin, 1981). According to Yin, (1994, p. 33) findings identified from case studies can be categorized into appropriate domains:

'…the domain to which a study's findings or presumed causal relationships can be generalized'.

Likewise Bonoma, (1985, p. 200) discusses the advantages of case study data as:

'…the characteristics of research that affect the contextual relevance of findings across measures, methods, persons, settings and time'.

Researchers deploying field and case study research should consider theoretical applicability from their findings as Richardt and Cook, (1979, p. 15) argue in defence of theory building from case research as;

'…there is no reason quantitative results should be inherently more generalizable than qualitative results'.

From this perspective, Meredith (1998, p. 453) warns of the breadth and rigour that must be applied to qualitative operations management research as:

'case/field research must be conducted with rigour to satisfy the standard requirements of competent research'.

Phenomenological approaches defined as, '*meaningful acts of consciousness'* result from conceptual ideas derived from everyday experience, (Hughes and Sharrock, 1997). Confirmation is given in Schutz (1962, p. 248) because the central and key advantage of phenomenological research is its inherent ability to give a range of different outcomes depending on the phenomena being observed at the time. However, there are parameters according to Hughes an Sharrock (1997), that a research model and underpinning philosophical perspectives must conform to formal logic and adequacy that is accessible because it relates to and is understood by its benefactors.

Within operations management research, environmental issues are still in their infancy (Angell and Klassen, 1999). This provides considerable opportunities for developing research and appropriate methodological approaches in this paradigm. The World Commission on Environmental Development (1987) called for integration of environmental practices in plant location and manufacturing processes. Gupta and Sharma (1996), identify the relevance of environmental management in key decision-making and strategic management processes. The wider issues in operations management relate to the 'green' supply chain literature that includes relationship management with suppliers and transport providers in order to decrease the carbon footprint and lower operating costs (Sarkis, 1995; Shrivastava, 1995 and Post, 1991). Performance measurement of environmental practices (Ettlie, 1993 and Klassen, 1993) have led to disparate and disjointed research because to date there is no framework and clear constructs that both shape and define supply chain integration in the environmental and ecological literature (Angell and Klassen, 1999). Historically, environmental management was confined to legal and corporate functions governing environmental legislation. Research focused on efficiency improvements and cost reduction whilst adding environmental constraints to core manufacturing outputs. Such a restricted operational strategy ignored both process and stakeholder phenomena across the supply chain from an environmental perspective (Wheelwright and Hayes, 1985). Application of phenomenological approaches not only helps make sense of the present situation but also drives future research (Morgan and Kreuger, 1997; Calder, 1977).

The literature provides evidence of a growing trend in operations management to consider alternative methods that provide a holistic view and greater understanding of novel and nascent sectors. From a philosophical perspective it is confirmed that the study will support triangulation of methods in order to attain optimal outcomes to the aim and research questions provided in chapter one on page 18.

Table 3.2: Advantages and Disadvantages of Rationalist and Case Research Methods in Operations Research.

Philosophical and Theoretical Perspective in SCI	Advantages	Authors	Dis-advantages	Authors
Rationalist: **TCE, RBV & PAT**	Precision Reliability Standard Procedure Testability	Hair et al. (2006); Filippini (1997); Chase (1980); Voss et al. (2002); Flynn et al.,(1990) Meredith et al. (1989).	Sampling difficulties Trivial data Model-limited Law explained variance Thin results	Bertrand & Fransoo (2002); Lambert et al. (1998).
Case Study/Action Research: **Grounded Theory, MAUT**	Relevance Understanding Exploratory Depth	Yin (1994); Swamidass (1991); Meredith (1998); Forker et al. (2002); Spencer & Guide (1995); Bartunek e& Seo (2002).	Access and time Triangulation requirements Lack of controls Unfamiliarity of procedures	Morgan & Krueger (1997); Calder (1977).

Source: Adapted from Meredith, 1998, p. 443.

3.3: Methods Deployed in Bioenergy SCI: Gaining Access to the Field.

A pragmatist approach is justified because underpinning this approach are prepositions that help develop new constructs in novel areas of study that have not been previously studied.

Contemporary research in this field cites that not enough is known about supply chain characteristics particularly indicators that optimize supply chain performance. Methods deployed in the supply chain literature and cited in chapters one and two consider the concept of bioenergy supply chain development and its integration. Fuzzy logic methods used to develop decision systems are based on the assumption that secondary data used to model such systems are 'clean' data. Use of secondary data is challenged due to the validity and reliability of its source. However, its use is advantageous in terms of cost and time.

Empirical studies often use survey questionnaires and semi-structured interview approaches are relatively easy to deploy (Randell and Gibson, 1990). Given the challenges, such qualitative methods can add greater depth of meaning to understanding phenomena but access to willing respondents can prove difficult (Liedtka, 1992). The types of secondary data included in the analysis of methods sampled in this chapter could be defined as, '*data collected by others'* (Cowton, 1998, p. 423). Furthermore, such data was collected not by other researchers within a given project but by external parties (Frankfort-Nachmias and Nachmias, 1992).

It is true that the methods literature cited in this chapter attempts to reclassify and categorize into specific groups prior to modelling their data. Whether there are either 'good' or, 'bad' sources of data is a question that is difficult to evaluate from the evidence provided in the papers that were cited. In chapter two, part II table 2.8.1 found that the majority of authors cited in the table (53 out of 65 references cited) utilised large data sets from secondary data sources. Certainly, policy and government documents can be considered more robust and reliable than data from 'unofficial' sources. There are also a number of quasi-legal groups, all of who have a 'green' agenda and, are not mainstream and tend to operate from 'non-governmental' level to 'agent provocateur' (Cowton, 1998). It is therefore difficult to distinguish from these papers whether the researchers had full cognizance of secondary data sources in develop such models in bioenergy business performance. It is apparent from the multi-criteria analytical methods that they attempt to fill a gap in understanding how bioenergy performs from a technology, economic and environmental perspective in relation to process and stakeholder attributes. However, there is scant evidence in the literature on identification of factors that enable a bioenergy firm and businesses related to it perform effectively.

3.4: Methods Used in the Study: Taking First Steps - Doing a Scoping Study.

Deployment and design of research methods to answer given questions and objectives in a particular study can be conceived via a range of appropriate and robust research tools. One of the initial approaches to help develop the main study was by conducting initial fact finding by conducting a review of the literature; also by undertaking a scoping study and interviewing people involved in the bioenergy business. The prime function of a scoping study is to test the feasibility and sustainability of a research question and model (van Teijlingen and Hundley, 2001). The scoping study had a dual purpose, first to trial and design methods applicable to the main study and second, provide a better insight into bioenergy supply chain integration. This helps mitigate risk as van Teijlingen and Hundley (2001, p. 1) identify:

'...give advance warning about where the main research project should fail'.

According to Tashakkori and Teddlie (1998) the scoping study usually starts by collecting qualitative data around a topic, which has not been extensively researched. Design and organization of the scoping study questionnaire, (Appendix 1: Scoping Study Questionnaire, pp. 328-331) was developed from a generic supply chain and logistics study by Bernon et al., (2008). Modifications were made so that questions related to 'typical' bioenergy businesses that were devised by reviewing the literature in bioenergy and supply chain constructs. The scoping study surveyed UK-based bioenergy businesses and was sent to 100 companies between 2010 and 2011 that were representative of the supply chain. A total of 26 completed the questionnaires illustrated in Table 4.2.1: Participants in the Scoping Study, Chapter Four, p. 112. There were eight sections in the questionnaire and participants ranked questions on a scale 1-5, (1-unimportant to 5-highly important). The eight sections comprised questions and statements that corresponded with the bioenergy supply chain as:

Supply Chain and Logistics Planning: This section involves supply chain characteristics at a strategic level to ascertain integration between up and downstream functionality.

Logistics Functions: This includes transport operations to the site, on-site and distribution channels, (e.g. pipelines for gas/fluids), containers and transport adapted for biomass.

Organizational Role: The questions refer to individual supply chain operations, for example co-ordination of feedstock, managing suppliers or customers, etc.
User Satisfaction: This section refers to how bioenergy organizations promote their public image.

Impact of Use: This section gauges questions on how the bioenergy organization treats its employees and actors across the supply chain.

Organizational Performance Costs: Operational costs involved in the day-to-day operations of the bioenergy organization and its supply chain.

IT applications: Function and operations across the bioenergy supply chain that involve the use of Information Technology, e.g. auditing, procurement, vehicle routing and scheduling.

Waste Management: Whilst biomass feedstock can be derived from another sector's waste stream, this section is concerned with how bioenergy organizations' process their waste from energy conversion.

Data was analysed using SPSS to collate and calculate the mean figure and weighted average according to the ranked scale of 1-5. The results were tested for reliability using Cronbach's Alpha in SPSS and Table 3.4.1 shows 0.995 reliability out of 26 respondents. The results of the scoping study are discussed in Chapter Four, Section 4.2, Scoping Study Results, pp. 110-124.

On reflection of conducting a scoping study it was assumed that the participants were acquainted with the terms used in supply chain management. Therefore this was not going to present any confusion and ambiguity in completing the questionnaire. However, this was not the case because participants' roles in bioenergy were diverse and therefore not wholly familiar with some of the context of the questions. Further application of survey methods will have to overcome such misunderstandings by either providing explanations or, rephrasing questions to ensure that they are effectively understood. This is a problem documented in the methods literature as Sheatsley (1983) confirms:

'It usually takes no more than 12–25 cases to reveal the major difficulties and weaknesses in a pretest questionnaire" (Sheatsley 1983, p. 226).

In addition, it was apparent that consensus had developed from particular questions given in each section. This was noted in Buchholz et al., (2009) who conducted expert interviews and surveys and found consensus in their results. In the case of the scoping study, confidentiality was integral to distribution because participants were selected from discrete and separate organizations so that they were representative as far as was possible of a 'bioenergy supply chain'.

3.4.1: Main Study Approach: Lessons Learnt.

Valuable lessons were learned from the scoping study particularly amending questions and statements used in the scoping study questionnaire. According to Denzin and Lincoln (2000), the research process needs to be continually re-evaluated in order to fully engage with understanding the relationships between phenomena. The researcher plays an active role in the investigation (Habermas, 1984, 1987; Lewin et al., 1939).

The scope of the research question required an approach that incorporated survey questionnaires and in addition, semi-structured interviews, site visits to a range of companies involved in bioenergy production. Typical examples of such companies were conversion facilities, maintenance engineers, boiler manufacturers and logistics companies that had specialist transport facilities for biomass. The main study was conducted over four years from 2011 to 2015 and commenced when results from the scoping study had been completed. Table 3.4.2 illustrates the timescale and methods deployed in the research from 2008-2015, p. 102.

The research area in the main study was restricted to the West Midlands and adjacent counties due to the research being part-time and convenience of accessing field work in close proximity to that of the researcher. Henning (2004) confirms the employment of contract research staff in collecting primary data. Similar opportunities were sought from EU funded projects from 2012 to 2015. Despite the potential for collection of data from the bioenergy projects, they were not wholly compatible with this research and dependence on partners further afield placed this research at risk. Despite this set-back, survey data was collected from 21 researchers to gather their views and experiences of bioenergy development and whether they were motivated in the same way as bioenergy businesses in the Region. Pasmore (2006) finds engaging with participants rather than merely observing them reveals differences of opinion, and this may explain lack of innovation in bioenergy technology and acceptance of new approaches in bioenergy amongst key decision-makers.

Table 3.4.2 shows the range of methods deployed throughout the whole study period from survey, interviews and desk research and table 3.4.3 show how methods were developed from the literature review to scoping study, main stakeholder and process integration survey and case studies, and researcher questionnaire, (p. 103).

Further data for the main study was sought from a series of interviews with stakeholders and operators in bioenergy within the region. The structure of the questions was developed out of the constructs in supply chain integration ascertained from the literature review and scoping study. Meetings with stakeholders and operators were conducted at their business premises. This served two useful purposes; first, the researcher gained access and better understanding of the nature and scope of bioenergy business functions and second, convenient and amenable to participants which, in turn proved beneficial in gaining insight into bioenergy operations from either a stakeholder or process perspective (Hannerz, 2003). Criteria for selection of cases are listed on pages 101-102. They were chosen on the basis of proximity to the researcher and thus, regional location (i.e. West Midlands) and ability to gather information from stakeholder and process integration constructs. The latter criterion was the most important because it tested the validity of supply chain integration constructs ascertained from the literature review (Gold and Seuring, 2011). It is argued that basing assumptions from interview data are not robust as Silverman (1993) contends that interviews are subjective because they are biased towards the researcher (interviewer) rather than the interviewees. Similar views are found in Holstein and Gubruin (1995). However, Bowker and Star (2000) argue that interview data can take a constructivist approach despite being a qualitative tool. Bryman (2001) encourages mixed methods of data collection in order to obtain holistic views of the phenomena under observation. It was found that survey methods were helpful, firstly to test findings from the literature and field in a scoping study and then to test the research model developed from secondary research, (Blaikie, 2000; Bulmer and Warwick, 1993). Questionnaires have a central role in field research because they interact effectively with other methods of data collection and analysis as Olsen (2004, p. 13) confirms:

> *'Survey data can interact with case-studies of individuals or life-histories of households, giving a rounded view of a limited number of cases alongside an extensive view of a wide range of cases'.*

The main bioenergy questionnaires are found in Appendices 2 and 3 (pp. 332-344, pp. 345-355).

Case studies were formed from interview and desk research data (Yin 2013). The purpose of case studies presented in Chapter Six: Case Studies In Regional Bioenergy Businesses in the UK, pp. 215-241, is to determine the viability of bioenergy businesses and whether the contract is pivotal in the extent of business viability in those case study companies. Selection of case study companies complied with five criteria:

1. Based in the West Midlands for the purpose of the main study,
2. Accessible to researcher and within easy travelling distance, (distances between 30-35 miles),

3. Willingness to participate and co-operate with the researcher,
4. Case study companies in the West Midlands were commercially viable in order to ascertain factors of best practice and,
5. Case study selection as far as possible reflected either process or stakeholder characteristics and, in some cases both aspects of supply chain integration in bioenergy.

Table 3.4.2: Methods Used in the Research 2008-2015.

Method	Timescale	Overview
Desk research	2008-2009	Research scope of topic and formulate research model and approach, (Verschuren et al., 2010; Saunders et al., 2011).
Interviews	2008-2010	Semi-structured interviews conducted with people involved in the bioenergy industry, (see Table 4.1.l: Scoping study participants, p. 103).
Survey Design for Scoping Study	2010-2011	Design developed from secondary research in bioenergy and results from interviews, (Peltola et al., 2009).
Survey Design for Main Study	2012-2014	Main survey developed from scoping study results and boundaries developed for main study, (identification of region for study), Selection of case studies in West Midlands Region, (Tate et al., 2012).
Expert Interviews	2012-2015	Continuation of semi-structured interviews within study boundary, (Steubing et al., 2010).
Desk Research	2013-1014	Secondary data from published sources to develop and evolve field research data, (Sachen and Datta, 2005; Meredith, 1998).
Collation, Analysis of Survey and Case Study Data	2015	Identification of main supply chain constructs from survey and case study data, (Yin, 2014; Pagell & Wu, 2009; Seuring, 2008; Corbin & Strauss, 2014; Voss et al., 2002; Darke & Shanks, 1998; Becker, 1988).

Table 3.4.3: Research Methods Developed in the Study from Literature Review, Scoping Study and Main Study.

Supply Chain Integration Constructs identified from the Literature Review	**UK-Wide Scoping Study: Survey Questionnaire**	**Main Study Surveys: Stakeholder/Operator and Researcher Questionnaire**	**Case Studies of Companies in the West Midlands Region**
Stakeholder Constructs: Planning & installation, Funding/ Financial incentives, Policy, regulations & Legislation, Types of agreement, Technology decision, Location decision.	Length of agreement Maintenance contracts Hand-over period Development of supply chain Policy & regulations Legislation Technology selection Location Supply chain design.	Planning approval Technology decision Location decision Funding sources Dissemination of policy, regulations and legislation Length of contract, Financial performance, Compliance, Marketing & communications policy, Impact of research on technology decision, Impact of research on environmental decision.	Location decision, Investment decision, Funding sources. Technology decision, Length of agreement, Distribution Centralized vs Decentralized energy systems). Principal Contractor co-ordination & project management.
Process Constructs: Finance & purchasing, ICTs, Technology & production systems, Logistics operations, Marketing.	Technology operations, Logistics operations Supplier agreement & relationships ICT usage Marketing & communications, public image, Waste management operations, Decision to outsource operations Location of suppliers & customers	Technology operations, Number of years in production, Number of suppliers & customers, Biomass replenishment, (stock control & processing), Logistics operations, Supplier & customer interaction, Supply chain risk, Dissemination & application of policy, regulations & compliance, Quality management, Financial management, Waste management, ICT applications.	Long to short term contractual agreements, Inbound & outbound logistics, Transport operations, Vehicle routing & scheduling, Quality management, Supplier relationships and agreements, Financial management, Purchasing

3.5: Evaluation and Justification of the Methods used in the Study.

One of the criticisms emanating from bioenergy research is the lack of practical relevance from a business viewpoint. This results in a mismatch between theory and practical contribution (Gold and Seuring, 2011b). By far the majority of methods derived from the bioenergy literature consider secondary data and desk research approaches identified in Table 2.8.1: Summary of Research Methods in Bioenergy, (pp. 71-80). Very few of these methods were determined by fieldwork and primary data collection. One of the reasons for this could be due to lack of commercial examples. Even the bioenergy research projects used for some data collection in this study developed experimental pilot plants rather than base research from fully operational and commercial bioenergy companies.

Methods that encompass the whole range of bioenergy activities from a multi-criteria perspective can measure the impact of stakeholder interventions on processes but not include both qualitative and quantitative data. For example, pre-treatment of biomass requires mechanical and chemical processes to convert biomass into the correct material for conversion. Such processes also include other operational processes such as handling, storage and transportation (Larsen et al. 2010; Kumar and Sokhananj, 2007). However, by separating distinct operations deals with bioenergy processes as discrete entities and not as a supply chain. Carolan et al. (2007) proposes a supply chain model and foresees the need to model an end-to-end supply chain approach because this helps reduce costs between parties in the supply chain. Linear programming methods cited in Kanizan et al. (2009) and Tatsiopoulos and Tolis (2003) consider biomass production and pre-processing including the problem of different suppliers of biomass to storage facilities in mixed-integer programming models, concluding with the fact that such facilities need to be closely located to conversion sites:

'*…in order to minimize the total costs of biomass supply chans the location of inter-model storage/distribution center should be as close as possible to bioenergy production facility'* (Mafakheri and Nasiri, 2014, p. 118).

Linear programming and scheduling minimize farm-to-storage costs but do not account for seasonality in biomass production (Mafakheri and Nasiri, 2014). There is a need to integrate the schedule of storage and inventories with supply chain operations (Dunnett et al., 2007). Mixed-integer programming applied to logistics and transport in bioenergy is determined by the supply and demand for biomass (Annevelink and de Mol, 2007; Diekema et al., 2005).

Geographical Information Systems (GIS) applied to transport costs in biomass (Graham et al, 2000) are used to develop an optimization model. Such applications are seen in hybrid approaches for location decisions as cited in Zhang et al. (2011). However, use of GIS programs cited in the literature have been incorporated into mixed integer programming for technical and location decisions in selection of biomass. McKendry (2002) used mixed-integer programming with GIS software in biomass selection and pre-processing technologies. Optimization of conversion technologies with biomass selection and location are considered in You and Wang, (2011). Non-linear programming models applied to costs in biomass yield and conversion optimization are cited in Rentizelas et al. (2009). Dynamic programming using discrete event simulation proposed by Mahmoudi et al. (2009) and Sims and Venturi (2004) consider the environmental performance of bioenergy plants but found that discrete event simulation did not include the uncertainties, particularly in relation to energy price fluctuation and, changing energy policy in the UK in renewable energy incentives. Discrete event simulation models visualize supply chain performance and measure environmental impact (Zhang et al, 2012). Life Cycle Assessment (LCA) methods centred on environmental characteristics and their impact of bioenergy systems are largely centred on technological constraints. The challenge with LCA methods is not that this method is cited in environmental impact of biomass supply chains but that it is impractical to apply as Cherubini and Strømman 2011, p. 446 confirm:

> *'The work points out and discuss the key issues and methodological assumptions for wide ranges and uncertainties in bioenergy LCA. These aspects do not make possible to provide once for ever exact quantification of the environmental impacts of bioenergy because too many variables are involved'.*

There is a trend towards Multi-criteria Decision Analysis (MDCA) and fuzzy logic that consider stakeholder and process integration characteristics wholly from a technological and economic viewpoint (Elghali et al., 2007) but make assumptions based on secondary data sources. The literature supports MDCA and fuzzy logic methods to take account of institutional values, and actor interests at stakeholder level that work in parallel with measuring performance of feedstock production, transport, conversion operations at process level (Gold, 2011; Altman and Johnson, 2008) as Mafakheri and Narisi, (2014, p. 121) confirm:

'There is a need to adopt decision models capable of filtering routes and biomass sources that are less sustainable whilst optimizing for operational performance of supply chains'.

Bioenergy supply chains have been neglected in the literature despite the depth of bioenergy research (Mafakheri and Nasiri, 2013). What is missing from bioenergy supply chain research is first identification of factors that comprise a bioenergy supply chain. This has been examined in the literature and it is assumed that the research takes the view that supply chain integration is distinct from supply chain management. Secondly, supply chain integration is divided into stakeholder and process constructs that were also identified in the literature, and finally the study centres on ascertaining what factors integrate a bioenergy supply chain from the position of the two actors, stakeholder and process. In order to undertake further analysis, primary research developed out of findings in the literature. The approaches adopted can be justified due to the need to study 'new' phenomena. In conclusion, application of action research is not so much as to create a 'right' way as proposed by rationalist approaches. Emphasis is to generate new associations and build constructs within an emergent supply chain (Reason and Bradbury, 2006, p. 19).

There is a tension in substituting secondary data where there is not sufficient evidence from practice. From the methods cited in chapter two, part II, as well as discussed at the start of this section, it is apparent that these are being developed to model bioenergy performance alongside LCA. However, none use wholly primary research to validate either a research question or a hypothesis. Whilst such methods demonstrate robustness, the question has to be asked is it the research model that takes precedent over the research question? Survey data was used to link into case studies, (see Table 3.3.4) and in both instances was intended for participants with experience in bioenergy planning and production. This basis for 'expert' respondents was applied in Buchholz et al. (2009) who advise:

> *'Respondents were asked to provide information about their professional background, geographical expertise, scale of bioenergy projects they are familiar with',* (Buchholz et al., 2009, p. S87).

It was a challenge to achieve a sufficient response rate in survey methods, and the study failed to obtain any responses from partners within two bioenergy projects running concurrently during the time of the study. Yu and Cooper (1983) suggest monetary incentives to increase survey completion rates. In order to overcome this risk, the researcher sent preliminary notification of the questionnaire to potential respondents, contacted Bioenergy Associations (for example Renewable Energy Association; Anaerobic Digestion and Bioresources, ADBA) and attended national exhibitions in renewable energy in order to meet and gain participation from potential respondents. This approach proved to be successful in obtaining data and gaining permission to develop further case studies.

Case study research is where the researcher can generate questions but has no control over the outcome. It is exploratory and descriptive (Yin, 2014). In contrast to hierarchical decision-making tools, case study research establishes relationships between factors that are not based on assumptions and as Yin (2014, p. 16) argues the case study is an:

> *'empirical enquiry that investigates a contemporary phenomenon (the case) in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident'.*

A case study enquiry deals with technical distinctive situations where there are many variables compared to data points, thus many action research methods such as case study approaches use triangulation. In turn, this helps develop theoretical prepositions to guide data collection and analysis. Coding data from qualitative methods applies a Grounded Theory approach that is referred to as a 'constant comparative' method

(Glaser, 2012, 1965; Glaser and Strauss, 1967; Strauss and Corbin, 1989). Putting information into different arrays involved developing a matrix of categories and placing the evidence within each category (Miles and Huberman, 1994). Creating data displays such as flowcharts, tabulated formats and other graphics helps display and disseminate the data. Flyvberg (2006) supports qualitative inquiry through case study research, particularly multiple case studies that link up a series of narratives, which tell a story. Emphasis is based on factors from case studies and linkages with a given theory are less important. Instead, case study data relates to much broader philosophical positions (Flyvberg 2006, p. 238). This is supported in Nehamas (1985, p.165):

'Good studies should be read as narratives in their entity'.

The study continues with results of surveys and cases studies following analysis and evaluation of methods in this chapter to provide findings from the scoping study in chapter four and main study in chapters six and chapter seven.

Chapter Four: Results and Lessons from the Scoping Study.

4.0: Chapter Overview and Contribution.

The main purpose and function of this chapter is to test the methods selected for the study. Initial fact finding based on face-to-face meetings, site visits and a scoping study questionnaire demonstrated rigour and robustness of research aim and questions. The chapter demonstrates the transition from secondary and desk-based research provided in the literature review and methods chapter towards conducting fieldwork, utilising wholly primary research methods. From this perspective, the researcher was able to test and validate both the research questions and methods. In addition, by performing an initial scoping study enabled the researcher to gain better awareness and experience of the challenges and issues inherent in bioenergy businesses. The scoping study provided a valuable insight and understanding of how bioenergy supply chains are configured.

4.1: Introduction: Establishing the Research Boundaries and Understanding the Topic.

Prior to the development of the research question, the research boundaries needed to be fully explored in order to understand the nature and scope of bioenergy and of supply chain integration. It was assumed at the commencement of this study that conventional supply chain constructs could be adapted to suit those of a bioenergy supply chain. How is a bioenergy supply chain organized is a fundamental question that was asked because it was evident, even at the early stages, that there is a lack of understanding as to how a bioenergy supply chain is defined and what factors integrate 'typical' bioenergy supply chain actors and their respective firms? Historically, energy systems are vertically integrated, where every section from exploration to distribution has its own discrete supply chain (Hilson, 2000). Whereas, bioenergy systems tend to operate matrix structures that function both vertically within sections, and horizontally between main divisions within the supply chain (Rivza and Rivza 2011). Accountability in bioenergy companies is evidenced in the literature that shows how contracts are devised amongst stakeholders up to operational activities once the company is established. The practice of the turnkey contract which realises the complete project prior to 'going live' determines the level of accountability throughout the bioenergy business (Malik, 2008). However, there is limited knowledge in the long-term viability and supply chain maturity of these businesses. Identification of supply chain characteristics pertinent to bioenergy were tested through a scoping study because the findings would reveal how bioenergy organizations performed from biomass-to-bioenergy conversion, (upstream factors); involvement of stakeholder actors and conversion-to-distribution-to waste stream, (downstream supply chain factors).

This chapter follows the structure and organization of the scoping study questionnaire, (see Appendix 1: Scoping Study Questionnaire, pp. 328-331). The next section provides a brief overview of the scoping study approach, of which there were eight parts for respondents to answer. The final sections in the chapter provide a discussion and analysis of the scoping study findings.

4.2: The Scoping Study: Results and Findings

The approach adopted for the scoping study has been provided in Chapter Three, Section 3.4.1: Main Study Approach, pp. 99-103 together with the definition of each of the eight sections within the questionnaire. It was distributed to 100 potential respondents, electronically via email and the Internet such as the social media site, LinkedIn to bioenergy interest groups. Other approaches of contact included personal interviews such as face-to-face and telephone interviews, and also contact of potential participants from the two EU projects running concurrently with this study. The Internet social groups such as LinkedIn and the EU project did not yield any participants at the scoping study stage. It was assumed that Internet-based special interest groups in renewable energy would firstly possess the experience and expertise in bioenergy business practice, and secondly that they would participate. Likewise, the same assumption was made with the two EU funded bioenergy projects. This contradicts the views documented by Van Selm and Jankowski, (2006) and Swoboda et al. (1997, p. 243) who report the merits of web-based surveys:
'These selected groups enable in other words, the conduct of expert interrogations'.

The advantage of online surveys via the Internet and e-mail provide immediate access and potentially a cost-effective method of distributing questionnaires. However, use of web-based survey tools can incur additional costs, for example Survey Monkey, a web-based questionnaire design and distribution tool restrict the number of questions, unless the researcher pays for additional pages (Mann and Stewart, 2000). Electronic mail was also used to distribute the questionnaire and this achieved more success because the researcher made personal contact prior to sending the questionnaire electronically. In addition, site visits could be arranged and the researcher was also given the opportunity to either telephone or meet the participant face-to-face (Van Selm and Jankowski, 2006). The problem with Internet-based surveys is that firstly, the Internet does not provide any feedback data as to why the response rate is poor (Kay and Johnson, 1999) and as Van Selm and Jankowski, (2006) find:

'Online surveys have generally failed to meet the response standard set by comparable mail techniques' (Van Selm and Jankowski, 2006, p. 447).

Aside from attempts to collect data via Internet special interest groups, the researcher attempted to encourage participation in this study from other researchers involved in the two EU bioenergy projects. Again, this met with a very poor response rate. Similar assumptions were made that experts from North West Europe's leading academic institutions would possess the necessary experience and knowledge of bioenergy businesses. However, for whatever reason for limited co-operation such as the comments indicated below:

'I don't have the time' and,

'I am too busy working on the bioenergy project' and,
'This is not my area of expertise'.

All of which meant that the researcher had to develop an independent network of commercial practitioners involved in bioenergy production. It is interesting to note that Piterou et al. (2008) experienced the same problem in working with other research organizations. Shaefer and Dillman (1997) suggest mixed mode distribution of questionnaires and the researcher found personal contact was the most effective as this could be followed by a site visit and, furthermore become potential case study sites for the main study.

Table 4.2.1: Participants in the Scoping Study.

Type of Company	Role in the Company
Timber CHP Plant 15 MW	**Plant Manager:** Operations and production **Account Director**: Overall responsibility for financial accounting in the company and development plan **Project Engineer**: Installation Engineering Company
Energy Provider	**Supply Chain Manager:** Global sourcing and procurement of feedstock **Supply Chain Manager**: Green energy projects
Timber CHP 30 MW	**Plant Manager**: operations and production **Logistic Manager**: Biomass vehicle routing and scheduling, fleet management
Boiler Manufacturer	**Company Director**: Design and building bespoke CHP boilers
UK District Energy Company specializing in renewable energy	**Managing Director:** District heating **Operations Manager:** Day to day operations for public and district heating projects
Bioenergy Consultants Regional Development Agency and Board of Directors for Bioenergy Ltd Company.	**Bioenergy Consultants x 5**: independent consultancies, Regional Development Agencies who acted as intermediaries for fledgling bioenergy businesses. Board of Directors for bioenergy businesses. Their role was to advise on policy, regulation and financial opportunities
Logistics Company	**Biomass Logistics Manager**: Responsible for scheduling transport but has wider role in storage and processing feedstock **Procurement Manager**: 3PL contracts
Timber Supplier	**Operations Manager:** Growing, sourcing timber from forestry, sawmills, chipping and storage of biomass. Timber supplier was co-located to 30 MW Timber CHP Plant. **Procurement Manager and Officer**: Biomass contracts
Co-Generation Coal/CHP Firing Station	**Procurement Manager**: responsible for coal and biomass contracts **Operations Manager**: Day-to-day plant operations **Marketing and Communications Officer**: Company marketing and communications
Incineration Plant (waste company)	**Procurement Manager:** Biomass contracts, fleet leasing, **Operations Manager**: Responsible for day-to-day operations on site **Logistics Manager:** Vehicle routing and scheduling, storage management

4.2.1: Overview of Participants in the Study

Participants were representative of operations across the bioenergy supply chain, which totalled 26 respondents. Table 4.2.1: Participants in the Scoping Study, (p.103), provides details of their role and expertise. There were no participants from downstream areas of the supply chain such as distribution and marketing. It was observed that downstream characteristics of bioenergy supply chain integration commenced at the point of conversion rather than distribution as seen in the conventional supply chain and logistics literature. It was also noted that synergies between a timber feedstock provider and a logistics company were co-located adjacent to the site of a 30 MW plant. In addition, to co-location, long-term contracts were in operation that locked participating companies into a minimum of 5 year contracts to supply this particular CHP plant. It confirms that co-location between firms is an important characteristic of upstream integration.

The role of bioenergy consultants in the study helped provide an overview of this sector. Factors pertaining to how renewable energy is implemented and distributed into energy markets are yet to be determined into what is a heavily regulated and centralized industry (Tate and Mbzibain, 2012). Amongst the list of participants there were a number of equipment manufacturers. Most of these were Danish with only one participant, a boiler manufacturer located in the UK.

4.2.2: Section One - Supply Chain and Logistics Planning.

Security and reduction of risk in supply chain and logistics necessitates collaboration with suppliers through partnership and purchasing agreements. Dedicated UK bioenergy businesses are compelled to operate in this way, primarily due to the regulatory framework, and secondly, to meet planning and selection criteria that satisfies the main stakeholders. Table 4.2.2: Supply Chain and Logistics Planning gave a range of questions on supplier selection, inventory replenishment and carrier selection.

Table 4.2.2: Supply Chain and Logistics Planning

Section Question	Mean	Standard Deviation
1.1. Supplier selection, including energy companies is important to ensure security of supply of resources.	3.576923077	1.89
1.2. Inventory replenishment is important to ensure effective operations of bioenergy production.	3.538461538	1.88
1.3. Carrier selection is important to bioenergy supply chain planning and logistics.	3.538461538	1.88
1.4. Direct transport services is important to bioenergy supply chain planning and logistics.	3.615384615	1.9

The results showed that '1.4. Direct transport services are important to bioenergy supply planning and logistics, (AVGw: 4.192) was ranked highest followed by, '1.1. Supplier selection including energy companies is important to ensure security of supply of resources', (AVGw: 3.769) ranked the second highest. This would indicate that direct transport of feedstock into the conversion plant is regarded as the most important in supply chain planning and logistics and also indicates a positive relationship between transport services and supplier selection. The lowest score was found in '1.2. Inventory replenishment is important to ensure effective operations of bioenergy production', (AVGw: 3.385) indicated that this was not an important factor in supply chain and logistics planning. This could mean that the term, 'Supply chain and logistics planning' is seen from a strategic and stakeholder perspective rather than operational.

It was found that all participants that responded to the scoping study sought long-term contracts with feedstock providers of up to 5 years in the smaller plant, (15 MW) and up to 25 years in the largest plant of 30 MW. These forms of supplier agreements were not typical of co-generation and conventional energy producers. It may be the case that dedicated bioenergy companies who participated in the study sought longer term contracts to retain viability. Slade et al., (2011) confirm this as characteristic of such plants.

The accountant participant explained: '*We usually devise contracts with our suppliers of up to 10 years'*, but on the contrary, the Plant Manager from the co-generation company stated that their contracts, *'...lasted up to one year'*. This indicated a distinction in supplier agreements between feedstock suppliers in dedicated bioenergy and the co-generation company. Further interview data indicated that suppliers were selected on the quality of biomass and ability to supply.

4.2.3: Section Two – Logistics' Functions.

This section of the scoping study related to logistics operations in transportation and processing of biomass from feedstock provider to bioenergy producer seen in table 4.2.3: Logistics' Functions. Collaboration with third party logistics was in place prior to production, thus confirming the use of turnkey procurement practices. Development of the 'supply chain' during the planning phase of a bioenergy facility included selection of third party companies, namely logistics providers.

Table 4.2.3: Logistics Functions.

Section Question	Mean	Standard Deviation
2.1. The collection of bio-fuel/mass resources is an important feature in the logistics operations of the bioenergy organisation.	3.423076923	1.85
2.2. Storage of bio-fuels/biomass is a feature of logistics functions.	4.15384615	2.03
2.3. Sorting is part of the logistics operations.	3.23076923	1.79
2.4. Transitional processing is part of the logistics operations in the logistics operations.	3.57692308	1.89
2.5. Our company outsources all of the above.	4	2

Out of the five variables in Logistics Functions, '2.2. Storage of bio-fuels/mass is a feature of logistics operations', (AVGw: 3.923) was ranked the most important followed by, '2.5. Our company outsources all of the above', (AVGw: 3.769). This was attributed to the fact that bioenergy is a novel sector in the UK, therefore there are very few companies specialising in transportation of biomass. Co-location meant that feedstock and conversion facilities did not demand transportation, which is reflected in the results. The lowest ranking score was '2.1. The collection of biofuel/mass resources is an important feature of the logistics operations of the bioenergy organization', (AVGw: 2.423) and, '2.3. Sorting is part of the logistical operations in the organization', (AVGw: 2.423). This confirms that logistics' functions are not wholly integrated into management of bioenergy supply chains, coupled with the fact that there are few logistics companies that specialise in biomass and biofuel transportation, (at the time of writing in August 2015). However, one logistics provider who participated in the scoping study had made a significant investment in a fleet of 50 walking floor trailers and tractor units[1] to transport from biomass suppliers to conversion sites. The same company was also expected to store biomass (woodchip) until it reached the correct moisture levels prior to conversion. The literature confirms that most companies co-locate feedstock production and

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[1] **Walking Floor Trailer** is a hydraulically-driven moving floor designed to convey woodchip in this case and **Tractor Unit** refers to the driver cabs used in conjunction with a trailer

processing with conversion in order to minimize the distance to conversion sites (Mckechnie et al., 2010).

4.2.4: Section Three - Organizational Role.

Organizational role comprised six questions on the range of operations and processes in bioenergy production seen in Table 4.2.4. The majority of respondents ranked, ‘3.6. Partnerships and responsibility to Project Management Team, Funding Bodies are an important feature in the overall organizational strategic aim and objectives’, (AVGw: 4.615).

Table 4.2.4: Organizational Role.

Section Question	Mean	Standard Deviation
3.1. Co-ordination and organization of delivery are undertaken by the organization.	4.23076923	2.05
3.2. Decontaminating and cleaning is part of the operational role in the organization.	3.73076923	1.93
3.3. Waste management is critical to the operations of our organization.	3.03846154	1.74
3.4. Waste management is outsourced and passed on to 2nd customers in terms of the management of waste and/or bi-products from biomass.	3.84615385	1.96
3.5. Location is taken into consideration in the decision-making process of choice of site.	4.26923077	2.06
3.6. Partnerships and responsibility to the project management team, funding bodies is an important feature in the overall organizational strategic aims.	5.38461538	2.32

This confirmed bioenergy organizations in the UK tend to involve stakeholders from both public and private sectors. The second highest ranked score came from, '3.1. Co-ordination and organization of delivery is undertaken by the organization', (AVGw: 4.192), indicated that day-to-day operations were necessary to ensure effective management of the supply chain. However, some participants were concerned at the number of outside organizations and their level of interference as one Plant Manager commented:

'There are too many parties that are not part of the day-to-day operations and who interfere with running the plant'.

The lowest ranked score, '3.3. Waste management is critical to the operations of our organization', (AVGw: 3.038), showed utilization and management of waste products were not seen as of the responsibility of bioenergy production within the plant.

4.2.5: Section Four - User Satisfaction.

Section four: User Satisfaction in the scoping study questionnaire considered questions about customer relations' management, (see Table 4.2.5: User Satisfaction), The highest score was, '4.4. Marketing and brand image is important to the competitive strategy of the organization', (AVGw: 4.385) followed by, '4.3. Cost saving enables the organization to be more competitive', (AVGw: 3.962). Such responses indicated relationships between organizations in the supply chain are important factors. Bioenergy organizations in the UK tend to have an open door policy, which means that they promote bioenergy to the wider public. Many of these organizations are part funded by the public sector through National Government Initiatives and the European Union. Permitting the public to visit sites is seen as part of customer relationship management and a wider dissemination of the benefits of bioenergy (Faaij, 2006; Domac et al., 2005).

Table 4.2.5: User Satisfaction.

Section Question	Mean	Standard Deviation
4.1. Effective communications is important to user satisfaction in the organization.	3.69238768	1.92
4.2. Overall working relations is necessary to effective operations in the organization.	4.42307692	2.1
4.3. Cost saving enables the organization to be more competitive.	4.23076923	2.05
4.4. Marketing and brand image is important to the competitive strategy of the organization.	4.30769231	2.07
4.5. Service improvement is necessary to gain better user satisfaction ratings.	3.73076923	1.93

4.2.6: Section Five - Impact of Use.

Aligned with 'Organizational Role' and 'User Satisfaction', the fifth section posed questions on 'Impact of Use', (see Table 4.2.6). This was the smallest section of the scoping study questionnaire that ranged from customer satisfaction, profitability and employee morale. Question 5.2, 'Profitability is a key indicator of usage of bioenergy in our organization', (AVGw: 4.115), followed by, '5.1. Customer satisfaction is measured by the organization', (AVGw: 3.769) and the least important in this section was, '5.3. Employee morale is a measure of effective operations in the organization', (AVGw: 3.115). This was an interesting result because it confirmed bioenergy organizations, being a relatively new sector, have yet to acquire an infrastructure for internal operations such as human resources, training and development of employees. It was evident from site visits that the companies participating in the scoping study had only been established for less than two years and that there were no HR and marketing departments on site.

Table 4.2.6: Impact of Use

Section Question	Mean	Standard Deviation
5.1. Customer satisfaction is measured by the organization.	3.61538462	1.90
5.2. Profitability is a key indicator of usage of bioenergy in our organization.	3.76923077	1.92
5.3. Employee morale is a measure of effective operations in our organization.	3.23076923	1.79

4.2.7: Section Six - Organization Performance Costs.

This section did not require respondents to identify specific costs of value and running operations in their respective organizations, (see Table 4.2.7, p. 121). Instead, questions were aimed at identifying how important costs were to the overall performance of the organization. Of the five questions in section five of the scoping study questionnaire, '6.4. Flexibility in bioenergy production is important to the business', (AVGw. 4.154). Supply chain performance costs were difficult to specify due to the number of third parties involved within each organization. This was a major factor amongst the participants taking part in the scoping study, thus costs were merged with total operating costs of the main company, (where the bioenergy plant was part of another business and therefore did not operate independently). Another issue that arose from the findings was that there were no models of best practice and as the literature confirms current costs of energy produced from renewable sources are higher compared to energy produced from fossil fuels, which challenges some of the viability of horizontal integration in their supply chain. In section two of the scoping study questionnaire, 'Logistics functions', it was found, not only was transport outsourced but also co-location helped reduce such costs (Pereira, 2011; Lam et al. 2010).

Table 4.2.7: Organization Performance Costs

Section Question	Mean	Standard Deviation
6.1. Quality is measured, as it is key to effective performance.	3.26923077	1.80
6.2. Cost is an important indication of performance in our organization.	3.65384615	1.91
6.3. Time is an important indication of performance in the organization.	3.96153846	1.99
6.4. Flexibility in bioenergy production is important to the business.	3.88461538	1.97
6.5. Customer satisfaction is a performance measure.	3.92307692	1.98

4.2.8: Section Seven - I.T. Applications

The next section required participants to respond to six statements on how they applied Information Technology programs to bioenergy operations, (see Table 4.1.8:

I.T. Applications). These included functions such as auditing, procurement and other financial management programs for example. The results showed, ‘7.3. IT is used for planning the supply chain’, (AVGw: 4.038) as most important followed by, ‘7.1. IT is used for storage management’, (AVGw: 3.923). Information Technology and information sharing in bioenergy are central to decision-making and integration for optimizing visibility and parity between partners. In the case of the CHP plant involved in this scoping study, visibility in the supply chain was built into their infrastructure as part of the turnkey procurement arrangements. The least important factors in section seven were, ‘7.2. IT is used for order management’, (AVGw: 3.00) and, ‘7.5. IT is used for freight payment’, (AVGw: 3.00). I.T. software specifically developed for bioenergy operations was not in evidence during the scoping study. I.T. programs used by the companies were already in circulation and inherited from previous business operations.

Table 4.2.8: I.T. Applications

Section Question	Mean	Standard Deviation
7.1. IT is used for storage management.	3.30769231	1.81
7.2. IT is used for order management.	3.26923077	1.8
7.3. IT is used for planning the supply chain.	3.53846154	1.81
7.4. IT is used for shipment and tracking.	3.30769231	1.81
7.5. IT is used for freight payment.	2.69153846	1.72
7.6. IT is used for environmental auditing in the organization.	3.07692308	1.75

4.2.9: Section Eight - Waste Management Operations

Waste management operations were the final section of the scoping study questionnaire and required respondents to rank in order of importance statements on managing bi-products after the conversion of biomass. The content of this section ranged from questions and statements from using waste products as biomass to obtaining biomass feedstock from energy crops for example. The results in Table 4.2.9: Waste Management Operations, p. 124, showed the highest score was '8.2. The company sorts its own bi-products from bioenergy production', (AVGw: 4.231). However, the remaining four questions scored an AVGw >4. It was noted that the majority of participants came from biomass production and conversion, (upstream operations) rather than downstream operations in bioenergy. This may explain lower weighted average scores in downstream areas of bioenergy.

It was also reported during the scoping study fieldwork that levels of waste were negligible. The timber CHP Company reported high levels of alkaline in ash from combusting wood chip. This is referred to as Incinerator Bottom Ash (IBA), which could neither be used as fertilizer nor disposed in landfill. The company contracted with hazardous landfill company to dispose of the ash correctly. Their production manager stated:

'*There are only two companies who are accredited to take our ash away and dispose of it correctly'.*

This indicated that waste management on the post-conversion and downstream aspects of the bioenergy supply chain is an area that is not well documented in the literature as it mostly cites closed-loop systems that recycle bi-products (waste) as biomass/fuel (Cornelissen et al., 2012; Buchholz et al., 2007).

Table 4.2.9: Waste Management Operations

Section Question	Mean	Standard Deviation
8.1. The company organises cleaning/decontamination of the waste products/bi-products.	3.70692307	1.94
8.2. The company sorts its own bi-products from bioenergy production.	3.88461538	1.97
8.3. Storage is on-site of the waste products.	3.80769231	1.95
8.4. Transportation is required for waste products.	3.80769231	1.95
8.5. Waste management is outsourced.	3.73076923	1.93

4.3: Discussion of the Scoping Study Findings

It was assumed that participants were familiar with terms used in supply chain management, and such terms were not going to cause any confusion in completing the questionnaire. On reflection, this was not the case, particularly as some of the respondents did not fully understand the context of some of the questions. This must be taken into consideration when designing the questionnaire for the main study. However, the benefit of conducting a scoping study is to test the field and understand the boundaries of the research problem.

It was apparent that consensus had developed from particular questions despite anonymity amongst participants. From section one, (supply chain and logistics planning) direct transport services were highly important in supply chain planning and logistics. Most of the companies participating used third party logistics providers that in turn, invested in specialist trailers with walking floors and blowers. This is contrary to what is cited in the literature where feedstock providers, (mainly from the agricultural sector) are responsible for transport-to-bioenergy facility (Ebadian et al. 2011). In 'Logistics Functions', the highest score was sorting and storage of biomass, which confirms robust contractual relationships between feedstock producers, third party transport providers and conversion facilities. It was evident that involvement from stakeholder actors interact with operational processes, which is also confirmed in the literature, (Scott et al., 2013) and comments made during the interviews and site visits during the scoping study. In section three, 'Organizational Role', participants identified their relationship with public sector bodies as being more important. This is not an unusual result, as all UK bioenergy companies undertake rigorous planning applications to gain approval. However, just how many governmental bodies are involved either directly or indirectly, is one question that needs to be addressed, and to what extent the robustness of planning applications impact on supply chain integration is also a question that requires further investigation. Section Four, 'User Satisfaction', dealt with the extent of public relations, but better phrased questions on information sharing would have added rigour on this particular aspect of supply chain integration. In section five, 'Impact of Use', the results confirmed how nascent the bioenergy industry is in the UK compared to other EU countries. Acquisition of skill sets and human resource management are key to effective operations across the supply chain but this remains under-developed as Watkinson et al, (2012) confirm. Organizational performance costs in section six of the scoping study questionnaire strengthens the argument to identify supply chain costs, which is not provided from the initial fieldwork and survey questionnaire. Financial viability is critical to any firm and this does not exclude bioenergy, even if some operate at a micro-level, (Grubic et al., 2010). From an economic perspective, Olssen et al., (2011) find the cost of biomass depends on processes that co-integrate with one another. Thus, organizational performance costs should not only be perceived as internal to the organization but in addition, be considered across the whole supply chain. Control of the supply chain adds value, particularly when treated as a whole entity. On the other hand, a high number of inter-firm linkages in the supply chain add complexity, but bioenergy firms tend not to have too many inter-firm linkages at a commercial level. On the other hand the Scoping study indicated many stakeholder interventions, particularly during the planning phases. This provides a challenge to the study because there are a limited number of examples of best practice. Hamelinck et al., (2005) and Kraxner et al., (2013) report on the number of European and regional variations in the structure of bioenergy organizations but neither have identified models of best practice. Section seven, 'I.T. Applications' considered the utilization of I.T software to support operational processes rather than internal and external information flow, as cited in the literature. Responses were biased towards application of information technology in storage and logistics operations. In the final section, 'Waste Management Operations', was similar to the previous section as responses erred towards functional attributes rather than strategic features of bioenergy operations. Respondents showed bias towards sorting and decontaminating bi-products after conversion. However, there was insufficient evidence in the scoping study to ascertain whether there were potential market opportunities should such waste be recycled. It would appear that bioenergy supply chains are not truly integrated due to lack of maturity. Upstream integration in bioenergy supply chains is determined by the ability to compete with other agricultural production and land-use. The view that upstream integration given in the literature is less challenging is a misconception because attributes in bioenergy are difficult to standardize because they vary in size and type of feedstock used. Co-location from biomass-to-bioenergy is a significant characteristic, but is a factor that is perceived as part of downstream attributes of supply chain integration rather than how renewable energy is sold and distributed (Banks et al., 2011). Experts leading strategic bioenergy projects in North West Europe view the end point of the downstream process as being at the point of conversion and not distribution. Therefore, the bioenergy energy supply chain is defined by biomass-to-bioenergy rather than to the point of consumption which defines conventional supply chains.

Relational values in the bioenergy supply chain provide credence to a decision framework and more importantly, measure performance. The methods by which to measure bioenergy supply chain performance using conventional quality tools are not appropriate and further research needs to be conducted to identify supply chain characteristics of bioenergy of which this scoping study was a first attempt at undertaking this task. Only then, can parties contemplate contractual criteria pertinent to the firm that is meaningful between parties and give the bioenergy business a viable route.

4.4: Summary and Conclusion to the Scoping Study

The scoping study finds that bioenergy supply chains are defined differently from conventional supply chains, which are characterised from the point-of-origin to the point-of-consumption. Fundamental to the supply chain and emanating from the scoping study is the need to fully understand the role of the contract within the industry. Lack of universal standards specific to bioenergy led to the adoption of a plethora of dovetailed initiatives that add complexity to what are essentially, local supply chain systems (Scarlat and Dallemand, 2011). Bioenergy supply chain constructs are determined through their contractual relationships from planning application to project realisation. Supplier agreements featured as highly important in the scoping study and length of agreement between contracting parties was determined by two factors:

1. Rural diversification in seeking new business opportunities in bioenergy and,
2. Seeking new business opportunities in bioenergy within an existing business.

The bioenergy CHP plant in the scoping study procured long-term contracts with suppliers of five to twenty-five years. This contrasted with the co-generation plant that instead, procured annual contracts with suppliers. Whilst there are advantages of longer-term contracts they are not without risk because parties are committed to an agreement even when they are no longer viable. For example, fluctuations in price of feedstock could result in parties being held into an unprofitable agreement. Upstream integration in supply and processing of biomass was a key area of collaboration between feedstock producers, logistics providers and conversion facilities. However, in the case of downstream, there was no evidence of integration from the scoping study findings. Energy distribution depends upon a number of factors, which were identified through interviews and site visits with the participants at the time of data collection. National Government renewable energy initiatives provided both dedicated bioenergy and co-generation plants on renewable energy production receipt of Renewable Energy Certificates, (RECs) and Renewable Obligation Certificates, (ROCs). RECs represent a contractual right of the holder to claim any benefit that is associated with energy created from renewable sources. They are also known as ‘Green Tags’ or ‘Renewable Energy Credits’. Each REC certifies that a single megawatt-hour (mwh) of electricity was generated from renewable sources. Renewable Obligation Certificates, (ROCs) are green certificates issued to operators of renewable generating stations for the eligible renewable electricity they generate. Operators can trade ROCs with other parties. These came into force in England, Wales and Scotland during 2002, and in Northern Ireland during 2005. Dedicated bioenergy producers benefit more from RECs than ROCs than co-generation plants but totally dedicated plants in the UK tend to be from small-scale producers. Further research needs to address organization costs in order to elicit data on the effectiveness of such initiatives. Respondents in the scoping study alluded to providing a high degree of accountability but the findings proved inconclusive, as the questions in the section on organizational performance costs were not well phrased. Likewise participants did not completely understand the questions in, 'User Satisfaction and 'Impact of Use' sections of the scoping study questionnaire. Specific questions on costs and length of agreement between suppliers would help form the basis of a quantitative study. Information Technology, in section of the questionnaire focussed on upstream processes in feedstock supply, quality assurance and conversion operations. I.T. Applications did not, however, include any downstream operations such as distribution and marketing of bioenergy. Respondents indicated the importance in co-locating with feedstock and logistics providers. Waste management operations and bi-products from conversion were less well defined. One respondent reported that waste processes were outsourced which, if proved significant in the main study would add more complexity and cost if such bi-products could not be re-used as feedstock. Increasingly supply chain relationships depend on 'soft' data, which embellish the depth of integration between parties.

The main study in chapters six (results from main study) and chapter seven (analysis from main study findings) takes some valuable lessons from the scoping study with which to develop the research question, 'What are the factors that integrate bioenergy supply chains in the UK?' Firstly, the literature and the scoping study confirmed the definition of a bioenergy supply chain, which is defined from the point of origin (biomass) to the point of conversion, (bioenergy). Whether this can be expanded to include, 'to the point of consumption' is an area for further study outside the parameters of this thesis. Such boundaries provide this study with a set of constraints (rules), which, then define the research constructs and enable the study to progress into the next phase. The next chapter defines the Region on which the main study is based and following on from chapter five, chapter six provides results arising from survey questionnaires and case studies in ascertaining what factors are effective in integrating supply chains in bioenergy.

Chapter Five: Overview and Scope of Renewable Energy in the West Midlands Region.

5.0: Chapter Overview, Purpose, Method and Main Findings.

Chapter five in the study starts by giving a general overview of the socio-economic background in the West Midlands region. Following on from this, the chapter provides data and analysis of renewable energy and in particular, focuses on biomass potential capacity within the Region. The intent of this chapter is to provide information about the biomass-to-bioenergy supply chain that comprise different technologies, feedstock and locations within the Region on which this study is based. Data and information sources for chapter five comprised secondary data from published sources and are cited accordingly. The findings from the data indicate the capacity for renewable energy, and in particular those technologies utilising biomass in the West Midlands region. The chapter, in addition, identifies the main constraints that hinder the development of supply chain integration in bioenergy.

5.1: Introduction: How Can the West Midlands Develop a Biomass-to-Bioenergy Supply Chain?

The purpose of this chapter is to provide an overview of renewable energy in the West Midlands. In particular, the chapter focuses on biomass technologies and locations. It takes most of its content from Local Authority feasibility reports on potential capacity for renewable energy, of which the latter part of the chapter provides the scope for development of a biomass-to-bioenergy supply chain within the region. The context neither defends nor argues the case for effective characteristics of supply chain integration in this chapter. This is provided in chapters six and seven, research findings and analysis.

5.2: Potential Bioenergy Capacity in the West Midlands: Setting the scene – The Socio-Economic Background.

Whilst the scoping study gathered data of bioenergy firms throughout the UK, the main study centres on the biomass-to-bioenergy supply chain in the West Midlands Region provided in sections 5.3 to 5.4. The first part of this chapter establishes the socio-economic background that leads to the development of bioenergy in this Region.

The West Midlands Region comprises counties of Herefordshire, Shropshire, Staffordshire, Warwickshire, the former West Midlands Metropolitan County and Worcestershire, (shown in Figure 5.2.1: Map of the West Midlands, p. 131). It is a land-locked area, surrounded by Wales, Gloucestershire and Oxfordshire in the West and South West; Leicestershire and Northamptonshire in the East; Cheshire and Derbyshire towards the North. Administratively, the West Midlands are made up of the former West Midlands Metropolitan County. It is 13,000 KM^2. The Region has the UK's smallest National Park amounting to 2% of total land area. However, the Region has five areas of outstanding natural beauty (AONB), which are: Malvern Hills, Cannock Chase, parts of the North Cotswolds in Worcestershire and Wye Valley in Herefordshire. These areas (AONB) cover 127,000 hectares and account for 10% of the total area in the Region. The Region has good communication links of both road and rail to other parts of the UK. It is served by several motorway links that include: M5, M6, M1, M40, M42 and M54. The main cities include, Birmingham, Coventry, Hereford, Shrewsbury, Stafford, Stoke-on-Trent, Telford and Worcester. The population is just over 5.4 million (mid-2009) and distribution of population (people per km^2) is given in Figure 5.2.2: Map of West Midlands Population Density on page 133.

Figure 5.2.1: Map of the West Midlands Region.

Source: Ordnance Survey Digital Map 2011.

The most sparsely populated counties in the West Midlands are Herefordshire and Shropshire representing =/< 99 people per km^2, with the most densely populated Counties of =/>2,500 people per km^2 in Stoke on Trent, Wolverhampton, Sandwell, Birmingham and Coventry. Compared with the national average increase of population of 3.3% in the UK. The former West Midlands Metropolitan Authority had a population of 2.6 million during 2009, comprising Birmingham, Coventry, Dudley, Sandwell, Solihull, Walsall and Wolverhampton. Birmingham has the second highest population compared to other Unitary Authorities the UK. During 2009 population density in the West Midlands was 418 people km^2, representing the fourth highest of all UK Regions and greater than the average for England (398 people km^2), (ONS 2011-2012).

Manufacturing in the West Midlands accounted for £14 billion, 15% of total GVA in the West Midlands, which was higher than the rest of the UK. Wholesale and retail (including the motor trade) accounted for 13% and 12% respectively. It was during this time (2011-2012) that the Region underwent major economic restructuring partly due to the economic downturn and rising unemployment as a consequence. The highest decline was in the total number of manufacturing jobs from 22% of the workforce employed in manufacturing in 1996 compared to just 11% of the working population employed in manufacturing in 2010. This amounted to 164,000 jobs in manufacturing to 112,000 jobs in the sector at the end of 2010. Reduction of manufacturing jobs has been compensated by an increase in the number of public sector jobs in health and social services, professional, scientific and technical sectors. These increased from 30,000 jobs in 2008 to 41,000 jobs in 2010. Potentially, jobs in these sectors could have been higher but the West Midlands spent less on R&D compared to other UK Regions. During 2008 approximately £1.2 million was spent on R&D, 73% of this amount directly from businesses (£892 million) with just 0.3% from National UK Government, (£4 million) and 27% from HE Institutions, (£33.4 million).

Figure 5.2.2: Map of the West Midlands and Population Density.

Source: Office of National Statistics

In summarising key factors that shape the region it has a geographical spread of highly urban and rural areas. The former Metropolitan County in the West Midlands accounts for 13,000 people per square kilometre, (2010 Census). In contrast, rural Counties of Worcestershire, Herefordshire, Shropshire has less than 1000 people per square kilometre, (2010 Census). Manufacturing, including car manufacturing dominated the West Midlands but has been in decline during the past decade. However, there are still areas of car manufacture in Coventry and Solihull, (Jaguar Land Rover) and Malvern (Morgan Cars) in Worcestershire. There has been a significant increase in technical and scientific jobs in the Region of 11,000 people since 2008, but such employment does not necessarily mean jobs in R&D. The figures could account for the eight universities in the Region, which include four universities based in Birmingham. In part, the HE sector does have some stake hold in bioenergy development, particularly with the EU funded projects referred to in the study. This amounted to 13.7 million Euros [1]and 7.9 million Euros in two bioenergy projects through the Interreg IVB programme.

In the light of population density and polarity between urban and rural areas in the Region gives rise to contrasting conditions for bioenergy requirements. Feedstock production and potential for bioenergy is different in rural and urban areas due to land use and characteristics inherent with each County.

5.3: Renewable Energy Potential in the West Midlands.

At the time of writing energy demand in the West Midlands totalled 188.5 MW, which equates to 80,000 households. The categories of renewable energy considered in the West Midlands are identified in Table 5.3.1: Categories of Renewable Energy on page 124. This table shows a range of potential sources for bioenergy production. The challenge presenting renewable energy development as a sector is biomass is difficult to define due to diversity of potential feedstock, according to the Department for Climate Change (DECC, 2010). Despite this factor, the EU Renewable Energy Directive and UK Biomass Strategy attempt to provide more precise definitions.

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[1] It should be noted that the figures provided for two EU Interreg IVB projects do not cover all initiatives in bioenergy and related sustainability initiatives in the West Midlands. The figures do not include Birmingham City Road Map - an initiative of £48 million EU funding to develop a 'Green' Enterprise District.

Generally, biomass is derived from plants (woody and grass material), animals, (slurry, manure) and human activity, (industrial and municipal waste). Plant biomass is sourced from managed woodland, energy crops, waste wood and agricultural arisings, namely straw for the purpose of generating electricity and heat. In the West Midlands Region plant biomass accounts for the second, lowest sources of low carbon feedstock, (3%, see table 5.3.1). Potential capacity from municipal and industrial waste (including commercial waste) has yet to be realised. This factor provides potential for an emergent supply chain.

Table 5.3.1: Categories of Renewable Energy.

Category	**Sub-Category Level**	**Description**
Wind	Wind Commercial and small scale	On-shore wind power generation
Biomass	Plant biomass	Managed woodland, energy crops, waste wood, agricultural arisings (straw)
	Animal biomass	Wet organic waste, poultry litter
	Municipal solid waste, commercial industrial waste	Domestic household waste and commercial and industrial waste
	Biogas	Landfill and sewage gas
	Co-firing of biomass (with fossil fuel)	Fossil fuel is mixed with a proportion of biomass e.g. olive stones.
Hydropower	Small-scale hydropower	Power generated by water
Micro-generation	Solar	Solar photovoltaic (PV), solar water heating
	Heat pumps	Ground source heat pump and air source heat pump.

Source: Adapted from the Renewable Energy Capacity Study for the West Midlands, March 2011, pp. 14-15.

Constraints in development of energy production from low carbon resources according to the Renewable Energy Capacity Study Report, 2011 are presented in Table 5.3.2: Renewable Energy Constraints, (p. 136). Given the number of constraints that determine implementation of renewable energy the underlying trend is to generate more energy from renewable sources in the Region. Table 5.3.3: Low Carbon Potential in the West Midlands by Local Authority on page 137.

Table 5.3.2: Renewable Energy Constraints.

Constraint	**Explanation**
Availability of Resources	Quantification of available feedstock and land use.
Technical Feasibility	How much can the West Midlands generate from renewable energy resources? How viable is the technology?
Physical Environment	Identification of physical barriers to renewable energy development and deployment.
Planning and Regulatory Constraints	Assessment, monitoring, H&S considerations to reduce the negative impact on the environment. Environmental integrity of the location of proposed renewable energy development.
Economic Viability and Supply Chain Planning	End-to-end business viability of renewable energy

Source: Adapted from Renewable Energy Capacity Study for the West Midlands, March 2011.

Data from the table confirms a relationship between stakeholder attributes and process attributes that integrate the biomass to bioenergy supply chain. For example, if the end-to-end supply chain is to be realised, linkages across planning, regulatory, technology and security of supply have to be secured through formation of contractual agreements.

Table 5.3.3: Low Carbon Potential in the West Midlands by Local Authority.

Local Authority	**Domestic demand GWh/y**	**Commercial demand GWh/y**	**>3000 KW/KM^2 combined demand GWh/y**	**Additional demand in area, GWh/y**	**Total demand GWh/y**	**% of total demand**
Herefordshire	0	0	0	0	0	0
Telford & Wrekin	0	0	315	0	315	0
Shropshire	0	0	0	0	0	0
Stoke-on-Trent	73	248	652	155	1,128	7
Birmingham	1,689	1.525	2,404	637	6,254	40
Solihull	55	0	383	2	440	3
Coventry	446	287	441	141	1,315	9
Wolves	161	127	680	83	1,052	7
Walsall	66	205	388	68	707	5
Sandwell	227	227	1,173	60	1,686	11
Dudley	111	0	866	31	1,008	7
Staffordshire	90	277	493	109	969	6
Warwickshire	75	0	365	21	461	3
Worcestershire	0	0	226	0	226	1
Total West Midlands	**2,992**	**2,896**	**8,366**	**1,306**	**15,559**	**100**

Source: Adapted from the Renewable Energy Capacity Study for the West Midlands, March 2011, pp. 4-5.

Potential accessible renewable energy in the West Midlands accounts for a total of 54,171 MW energy comprised of 38,361 MW on-shore wind power generation, 1,204 MW energy generated from biomass, 72 MW hydropower and 13,605 MW micro-generation, (which includes heat and air ground-source pumps) according to the Renewable Energy Capacity Study for the West Midlands, (March 2011). This can be sub-regionally divided into counties that align with a given type of renewable energy technology provided in Table 5.3.4: Bioenergy Technology Potential by Local

Authority in the West Midlands, p. 139. The table excludes electricity generated from managed woodland and energy crops and heat generated from waste wood because production of electricity and heat are mutually exclusive for these technologies. Low carbon energy from either combined heat and power (CHP) or tri-generation and district heating schemes could provide an opportunity to develop community-based schemes. Most renewable energy in the Region is based on demand for heat. Potential for the West Midlands is 15, 559 GWh/y, (1.8 GW) with Birmingham accounting for 74% of renewable energy production. The Renewable Energy Capacity Study (2011) outlined potential for renewable energy generated from on-shore wind of 54.2 GW. This dominates other sources of renewable energy generation and such technologies are not suited to the diversity of locations in the Region. Given such potential diverse sources for renewable energy there are a range of alternate routes and roles within the Regions Local Authorities to achieve a 15% target by 2020 of energy sourced from low carbon technologies with both wind and micro-generation comprising 93% of renewable energy capacity. Large-scale biomass could make a significant contribution by 2030 as the West Midlands has potential capacity for approximately 2 GW from CHP and tri-generation, (including district heating schemes).

Table 5.3.4: Bioenergy Technology Potential by Local Authority in the West Midlands.

Local Authority	**Bioenergy Technology**	**MW Capacity**
Herefordshire	Large-scale wind and biomass from energy crops	8,951
Telford and Wrekin	On-shore wind and micro-generation	1,270
Shropshire	On-shore wind, biomass from energy crops and hydropower	10,844
Stoke-on-Trent	Micro-generation	594
Birmingham	Micro-generation and Municipal waste	2,210
Solihull	Micro-generation	672
Coventry	Micro-generation	681
Wolverhampton	Micro-generation	626
Walsall	Micro-generation	613
Sandwell	Micro-generation	628
Dudley	Micro-generation	781
Staffordshire	Large-scale wind power, micro-generation, biomass from energy crops	9,400
Warwickshire	Large-scale wind power, micro-generation, biomass from energy crops	9,085
Worcestershire	Large-scale wind power, micro-generation, biomass from energy crops and hydropower	7,817

Source: Adapted from The Renewable Energy Capacity Study for the West Midlands, 2011.

Wind energy has more potential capacity in rural areas, but is constrained by being located the greatest distance from National Grid connections. To deploy power from on-shore wind would require construction work to develop grid connections where turbines are located. Table 5.3.5 shows that only the Counties of Herefordshire, Shropshire, Staffordshire, Warwickshire and Worcestershire are potential locations for production of bioenergy from biomass. The remaining upper tier Authorities in the West Midlands of Telford and Wrekin are located in rural areas with remaining, urban Authorities of Birmingham, Solihull. Coventry, Wolverhampton, Walsall, Sandwell and Dudley showing potential for micro-generation from solar, ground and air-source heat pumps. Considering the amount of domestic, commercial and industrial waste from these urban Authorities (e.g. Birmingham produces approximately 300,000 tonnes of domestic waste per annum), there is a lack of infrastructure to convert this potential feedstock into bioenergy. Most municipal waste is incinerated because of a long-term contractual agreement in place, (at the time of writing August 2015). Renewable energy from other sources show that in total the West Midlands have the potential to produce 54.2 GW is derived from wind power (36,727 MW, 71%), followed by micro-generation, (14,171 MW, 25%). The remaining 4% is comprised of biomass at 1,204 MW, (3%) and hydropower at 72 MW, (1%). This is demonstrated in table 5.3.5: Accessible Renewable Energy Potential by Technology Category on page 145. Adoption of renewable energy technologies could be attributed to the FiT and ROC GWh rates given in tables 5.3.5, (pp.141-142) and 5.3.6 (p. 143) of this chapter as both Couture and Gargnon (2009) and Lipp (2007) confirm the role of financial support through incentivising companies to develop renewable energy initiatives. In the example shown for the West Midlands, assuming that the ROC GWh and FiT rates are applied to renewable energy categories in the West Midlands (see Table 5.3.8: ROC GWh and FiT Rates for Renewable Energy Technologies in the West Midlands, p. 146). This would explain the low adoption for biomass compared to wind and solar power generation. It is difficult to calculate the exact value from FiT and ROC MWh rates for renewable energy technologies, therefore figures are based on sub-totals on from Table 5.3.7: Accessible Renewable Energy Potential by Technology Category, p. 145.

Table 5.3.5: Renewable Energy Technologies in Receipt of ROCs/MWh.

Generation type	**ROCs/MWh**	ROC * £41.50[2]
Hydro-electric	1[150 3]	41.50
Onshore Wind	1 [151 4]	164.00
Offshore Wind	1.5[152 5]	62.25
Wave	2	83.00
Tidal Stream	2	83.00
Tidal Impoundment – Tidal Barrage	2	83.00
Tidal Impoundment - Tidal Lagoon	2	83.00
Solar Photovoltaic	2 153[6]	164.00
Geothermal	2	83.00
Geopressure	1	41.50
Landfill Gas	0.25	10.37
Sewage Gas	0.5	20.75
Energy from Waste with CHP	1	41.50
Pre-banded gasification	1	41.50

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[2] Price per ROC/MWh is £41.50 as at March 2014.

[3] [150] Small-scale hydro below 1MW receives increased support in Northern Ireland varying from 4 ROCs to 2 ROCs according to scale. In Scotland, enhanced tidal stream receives 3 ROCs and enhanced wave receives 5 ROCs.

[4] [151] Small-scale onshore wind 250kW or below in Northern Ireland receives 4 ROCs per MWh

4. 2 ROCs subject to meeting specific criteria from 1 April 2010,
5. [153] Small-scale PV 50kW or below in Northern Ireland receives 4 ROCs per MWh

Table 5.3.5: Renewable Energy Technologies in Receipt of ROCs/MWh, (continued).

Pre-banded pyrolysis	1	41.50
Standard gasification	1	41.50
Standard pyrolysis	1	41.50
Advanced gasification	2	83.00
Advanced pyrolysis	2	83.00
Anaerobic Digestion	2	83.00
Co-firing of Biomass	0.5	20.75
Co-firing of Energy Crops	1	41.50
Co-firing of Biomass with CHP	1	41.50
Co-firing of Energy Crop with CHP	1.5	62.25
Dedicated Biomass	1.5	62.25
Dedicated Energy Crops	2	83.00
Dedicated Biomass with CHP	2	83.00
Dedicated Energy Crops with CHP	2	83.00

Source: Adapted from National Renewable Energy Action Plan for the United Kingdom Article 4 of the Renewable Energy Directive 2009/28/EC, p. 114.

Table 5.3.6: Feed-In-Tariff Rates Between March 2014 and April 2015 by Renewable Energy Technology Scheme.

Renewable Energy Technology Installation	Tariff Period Date	Tariff pence per kilowatt hour (p/kWh)
AD =/<250 kW	01.04.14-31.03.15	12.46*
AD 250-500 kW	01.04.14-31.03.15	11.52*
AD >500 kW	01.04.14-31.03.15	9.49*
Hydro =/<15 kW	01.04.14-31.03.15	21.12*
Hydro 15-100 kW	01.04.14-31.03.15	19.72*
Hydro 100-500 kW	15.03.13-31.03.14	16.41
Hydro 500 kW-2 MW	01.04.14-31.03.15	12.18*
Hydro > 2 MW	01.04.14-31.03.15	3.32
Wind =/<1.5 kW	01.04.14-31.03.15	22.23
Wind 1.5-15 kW	01.04.14-31.03.15	17.78
Wind 15 kW-100 kW	01.04.14-31.03.15	17.78*
Wind 100-500 kW	01.04.14-31.03.15	14.82*
Wind 500 kW-1.5 MW	01.04.14-31.03.15	8.04
Wind >1.5 MW	01.04.14-31.03.15	3.41

*Retail Price Index (RPI) annually adjusted (Dec 2013) at 2.7. Tariff rates are pence per kilowatt-hour at 2014/2015 values.

Source: Adapted from https://www.ofgem.gov.uk/ofgem-publications/87072/010214rpiadjustedtariffspv1.pdf and https://www.ofgem.gov.uk/ofgem-publications/87072/010214rpiadjustedtariffspv1.pdf

According to tables’ 5.2.5 and 5.2.6 in this chapter, the following amounts could be generated:

Wind (small-scale on-shore wind power =/<1.5 kW) x FiT rate
38,361 x 22.3
= £85,540.30
Wind (small-scale on-shore wind power =/<1.5 kW) x ROC MWh
38,361 x 164
= £6,291,204

Biomass 1,204 MW x FiT rate @£12.46
= 1,204 x 12.46
= £15,001.84
Biomass x ROC MWh
= 1,204 x 41.50
= £49,966

Hydropower (small-scale =/<1.5 kW) x FiT rate @ £21.12
= 72 x 21.12
= £1,520.64
Hydropower (small-scale =/<1.5 kW) x ROC MWh @ £41.50
= 72 x 41.50
=£2,988

Microgeneration (solar PV, ground and air source heat pumps) x FiT rate @£6.61
= 14,171 x 6.61
= £93,670.31
Microgeneration (Solar PV) x ROC MWh @ £164
= 2531 x 164
= £415,084
Microgeneration (Ground and air source heat pumps) x ROC MWh @ £83
= 11,074 x 83
= £919,142.

Table 5.3.7: Accessible Renewable Energy Potential by Technology Category.

Technology Group	MW by tech group	Sub-category	Description of sub-category	MW by sub-category
On-shore wind	38,361	Wind-commercial scale Wind small-scale	15-100 kW =/<1.5 kW	36,727 1,634
Biomass	1,204	Plant biomass Animal biomass Municipal solid waste Commercial & industrial waste Biogas Co-firing biomass with fossil fuel	Managed woodland, waste wood, straw Wet organic waste, poultry litter Domestic refuse, garden waste Pallets, stationery, packaging Landfill & Sewage gas Mix of agricultural waste e.g. olive stones	1,737 183 209 145 45 106
Hydropower	72	Small-scale	=/<1.5 kW	72
Micro-generation	14,171	Solar	PV, water heating Ground & air source heat pumps	2,531 11,074
TOTAL	**54,171**			**54,171**

Source: Adapted from The Renewable Energy Capacity Study for the West Midlands, March 2011, pp. 16-17.

Table: 5.3.8: ROC GWh and FiT Rates for Renewable Energy Technologies in the West Midlands.

Renewable Energy Category	GW capacity[7]	FiT [8] £	ROC MW/h [9] £
Wind	3.6	Small-scale 22.23 Large-scale 17.78	164.00
Biomass: AD (municipal, inds, agri waste) **Biogas:** Landfill Gas Sewage Gas **Co-Firing Biomass**	0.12	Small-scale 12.46 Large-scale 9.49	41.50
Hydropower	0.07	21.12	41.50
Solar: PV Ground Source Heat Pumps Air Source Heat Pumps	1.4	6.61	164.00 83.00 41.50
West Midlands Total	**5.19**	**£195,733.09**	**£7,678,384**

At 5.19 GW the West Midlands potential revenue through FiT and ROC MWh rates would be £7,874,117.09 million for renewable energy. This is based on Department of Climate Change rates up to 1st April 2015 and data for renewable energy potential in the West Midlands. In addition, this figure is without revenue generated from heat and electricity production.

The study will focus on biomass rather than solar, hydropower and wind power generation. Firstly, because the biomass-to-bioenergy supply chain is not well documented in the literature and secondly, biomass shows the most potential in distribution across urban and rural areas in the region.

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[7] Figures have been rounded up taken from Table 5.3.8 therefore total for West Midlands is 5.19 GW as opposed to 5.4 GW.

[8] FiT rates are based on calculations on page 143.

[9] ROC MWh rates are based on calculations on pages 141-142.

5.4: Potential Renewable Energy Capacity from Biomass in the West Midlands.

Managed woodland is an accessible resource in the West Midlands and can be easily transported to a conversion facility. This has implications for development of a supply chain due to the requirement for third party involvement and supplier-buyer transactions between feedstock provider and conversion site. National criteria for supply of woody material is determined by the Forestry Commission's Wood Fuel Resource Tool and National Inventory of Woodland (2003) provides data on oven dried tonnes, (odt) of biomass of different wood types, of which there is approximately 98,474 hectares of woodland in the West Midlands (Forestry Commission, 1997). The DECC benchmark is 6000 odt pa of biomass per 1 MW of electricity capacity from wood biomass. It therefore is assumed that conversion plant efficiency over actual output over time and operating costs over the same time period could generate 80% heat whilst operating at 45% capacity (DECC and Carbon Trust Guide, 2009). The Renewable Energy Capacity Study (March, 2011) give output of both heat and electricity from managed woodland sources by Local Authority. Table 5.4.1: Managed Woodland Biomass Heat and Electricity Potential Output on page 148 shows 31 MW electricity and 36 MW heat could be generated in the West Midlands. Shropshire and Herefordshire provide 20-30% of managed woodland resource, which is characteristic of these being Local Authorities in rural areas. There is potential to increase utilisation of wood biomass due to ease of transportation linkages and availability of storage and this in turn, provides added value. However, the development of this supply chain is restricted by high transport costs and infrastructure as the Biomass Energy Organization provides (www.biomass-energy.org).

Energy crops provide another source of biomass. The Department for Climate Change (n.d.) identifies three categories of crop agriculture comprising high, medium and low categories. Only low land use categories are permitted under the Energy Crop Scheme for biomass. High and medium categories are required for food production. Within the Region, energy crops include miscanthus and short rotation coppice and of which generates 229 MW of electricity and 1,321 MW heat. Table 5.4.2: Energy Crop Potential Capacity for Electricity and Heat (MW) on page 149. For information, data presented in the tables: 5.4.1 to 5.4.10 show sub-totals inclusive of the Unitary Authorities of Staffordshire, Warwickshire and Worcestershire. In addition, figures have been rounded up to the nearest next number.

Table 5.4.1: Managed Woodland Biomass Heat and Electricity Potential Output.

Local Authority	**Electricity**		**Heat (MW**	
	MW	**%**	**MW**	**%**
Herefordshire	6.0	20.0	7.0	20
Telford and Wrekin	0.2	1.0	0.2	1.0
Shropshire	9.0	30.0	11.0	30.0
Stoke-on-Trent	0.1	0.2	0.2	0.2
Birmingham	0.2	1.0	0.2	1.0
Solihull	0.1	0.4	0.2	0.4
Coventry	0.1	0.2	0.1	0.2
Wolverhampton	0.0	0.2	0.1	0.2
Walsall	0.1	0.2	0.1	0.2
Sandwell	0.1	0.2	0.1	0.2
Dudley	0.1	0.2	0.1	0.2
Staffordshire	7.0	22.0	8.0	22.0
Warwickshire	3.0	10.0	3.0	10.0
Worcestershire	5.0	16.0	6.0	16.0
West Midlands Total	**31.0**	**100.0**	**36.0**	**100.0**

Source: Adapted from the Renewable Energy Capacity Study for the West Midlands, March 2011, pp. 37-38.

The counties of Shropshire and Staffordshire have the highest potential in managed woodland feedstock compared to the remaining counties in the West Midlands, (Shropshire - Electricity 9 MW/30% and Heat - 11 MW/30%; Staffordshire Electricity 7 MW/22% and Heat 7 MW/22%) from a total of 31 MW electricity and 36 MW heat in the Region from managed woodland material. According to the report, the volume of managed woodland, which is virgin woodland, is unsustainable as a potential biomass feedstock compared to waste wood shown in the next table 5.4.2.

Table 5.4.2: Waste Wood Biomass Potential Capacity for Electricity and Heat (MW).

Local Authority	**Electricity**		**Heat (MW**	
	MW	**%**	**MW**	**%**
Herefordshire	1	3	1	3
Telford and Wrekin	1	3	1	3
Shropshire	2	5	1	5
Stoke-on-Trent	2	4	1	4
Birmingham	8	21	7	21
Solihull	2	4	1	4
Coventry	2	6	2	6
Wolverhampton	2	4	1	4
Walsall	2	4	1	4
Sandwell	2	5	2	5
Dudley	2	5	2	5
Staffordshire	5	14	4	14
Warwickshire	4	11	3	11
Worcestershire	4	10	3	10
West Midlands Total	**37**	**100.0**	**32**	**100.0**

Source: West Midlands Renewable Energy Capacity Study, March 2011, pp. 42-43.

In contrast to managed woodland as potential feedstock, it is not surprising that the area in the West Midlands with the highest population density has the most supply of waste wood, (8 MW electricity and 7 MW for heat) accounting for 21% in each case. The total for the West Midlands has the potential for 37 MW of electricity and 32 MW heat supply of feedstock from waste wood. It is easy to transport compared to virgin round wood but is marred by the problem of sorting and cleaning prior to combustion. The next table shows data that identifies potential output from poultry litter in Table 5.4.3: Energy Crop Potential Capacity for Electricity and Heat (MW).

Table 5.4.3: Energy Crop Potential Capacity for Electricity and Heat (MW).

Local Authority	**Electricity**		**Heat (MW**	
	MW	**%**	**MW**	**%**
Herefordshire	42.0	18.0	241.0	18.0
Telford and Wrekin	4.0	2.0	24.0	2.0
Shropshire	70.0	31.0	405.0	31.0
Stoke-on-Trent	0.1	0.0	1.0	0.0
Birmingham and Solihull	2.0	1.0	12.0	1.0
Coventry	1.0	0.2	3.0	0.2
Wolverhampton, Walsall, Sandwell and Dudley	0.1	0.3	4.0	0.3
Staffordshire	45.0	20.0	259.0	20.0
Warwickshire	34.0	15.0	194.0	15.0
Worcestershire	31.0	13.0	178.0	13.0
West Midlands Total	**229.0**	**100.0**	**1321**	**100.0**

Source: Adapted from the Renewable Energy Capacity Study for the West Midlands, March 2011, p. 40.

The table shows more potential for energy crops as a biomass resource than woody biomass. Potential capacity in the West Midlands is a total of 229 MW of electricity and 1,321 MW heat from energy crops. Shropshire has the highest potential (electricity 70 MW/31% and heat 405 MW/31%), followed by Staffordshire in the north of the Region providing a potential of 45 MW of electricity and 259 MW heat from energy crops. The Renewable Energy Capacity Study for the West Midlands (March 2011) considers that rural counties in the Region have the potential to produce higher volumes of biomass from energy crops than predicted in their report. Other agricultural material includes the bi-product referred to as agricultural arisings, which is straw in this case and is shown in table 5.4.4. Straw, however, does not have any heat potential but can be used for electricity production via combustion from CHP technologies.

Table 5.4.4: Potential Capacity from Agricultural Arisings (Straw) in the West Midlands.

Local Authority	**Electricity**	
	MW	**%**
Herefordshire	9.0	18
Telford and Wrekin	2.0	3
Shropshire	12.0	24
Stoke-on-Trent	2.0	0
Birmingham	0.2	0
Solihull	1.0	1
Coventry	0.1	0
Wolverhampton	0.0	0
Walsall	0.1	0
Sandwell	0.1	0
Dudley	0.1	0
Staffordshire	7.0	15
Warwickshire	13.0	26
Worcestershire	7.0	14
West Midlands Total	**51.0**	**100.0**

Source: West Midlands Renewable Energy Capacity Study March 2011, pp. 44-45.

Warwickshire shows highest potential of renewable energy from straw, (13 MW/26% for electricity production). In total the West Midlands has the potential to produce 51 MW from straw. Straw is a highly risky feedstock because not only is it a seasonal crop but, it is expensive to store and has a low calorific value during combustion in electricity production. Given the low value of straw and fluctuating prices, it does not justify the expense of transportation to a conversion facility. According to the Biomass Energy Centre in the UK, straw has a net calorific value (CV) or lower heating value (LHV) of around 13 MJ/kg from 15%-25% moisture content. In addition, due to high levels of nutrients during harvesting gives straw a relatively high ash content (around 6%) and this can lead to slagging and fouling problems in combustion. It also has to compete with other uses as cattle bedding, therefore straw is not likely to be exploited as a feedstock. There are, however, other forms of agricultural bi-products that serve as potential feedstock from the West Midlands. These are organic wastes both wet and dry matter, namely animal biomass and poultry litter which, include slurry from cattle and pigs and also commercial and industrial waste from food manufacturing processes. The processes of bioenergy production are different depending on whether the organic matter is either wet or dry. Poultry litter (dry organic waste) is combusted, whereas wet organic waste (slurries) is treated in an anaerobic digestion process. Table 5.4.5: Potential Renewable Energy from Poultry Litter shows data of dry organic waste.

Table: 5.4.5: Potential Renewable Energy from Poultry Litter in the West Midlands.

Local Authority	**Electricity**	
	MW	**%**
Herefordshire	12.0	63
Telford and Wrekin	1.0	4
Shropshire	4.0	22
Stoke-on-Trent	0	0
Birmingham	0	0
Solihull	0	0
Coventry	0	0
Wolverhampton	0	0
Walsall	0	0
Sandwell	0	0
Dudley	0	0
Staffordshire	1	3.0
Warwickshire	1	5.0
Worcestershire	0.4	2.0
West Midlands Total	**18**	**100.0**

Source: Adapted from the West Midlands Renewable Energy Capacity Study, March 2011, pp. 51-52.

The total potential capacity for electricity production from poultry litter in the West Midlands according to the table is 18 MW. Such low levels of production given the highest potential capacity is from Herefordshire is 12 MW, (63% of the total capacity) therefore, it is not considered as a viable potential source of biomass. However, micro-CHP facilities on site, (i.e. farms) could utilize poultry litter for electricity production, providing protocols are met, (Environment Agency/Wrap 2012). In the past it was used as a fertilizer but is currently illegal due to levels of botulism present in the material laid down by the EU Waste Framework Directive, (2008/98/EC).

Wet organic waste found in animal biomass, commercial and industrial slurries are treated differently in AD processes to produce biogas and electricity. The first of this category of biomass provides data on the total accessible wet organic waste in the West Midlands Region in Table 5.4.6: Potential Accessible Wet Organic Waste Resource.

Table 5.4.6: Potential Accessible Wet Organic Waste Resource in the West Midlands.

Local Authority	**Electricity**	
	MW	**%**
Herefordshire	26.0	16.0
Telford and Wrekin	2.0	1.0
Shropshire	54.0	33.0
Stoke-on-Trent	1.0	0.3
Birmingham	1.0	1.0
Solihull	1.0	1.0
Coventry	0.4	0.3
Wolverhampton	0.1	0.1
Walsall	0.3	0.2
Sandwell	0.3	0.2
Dudley	0.2	0.1
Staffordshire	50.0	30.0
Warwickshire	14.0	8.0
Worcestershire	15.0	9.0
West Midlands Total	**165.0**	**100.0**

Source: Adapted from the West Midlands Renewable Energy Capacity Study, March 2011, pp. 48-49.

The West Midlands could produce 165 MW of electricity from wet organic waste. Shropshire and Staffordshire account for the largest potential producers of wet organic waste feedstock in the biomass-to-bioenergy supply chain, (54 MW and 50 MW electricity respectively). However, both cattle and pig manure is also used as fertilizer and therefore this particular type of feedstock may have to compete against other uses in agriculture and horticulture sectors. In relation to specific slurries from animal biomass shown in the next table (Table 5.4.7), there is a small difference where non-animal wet organic wastes are excluded.

Table 5.4.7: Potential Accessible Animal Biomass in the West Midlands.

Local Authority	**Electricity**	
	MW	**%**
Herefordshire	38.0	21.0
Telford and Wrekin	3.0	2.0
Shropshire	58.0	32.0
Stoke-on-Trent	1.0	0.5
Birmingham	1.0	1.0
Solihull	1.0	1.0
Coventry	0.4	0.2
Wolverhampton	0.1	0.1
Walsall	0.3	0.2
Sandwell	0.3	0.2
Dudley	2.0	0.1
Staffordshire	51.0	28.0
Warwickshire	15.0	8.0
Worcestershire	15.0	8.0
West Midlands Total	**184.0**	**100.0**

Source: Adapted from the West Midlands Renewable Energy Capacity Study, March 2011, pp. 46-47.

There is a difference of 19 MW of potential electricity production from animal biomass compared to the total potential capacity of wet organic waste in the West Midlands, (total capacity of 184 MW electricity). Also similar to the previous table Shropshire and Staffordshire have the largest potential capacity of electricity production from animal biomass, (58 MW and 51 MW respectively). As a feedstock, animal biomass (wet organic waste) is collected where animals are housed. The manure typically contains between 6 to 10% of dry matter and is therefore inappropriate for combustion or gasification without deploying a costly drying process. In addition, it is inefficient to transport any distance or store owing to the high proportion of water content in the material. Despite this, some energy technologies make use of biomass in aqueous slurry, and these can make efficient use of such 'wet' materials. The high water, and low dry matter content means that the most appropriate energy technology for making use of animal slurries is anaerobic digestion for the production of biogas rather than electricity as shown in the West Midland Renewable Energy Capacity Study, (March 2011). The final two categories of biomass are residual solid waste, otherwise referred to as municipal solid waste (MSW) and potential capacity of renewable energy production from biogas sourced from sewage and landfill gas. Tables: 5.4.8 to 5.4.9 show potential from MSW and commercial and industrial waste.

Table 5.4.8: Potential Accessible Renewable Energy Capacity from MSW Resource.

Local Authority	**Electricity**	
	MW	**%**
Herefordshire	7.0	3.0
Telford and Wrekin	7.0	3.0
Shropshire	13.0	6.0
Stoke-on-Trent	10.0	5.0
Birmingham	42.0	20.0
Solihull	8.0	4.0
Coventry	13.0	6.0
Wolverhampton	11.0	5.0
Walsall	10.0	5.0
Sandwell	11.0	5.0
Dudley	12.0	6.0
Staffordshire	29.0	14.0
Warwickshire	19.0	9.0
Worcestershire	17.0	8.0
West Midlands Total	**209.0**	**100.0**

Source: Adapted from the West Midlands Renewable Energy Capacity Study, March 2011, pp. 53-54.

Residual municipal solid waste according to DEFRA is household and household-like waste, (DEFRA, 2013). It is either collected by local authorities or, commercial companies, and includes waste from shops, offices and schools for example. Table 5.4.8 shows MSW as a biomass resource and reveals the West Midlands has a capacity for 209 MW from this material. Birmingham provides the largest capacity for renewable energy potential from MSW material (42 MW which is 20% of total capacity). The next table shows potential capacity from commercial and industrial waste (C&I) in table 5.4.9. The definition of C&I waste is not clear. For the purpose of clarification it includes waste that is non-metallic waste material.

Table 5.4.9: Potential Renewable Energy Capacity from Commercial and Industrial Waste.

Local Authority	**Electricity**	
	MW	**%**
Herefordshire	4.0	3.0
Telford and Wrekin	5.0	4.0
Shropshire	6.0	4.0
Stoke-on-Trent	6.0	4.0
Birmingham	27.0	19.0
Solihull	5.0	4.0
Coventry	9.0	6.0
Wolverhampton	6.0	4.0
Walsall	7.0	5.0
Sandwell	9.0	6.0
Dudley	8.0	5.0
Staffordshire	21.0	15.0
Warwickshire	14.0	10.0
Worcestershire	16.0	11.0
West Midlands Total	145.0	100.0

Source: Adapted from the West Midlands Renewable Energy Capacity Study, March 2011, pp. 55-56.

The total potential capacity for renewable energy from C&I waste is 145 MW in the West Midlands, with Birmingham and Staffordshire identified as providing the highest volume of C&I, that could produce 27 MW and 21 MW of electricity respectively. The data from both tables: 5.3.8 and 5.3.9 shows residual solid waste volumes are determined by population density. There are 1,183.2 million in Birmingham and 902.7 million people in Staffordshire according to the West Midlands Renewable Energy Capacity Study Report, (March 2011). There is more potential renewable energy capacity from landfill and sewage gas. Biogas comprises methane (CH_4) and carbon dioxide (CH_2) and is the product from AD processes. It also occurs naturally from open pools, marshes and in landfill. The final table showing potential renewable energy capacity from landfill and sewage gas is provided in table 5.4.10.

Table 5.4.10: Potential Renewable Energy Capacity from Biogas.

Local Authority	Landfill Gas	Sewage Gas	Biogas	
	Elec. MW	**Elec MW**	**Electricity MW**	**% of total capacity**
Herefordshire	0.0	0.0	0.0	0.0
Telford and Wrekin	0.3	0.5	1.0	2.0
Shropshire	0.4	1.0	2.0	4.0
Stoke on Trent	0.0	3.0	3.0	8.0
Birmingham	0.0	16.0	16.0	38.0
Solihull	0.0	0.4	0.4	1.0
Coventry	0.0	0.0	0.0	0.0
Wolverhampton	0.0	1.0	1.0	2.0
Walsall	0.4	0.0	0.4	1.0
Sandwell	0.4	0.0	0.4	1.0
Dudley	1.0	0.0	1.0	3.0
Staffordshire Total	2.0	4.0	7.0	15.0
Warwickshire Total	4.0	5.0	9.0	20.0
Worcestershire Total	4.0	2.0	3.0	7.0
West Midlands Total	**11.0**	**34.0**	**45.0**	**100.0**

Source: Adapted from the West Midlands Renewable Energy Capacity Study, March 2011, pp. 58-59.

Combined total biogas capacity in the West Midlands according to the table is 45 MW with the highest biogas levels from Birmingham accounting for 16 MW of electricity from sewage gas (38% of total potential capacity). The capacity for landfill gas is negligible with the largest potential capacity of 2 MW of electricity in Staffordshire.

5.5: Summary of bioenergy potential in the West Midlands.

The West Midlands is a Region of contrasts between rural and urban counties confirmed by the findings from the data shown in tables: 5.4.1 to 5.4.10. Here the potential for biomass to bioenergy supply chain integration is determined by ability to supply distinct categories of feedstock. From a stakeholder perspective the key challenges concern contractual agreements that restrict innovation for potential development of the bioenergy industry in the West Midlands primarily due to public sector procurement rules. Since January 2007 medium and large contracts for new development of bioenergy conversion plants are procured through the EU Competitive Dialogue (CD) Programme under the Public Contract Regulations referred to as, The Public Procurement (Miscellaneous Amendments) Regulations 2011 (S1 2011/2053). This means that all bidders are compelled to submit a formal bid to the respective local authority. Public accountability is one of the layers of complexity that can serve to safeguard environmental integrity but is also responsible for centralization of renewable energy to conform to existing energy production and distribution models. From a process perspective, renewable energy has to justify the costs of production. Feedstock produced from urban and rural areas in the Region demand different conversion technologies. This polarity between urban and rural areas will require decentralization of energy systems in order to meet such requirements. In relation to wood material, clean round wood is costly to transport and the West Midlands does not have sufficient capacity to meet demand. A significant proportion of clean wood will have to be imported if it were to meet demands of CHP conversion and generate lengthy contractual agreements with transport, feedstock providers, and conversion site. The net calorific value (NCV) of wood depends on its pre-processed state. Wood chip with a moisture content of 30% has an NCV of 3.5 kWh/kg, log wood at 20% moisture content has an NCV of 4.1 kWh/kg, dry wood is 5.3 kWh/kg and wood pellets has a NCV of 4.8 kWh/kg. Furthermore, increased costs from importing wood from other regions increases risk in ability to supply. Waste wood is available from urban areas as demonstrated in table 5.4.1, (p. 139), which is cheaper to transport but pre-processing operations increase the cost of this material. Waste wood may also have been exposed to hazardous compounds that are restricted in use as governed by the Waste Incineration Directive, (DEFRA 2010). Seasonality of material and financial fluctuation add risk to agricultural arisings such as straw, which is also compounded by the fact that it has a low calorific value of 4 kWh/kg at a 15% moisture content level. Furthermore, the material has to compete with other uses as animal bedding for example. Animal residues such as poultry litter has potential to be used in micro CHP in a closed-loop system where electricity is both produced and used on-site. Wet organic waste has potential for either urban areas, such as domestic slurries in water treatment plants for the production of electricity and biogas. Similarly, animal slurries from rural areas offer potential capacity for anaerobic digestion operations. Municipal solid waste provides an interesting challenge because it shows considerable potential for development of bioenergy in urban locations but there are restrictions due to environmental controls. Likewise, there are restrictions on siting CHP and AD conversion sites due to smell and traffic to and from such sites. However, the waste incineration plant in Birmingham processes approximately 350,000 tonnes of MSW per annum of which it converts 25 MWe according to a DEFRA Report on Incineration of Municipal Solid Waste, (2013) contrary to the West Midland Renewable Energy Capacity Study (March 2011).

Without consideration of the current potential for bioenergy in the Region it would be difficult to place the case studies presented in the next section in context. Case studies and the subsequent analysis of data in the West Midlands Region identify factors that optimize supply chain integration in bioenergy from stakeholder and process perspectives.

Chapter Six: Bioenergy in the West Midlands: Findings from Survey Data and Case Studies.

6.0: Chapter Overview: Presentation of the Results from Survey Questionnaires and Case Studies.

Results from the main study presented in this chapter are the findings from two survey questionnaires and case studies. The surveys were conducted after completion of the scoping study from 2011-2014 and case studies from 2012-2015. One of the surveys was a combined stakeholder and operator questionnaire and its purpose was to identify and verify supply chain integration constructs, issues and challenges that relate to the first and second research questions proposed in chapter one. The second questionnaire was aimed at researchers in bioenergy within the Region (West Midlands). Its purpose was to ascertain two main factors. The first being if bioenergy research was conducted from a business and supply chain perspective and the second reason was to find if research into bioenergy had any impact on determining policy direction and decision in alternative forms of energy production. Selection of participants was based on their current role, knowledge and experience in bioenergy and West Midlands location. The chapter presents data from fieldwork and thus action research methods discussed in the literature review and chapter three, (Methodologies) and makes a valid contribution to understanding the components of supply chain integration characteristics and the viability of bioenergy from a business perspective.

6.1: Introduction: Bioenergy in the West Midlands Region.

The scoping study raised issues and challenges as to how bioenergy energy contracts are determined. How different types of contractual arrangement determine supply chain integration queries the range of contracts applied to bioenergy firms and whether or not these are advantageous to creating a robust supply chain. Characteristics that define contractual agreements in bioenergy are investigated further by identifying risks of long-term contracts in bioenergy companies and, in addition, amongst third parties. The scoping study and literature review found evidence that co-location was beneficial in the biomass-to-bioenergy supply chain.

This begs the question in the level of parity between parties that co-locate their businesses close to a conversion facility. The third sub-question concerns stakeholder influence and continued involvement in the context of how stakeholder relationships are managed once a bioenergy facility becomes operational. These questions, along with the main research question is presented in this chapter through the findings from firms operating in the West Midlands region.

The first part of this chapter presents findings from a survey questionnaire that was distributed to bioenergy operators, stakeholders and researchers. They were asked a series of questions in bioenergy on process and stakeholder characteristics that were identified from the literature review and scoping study survey. The remaining chapter sub-sections present case studies from companies situated in the area and involved in the biomass-to-bioenergy supply chain from either a stakeholder and process integration perspectives. The latter part of the chapter combines results from the survey and case study data, which were analysed and evaluated to ascertain what factors enable bioenergy supply chains to become robust and viable business units.

6.2: Bioenergy Survey Data Findings: Operator, Stakeholder and Researcher.

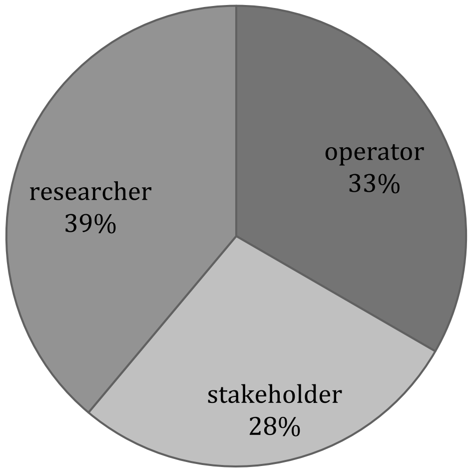
The survey was conducted between 2013 and 2014 of participants who were knowledgeable and experienced in either bioenergy production or, research, or strategic planning. General information was gathered in the first instance to ascertain their role in bioenergy, which is illustrated in Table 6.2.1: Role of Participants in Bioenergy.

Table 6.2.1: Role of Participants in Bioenergy.

Job Roles of Participants in Bioenergy Survey	Number of Participants	Sub-Total
Process Operations in Bioenergy		
Operations Manager Logistics		
Plant Manager	4	
Procurement Manager	8	
Sales Administrator	4	
	2	
		18
Stakeholders in Bioenergy		
LA Regeneration Manager	1	
Energy Consultancy	3	
Business Development Director		
Bioenergy Technology Consultancy	3	
	8	
		15
Research in Bioenergy		
Director Bioenergy Research	2	
Readers in Bioenergy Research		
Research Assistant	3	
Post-Doctoral Researchers	5	
PhD Researchers	3	
	8	
		21
Total Number of Participants		**54**

A total number of 54 people participated in the survey with the majority of participants based in bioenergy research (39% of the participants) and remaining categories were apportioned as 18 bioenergy operator participants (representing 33%) and 15 stakeholder participants, (representing 28%) responding to questions in the bioenergy survey illustrated in Figure 6.2.1: Division of Participant Roles in Bioenergy Survey 2011-2014.

Figure 6.2.1: Division of Participant Roles in Bioenergy Survey 2011-2014.



Not all participants were able to make a response to the questions in the survey due to the fact that the questions were either not relevant to their business, or they did not have sufficient knowledge of the background to their organization. For example, bioenergy researchers did not possess sufficient knowledge in relation to funding applications in their respective research centres. However, the questionnaire was a means of confirming key constructs in supply chain integration in bioenergy. Categorisation of survey data conforms to the order of supply chain constructs provided in the literature review from Chapter Two, part I, and scoping study in Chapter Four. These are given as follows:

- **Technological Constructs**: Category of Bioenergy Technology,
- **Stakeholder Constructs**: Planning, Location Decision, Funding Opportunities, Research in Bioenergy,
- **Process Constructs**: Research, Understanding and Perception of Bioenergy Supply Chains, Inventory Management, IT Functions, Waste Management and Demand Management,
- **Procurement**: Supplier Selection, Length of Contractual Agreement, Number of Suppliers, Supply Risk, Distance, KPIs, Quality Management,
- **Finance**: Performance, Costs and,

- **Marketing and Communications**: Awareness Raising, Stakeholder and Marketing in Bioenergy.

This research takes the general definition of a 'construct' in the context of integration of various conceptual elements and therefore by consensus in the first instance it was possible to identify a set of factors that were either applicable processes or stakeholder factors. In this study constructs pertinent to bioenergy supply chain integration were identified through initial findings from the literature review and trialled in the scoping study. Theory building from identification of new constructs based on secondary research and published case studies are given in Gold and Seuring (2011), Gold et al. (2010) and Meredith (1993). This study added a further dimension of a scoping study to ascertain if stakeholder and process constructs taken from the general supply chain literature were applicable to bioenergy supply chains. Thus the output from the main study will confirm if such constructs in bioenergy supply chain integration are applicable and, in addition add rigour and robustness to bioenergy businesses.

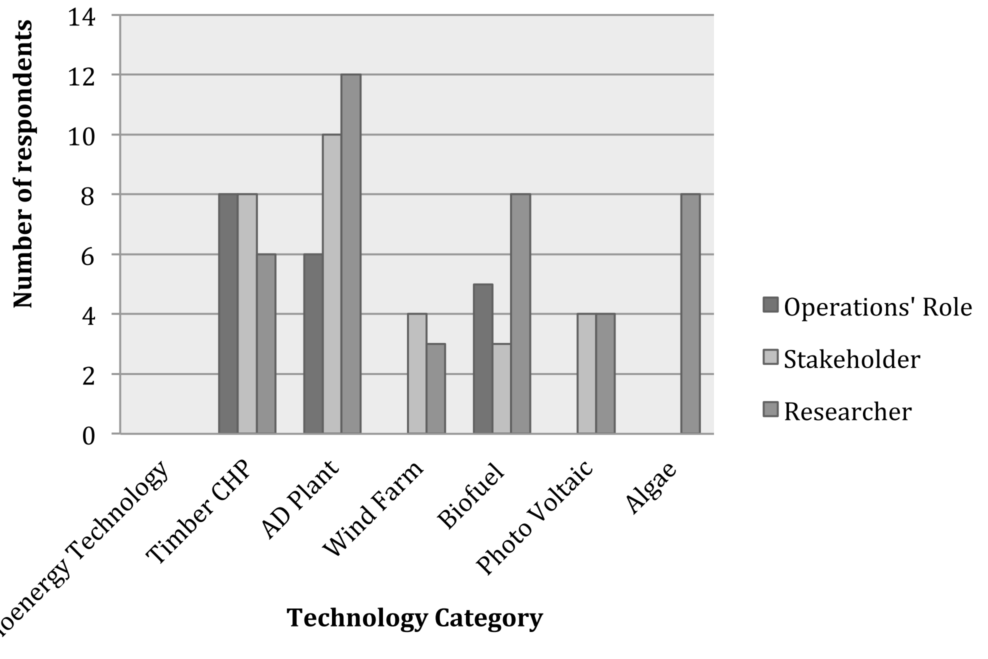
Division and organisation of categories for the distribution of both the academic and practitioner-based questionnaires were developed from initial findings from the literature review in chapter two, part I and tested in the scoping study provided in chapter four. For the most part, the literature views bioenergy characteristics as separate entities that either relates to process or, stakeholder constructs. However, there is the view that integration of both stakeholder and processes help reduce risk and add rigour to bioenergy businesses (Gold, 2011; McCormick and Tåberger, 2007). Survey data was taken from academics, practitioners from bioenergy operations to stakeholder in order to ascertain which of the integration factors were important in developing a viable bioenergy business.

6.2.1: Bioenergy Technology Selection

Participants ranked bioenergy technology choices in bioenergy from highest to lowest choice. The findings are illustrated in Figure 6.2.1.1: Bioenergy Technology.

Anaerobic Digestion was ranked highest amongst researchers, (12 respondents), followed by Algae (8 researchers). Operators and stakeholders selected other technologies using Timber CHP (8 operators and stakeholders) followed by AD (6 operators and 10 stakeholders).

Figure 6.2.1.1: Bioenergy Technology



None of the operators and stakeholders selected algae in bioenergy technology choice. Researchers had selected algae from technological and feedstock aspects because EU and Regional Development Agency Funding determined research in algae. A grant of 333,000 million € had been awarded in one particular project together with a grant of 1.5 million € at a University Research Centre in Bioenergy[1]. Combined heat and power, (CHP) followed AD in being ranked higher than other bioenergy technologies which is shown in figure 6.2.1.1 as 6 – Operators, 8 – Stakeholders and 6 – Researchers. The data confirms findings from the West Midlands Renewable Energy Capacity Study, (March 2011) which shows that the Region has potential of 720 MW of electricity from CHP and 878 MW of electricity from AD technologies. However,

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[1] It should be noted that not all this funding was directed at algae (macro and micro algae) bioenergy.

CHP technology has the potential to produce an additional 1389 MW of heat. Therefore both CHP and AD were considered to be the most effective of bioenergy technologies compared to biofuel and biogas production. Solar and on-shore wind was ranked the lowest amongst the respondents, shown as 4 from both stakeholders and researchers for solar; 3 and 4 stakeholder and researcher respondents for on-shore wind. No operator respondents selected solar and on-shore wind in bioenergy technology. This is surprising because financial incentives to utilize solar and wind are amongst the highest in the UK compared to CHP and AD technologies. Figures for these are provided in Chapter Five, Table 5.3.8: ROC GWh and FiT Rates for Renewable Energy Technologies in the West Midlands, p. 146, which shows that wind generates £164 ROC MW/h, FiT rates depends on whether the organization is either large scale (£17.78 GW) or small scale (£22.23 GW) and Solar generates £164 ROC GWh and FiT £6.61 GW. On the other hand biomass generates £41.50 ROC MW/h and FiT small-scale is £12.46 GW and large-scale £9.49 GW of renewable energy produced by this category. Therefore, from the data shown in Figure 6.2.1.1, it can be assumed that bioenergy technology selection is not driven by financial incentives. There have been UK Government changes in payments for renewable energy production that were reduced during August 2015 and thus risk in dependence on financial incentives from UK and EU Governments are seen as short-term but contrary to this, energy technologies are a long-term strategy, (Dincer, 2000). Comments from participants confirm distinct roles between researcher, stakeholder and potentially operator technology choices in bioenergy:

Researcher from the Bioenergy Research Centre added: ‘Pyrolosis’.

Bioenergy Research Centre Director: ‘Pilot scale and bench scale cultivation in bioremediation but we are not converting at the present time’.

Stakeholder from a Legal Firm: ‘We provide advice on timber CHP, develop from 5 MW up to 30 MW plants on farmland’.

Stakeholder City Authority: ‘None of these technologies, we are a local authority’.

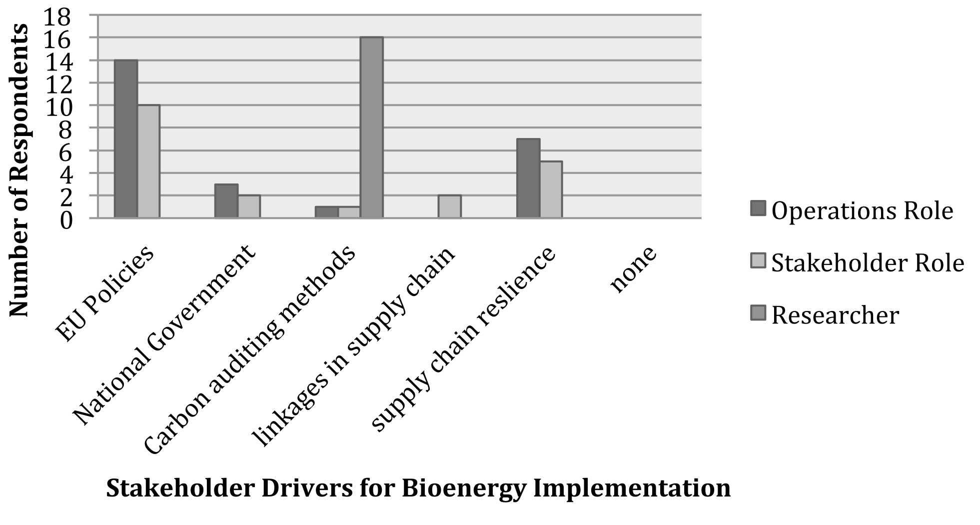
From a researcher view, bioenergy was constrained to specific research projects despite funding arrangements that involved public and private sector funding and links with stakeholders.

The next section presents survey data from bioenergy operators, stakeholder and researcher respondents on stakeholder constructs.

6.2.2: Stakeholder Characteristics in bioenergy.

The following section presents findings from the questionnaire on characteristics of stakeholder constructs from decision-making in relation to planning application, location; funding application and includes data from operator, stakeholder and researcher perspectives. The first is figure 6.2.2.1: Stakeholder Drivers and Figure 6.2.2.2: Decision Makers in Bioenergy on pages 167, 169. The final figure is of data collated from researchers in bioenergy in Figure 6.2.2.3: Stakeholders in Bioenergy Research on p. 170.

Figure 6.2.2.1: Stakeholder Drivers for Bioenergy



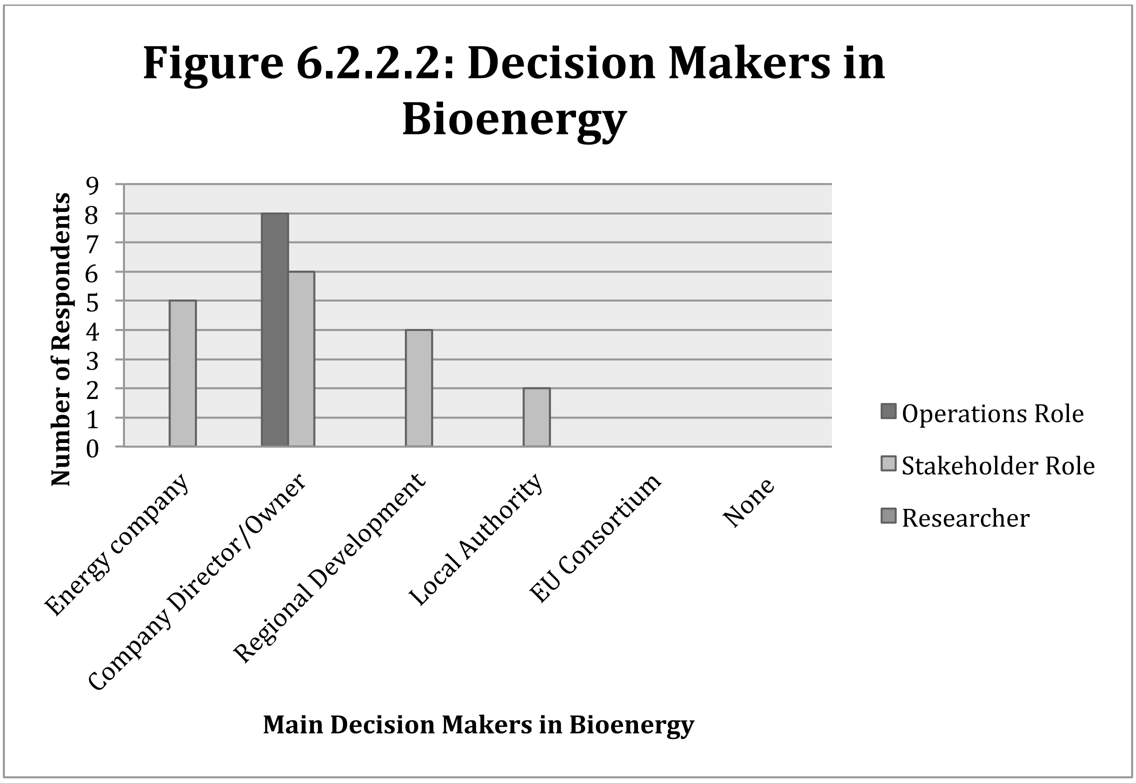
Respondents also commented:

Stakeholder Legal Firm: 'Substitution of existing energy use is more cost effective than fossil fuel, (oil). District heating systems, e.g. development of the 'heat village' changed consumer behaviour on use of heating'.

Research Director Bioenergy: 'We were internally funded to develop the lab in order to investigate and explore biomass options with a focus on industry needs'.

Plant Operator: 'EU policies are the main drivers for renewable energy, we could see an opportunity'.

There are three contrasting comments from the groups of participants in the survey. Starting from a researcher perspective, it is assumed that there is a time lag between bench scale development and the needs required of the bioenergy industry. Both operator and stakeholder are referring to imminent drivers to reduce use of fossil fuels and greenhouse gases. From the operator perspective such initiatives are determining the pace of renewable energy development. Figure 6.2.2.1: Stakeholder Drivers confirms renewable energy policies emanating from the European Union were the main drivers for bioenergy development in the West Midlands of 14 operator and 10 stakeholder responses respectively. This was followed by supply chain resilience that showed 7 responses from operators and 5 responses from stakeholders. This would indicate that both operators and stakeholders sought to develop the bioenergy industry as a robust sector through targeting supply chain viability. There were no 'business-aligned' selections from researchers where asked to respond on stakeholder drivers. Instead, the majority of bioenergy researchers selected carbon auditing as the main driver (16 responses from a total number of researchers being 21 persons). This would indicate that measurement of the environmental impact of bioenergy production was important to bioenergy research. In contrast, carbon auditing was the lowest ranked score amongst operators and stakeholders. There are two figures presented in bioenergy decision-making, the first being Figure 6.2.2.2: Decision Makers in Bioenergy from stakeholder and operator perspectives. Figure 6.2.2.3: Stakeholder Funding in Bioenergy Research (p. 170), has been separated because it was specific to bioenergy research rather than commercial ventures.



The figure shows that operators and stakeholders ranked company director/owner as the main decision-maker in bioenergy. However, the stakeholders also ranked energy companies (5 stakeholder responses) and regional development agency (4 stakeholder responses). The lowest ranked score was Local Authorities, (2 stakeholder responses). In the West Midlands, the leading funding authority (Advantage West Midlands) was initially established from several partnerships across the Region to promote economic development, under the Regional Development Agencies Act 1998 during the last labour Government. One of their remits was sustainable development that included renewable energy initiatives. However, Advantage West Midlands was abolished at 0.02 hrs. on 1st July 2012 by an Order S 30 (1) of the Public Bodies Act 2011. This impacted on research bids in bioenergy throughout the Region at the time including both Interreg IVB bioenergy bids.

Comments from respondents added other decision makers that determined their bioenergy firm:

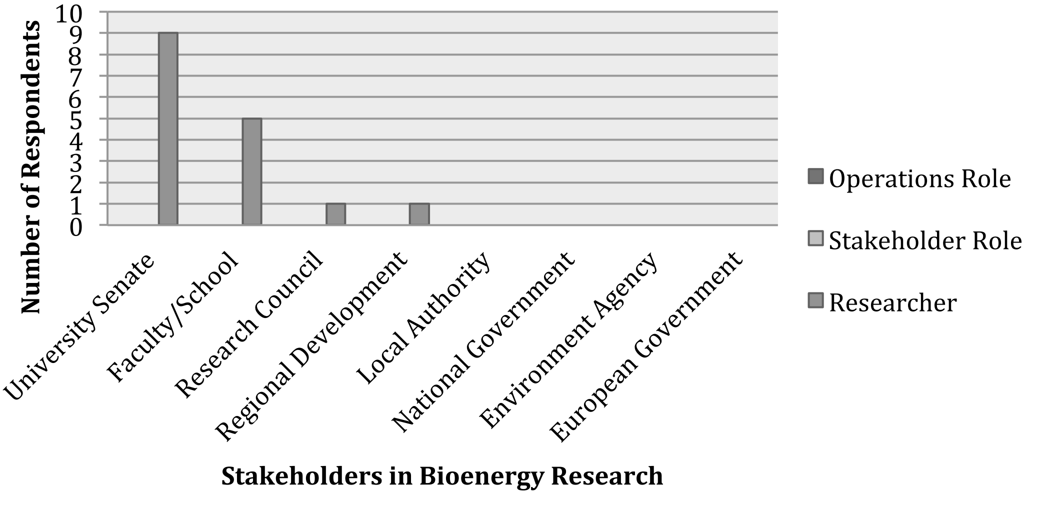
Engineering Contractor: 'Department of Environment and Climate Change, (DECC)'.

Project Manager Stakeholder: 'The energy companies determine how much goes into the national grid. Connection depends very much on size and ability to process energy to grid. Such clients drive bioenergy. The network operator rather than generator if grid connection has not been up dated, or the company doesn't have the scope. Lack of grid connectivity can stop bioenergy projects. Local Authorities are not really influential but have some involvement during the planning phase but not the operational stages'.

The last comment from a stakeholder involved in project management of bioenergy projects provided a revealing insight into the level of decision for successful fruition of renewable energy development. It also confirms that bioenergy projects need to identify their customers and output. Decisions on whether or not to provide approval depend on an effective and a viable business plan and ultimately, this depends on the robustness of a contract to supply to the national grid.

Figure 6.2.2.3: Stakeholder Funding in Bioenergy Research shows that the majority of researchers ranked their university senate at the main decision-making authority by indicating 9 responses followed by faculty/school (5 responses from bioenergy researchers). The majority of researchers were early career researchers and therefore, had limited knowledge of funding in their respective area of research, which is reflected in bias towards university management rather than other funding groups. However, their response confirms importance of research in this area.

Figure 6.2.2.3: Stakeholder Funding in Bioenergy Research



Apart from multi-choice questions in the survey, they were also given the opportunity to comment on research centre planning and approval:

Research Centre Director: ‘We were specifically set up as a bioenergy research centre and did not require planning approval, because our labs are based in the University. We are a lab-based research facility for bioenergy research’.

Post Doctoral Researcher: ‘Our research is being conducted in the UK as well as India as part of a Science Bridge project which is part-funded by a philanthropist’.

PhD Researcher: ‘I have a dual role in the UK and India and am involved in the development of bioenergy in Jodhpur which is being constructed at present’.

Research Assistant: ‘I am not working for a bioenergy research centre directly but my research involve biofuel and animal feeds’.

There were a number of questions in bioenergy planning development from public and private sectors. This was to identify where the sources of funding came from how this determined bioenergy decisions for operator, stakeholder and researcher perspectives. Figure 6.2.2.4: Planning Approval from Public Sector Organizations and Figure 6.2.2.5: Planning Approval from Private Sector Organizations. From operator and stakeholder perspectives there were similar responses in ranking 5-10 public and private sector organization involvement in their bioenergy firms and bioenergy development. From a research perspective the highest ranked score was allocated to PFI partnerships from 10 research respondents. Public Finance Initiatives (PFI) partnerships in this case are projects where the public sector (customer) procures from the private sector the design and construction of major capital projects such as the Bioenergy Research Centre. In this section, operators and stakeholders reported between 5-10 public and private organizations were involved in bioenergy projects. This is indicative of PFI partnerships identified from bioenergy researchers and confirmed from the literature review that find application of turnkey contracts in the development of bioenergy, (de Jager and Rathman, 2008; Piterou et al., 2008). The importance of securing a robust relationship between public and private organizations is confirmed in figure 6.2.2.5: Reasons for Bioenergy Bid Rejection show that the main reasons why bids are unsuccessful is due to the fact that they are unable to gain approval from stakeholders.

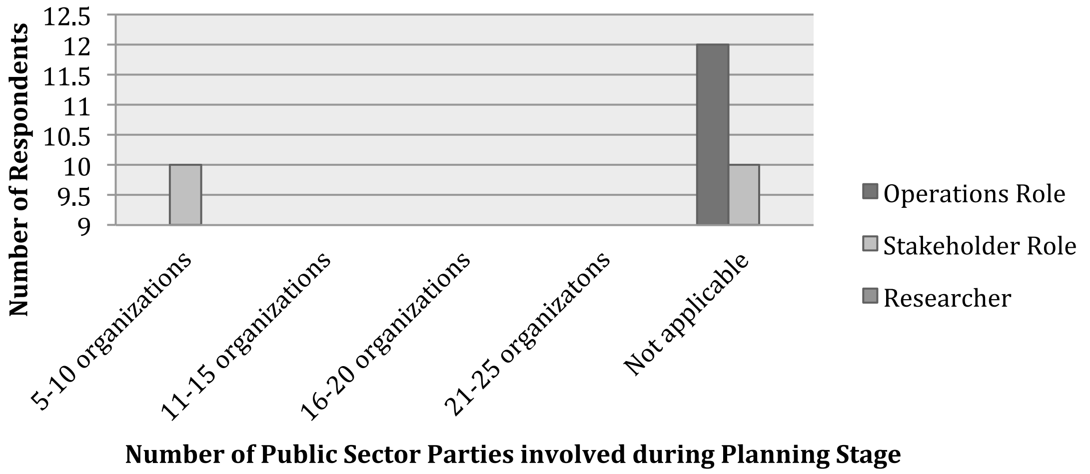


Figure 6.2.2.4: Planning Approval from Public Sector Organizations

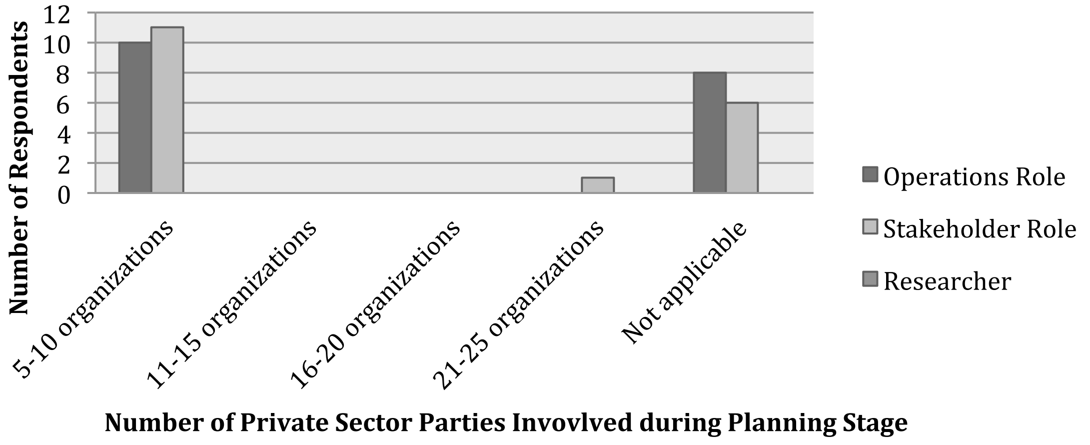


Figure 6.2.2.5:Planning Approval from Private Sector Organizations

Comments from participants identify the scope of organizations involved at a strategic level in their companies:

Engineering Contractors: '[2]REA, ADBA, NGV Europe, Low CVP, NGV Energy and Utility Alliance Networks'.

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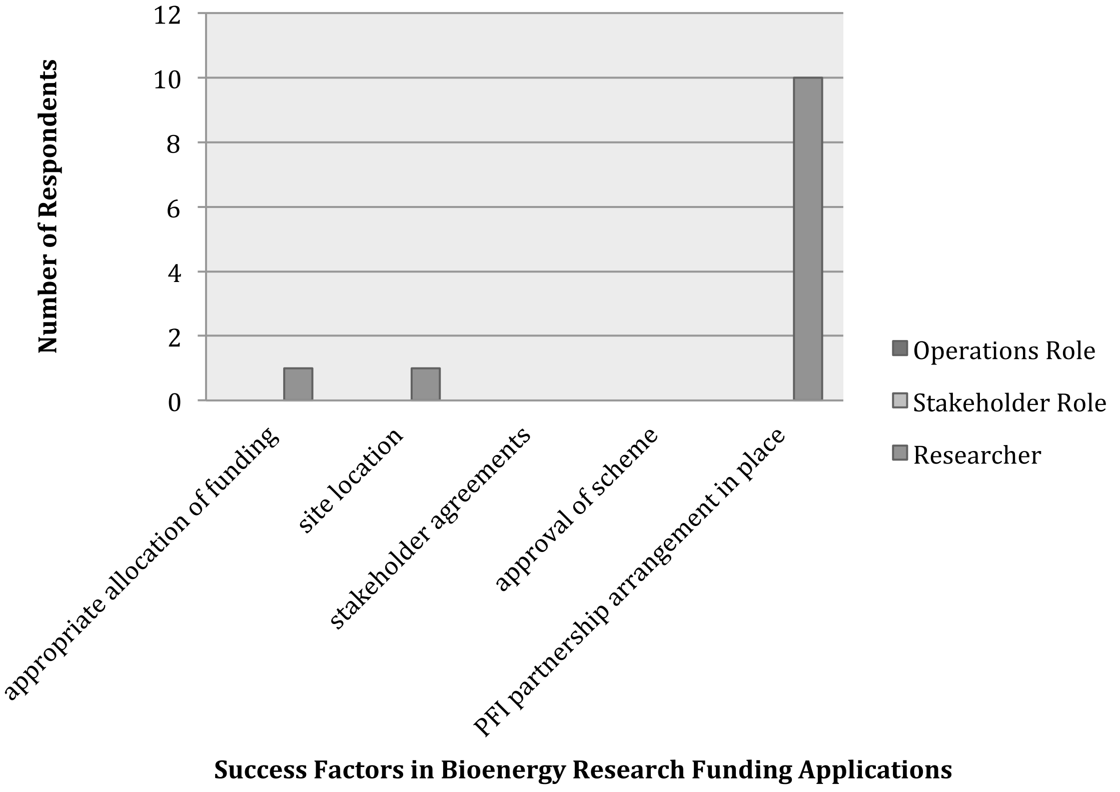
[2] REA: Renewable Energy Association, ADBA: Anaerobic Digestion and Bioresources Association, NGV Europe: Natural Gas Vehicle

Stakeholder Legal Firm: ‘From the public sector, Local authorities get involved in the planning aspects, DECC, Ofgem incentives, Environment Agency provide the permit, Health and Safety Executive. From the private sector, different companies get involved at different phases of the project. For technology, the funding comes from private equity. Usually there are 4 parties, builders, landowner and advisors’.

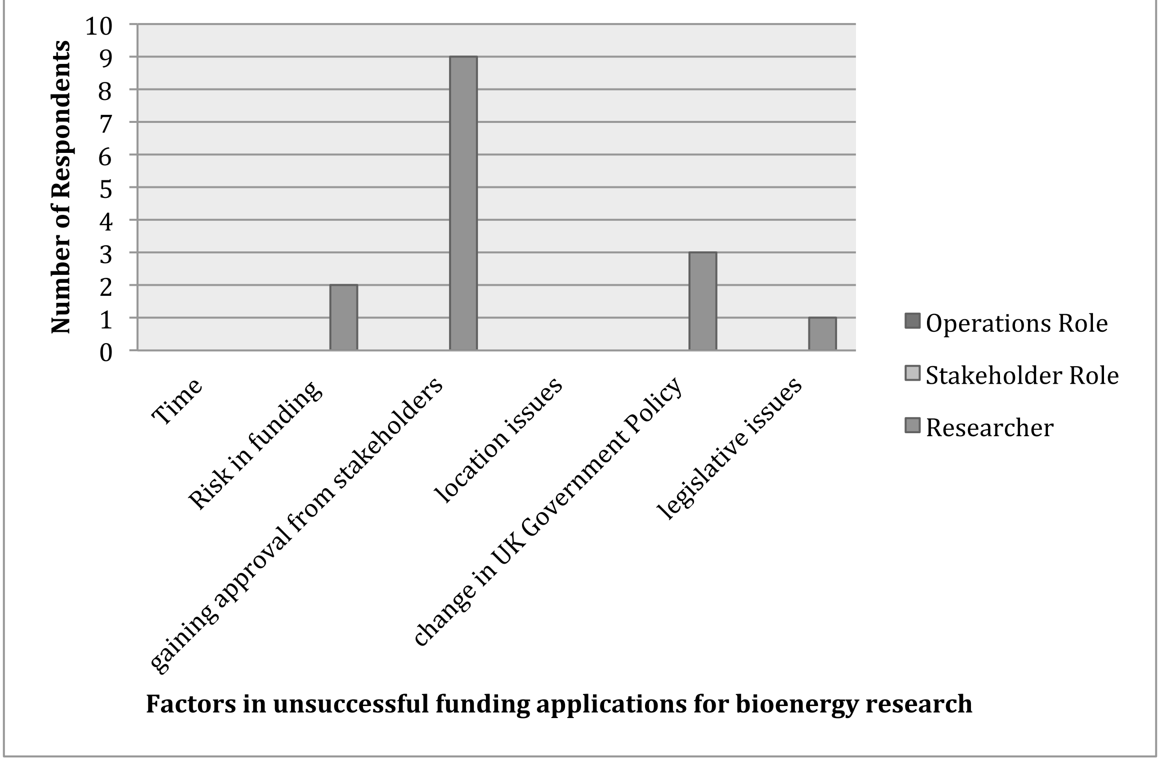
The comments confirm that that both public and private sectors are involved during the initial planning stages in order to provide the legal structure of the company and oversee compliance. The engineering contractor quoted a number of not-for-profit organizations present in the UK that provide advice and consultancy in renewable energy projects. However, private investors determine the construction of a bioenergy project.

Figure 6.2.2.6: Success Factors in Bioenergy Funding



Network, Low CVP: Low Carbon Vehicle Partnership, NGV Energy and Utility Alliance Network, (EUA): founded in 1905 a not-for-profit organization to develop and shape energy policy.

Figure 6.2.2.7: Reasons for Bioenergy Bid Rejection



Comments from researcher helped embellish their survey responses:

PhD Researcher: ‘We received cash funding from the University Senate and ERDF[3]. Parties from the University, Regional Development Agency and the previous Centre Director managed to secure funds to set up this centre and get approval from the University’s estate department. We applied for one particular project that did not get approval for an AD pyroformer under the EU Framework VII programme but it got rejected because we could not get buy-in from SMEs from the German partner. We were unsuccessful in 3 grant applications because one of the partners could not meet the project criteria’.

PhD Researcher: ‘I am part of a rural development project in India to develop electrification of the Region, (Jodhpur). It is very difficult in India irrespective of the benefits of this social enterprise to get past the planning authorities from Local and State Government. All energy projects go through the Pollution Control Board (India). It is the intention of this research project to promote bioenergy and match financial with technical skills needed for this project. My research is important is this respect’.

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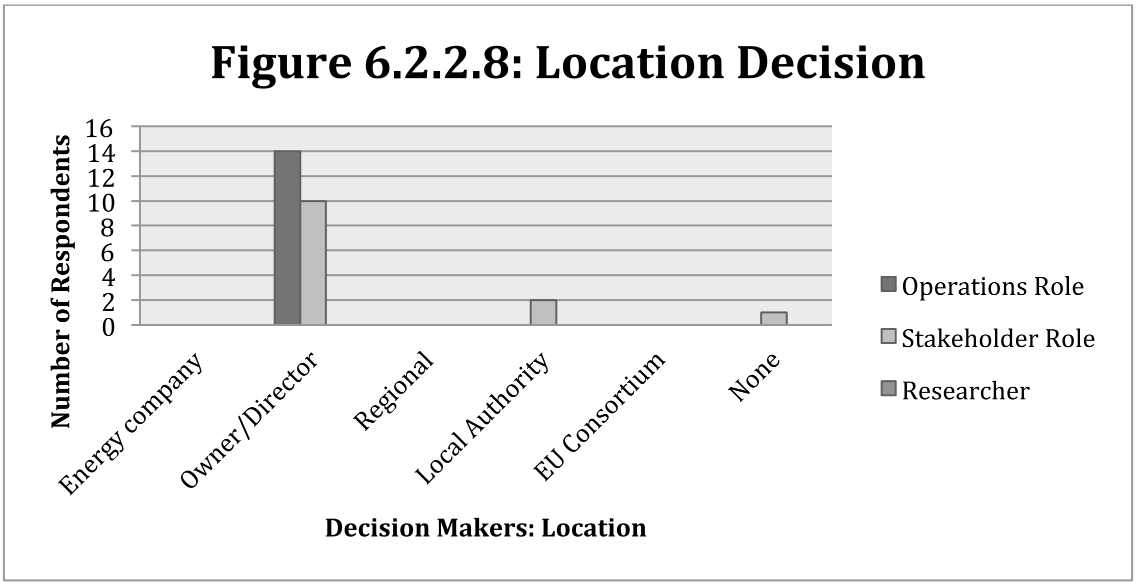
[3] ERDF: European Development Fund

The first comment from a PhD researcher in bioenergy assumes dependence on collaborative research funding applications particularly in a European context. The notion that the 'supply chain is as strong as the weakest link', is particularly true in this case where two of their research bids were rejected on the grounds of one of the partners not being able to meet one of the objectives. The researcher also commented on a 'cash' payment from the University for their Bioenergy Research Centre. Here it must be assumed that internal funds were transferred to develop the centre. The second comment from another PhD researcher was clearly involved in overseas development in bioenergy and it appears that public authorities in India have a stake hold in determining bioenergy.

In addition to planning for renewable energy the questionnaire required participants to respond to questions on location of their bioenergy facility. There are many examples in the literature of co-location of bioenergy sites with feedstock providers for example, (Dainaova et al., 2012). Figures 6.2.2.8 to 6.2.2.9 demonstrate location factors in bioenergy organization. Figure 6.2.2.8: Location Decision, (p. 176) and Figure 6.2.2.9: Location of Bioenergy Research Centre (p. 177). Location decision amongst stakeholders and operators shown in figure 6.2.2.8 indicate that the owner/director was most influential in decision to locate a bioenergy facility, (14 bioenergy operators and 10 stakeholders). The lowest ranked score was selection of Local Authority in determining location of bioenergy facility (2 stakeholders). No operator participants selected any other category other than 'Owner/Director'. This finding would confirm the use of turnkey contracts to oversee the development in site construction. Such major project construction contracts are distinct from those seen in contractual agreements with suppliers and customers.



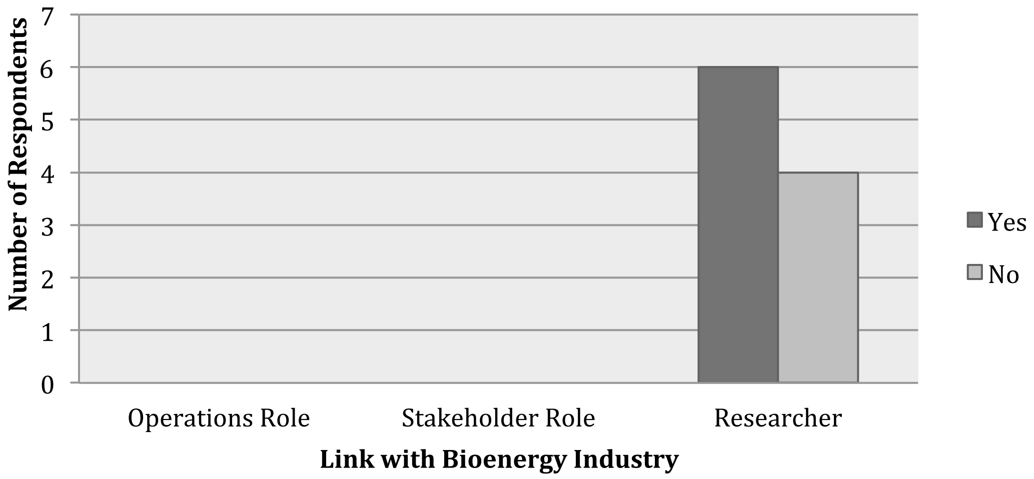
Comments from respondents highlighted reasons for their location:

Stakeholder Legal Firm: ‘Rural location. Historically, our company is 150 years old and our clients are mainly landowners who needed legal advice during the building of the railway across their land. Biomass supply companies need access to roads and a cost effective connection to the national grid. Feedstock must have the potential to convert to biomass and not present too many problems when disposed of as waste, (post-conversion) bioenergy industry is rural because of the isolation and less planning restrictions on inbound/outbound vehicle deliveries. AD is rural whereas biogas is urban-based’.

Logistics Manager Biomass: ‘We moved into biomass due to agreements with forestry producers. Our company headquarters is based on the outskirts of a National Park and therefore there are restrictions on congestion and use of vehicles in the Park but we pick up biomass and deliver throughout the UK’.

It can be assumed that optimal location of bioenergy from a supply chain perspective is more effective where sited in a rural rather than urban area based on the comments from a stakeholder and operator. The literature affirms this factor, as bioenergy is essentially a rural industry, (Adams et al., 2011).

Figure 6.2.2.9: Location of Bioenergy Research Centre



Location decision in bioenergy research was distinct from commercial bioenergy planning and development in this instance. Researcher participants were asked if their bioenergy research centre was determined by links with industry? From the data provided in Figure 6.2.2.9: Location of Bioenergy Research Centre show that the majority of researcher participants indicated ‘yes’ (6 respondents) to close links with industry compared to 4 ‘No’ responses from the same group. Given that the highest rank score in success factors in successful bioenergy applications resulted from PFI partnerships would confirm the need to work closely with industry in renewable energy, (Figure 6.2.2.7, p. 174).

Following on from location decision, figures 6.2.2.10 to 6.2.2.11 present sources of funding in bioenergy development. Sources of funding in this context refer to financing bioenergy development and are distinct from financial performance during operations. The first figure (Figure 6.2.2.10) confirms ‘Owner/Director’ (14 Operators and 10 Stakeholders) ranked higher than other options. One stakeholder selected the lowest ranked score, ‘Local Authority’. Again this conforms to current practice found in the bioenergy literature (see chapter two, part I, p. 19).

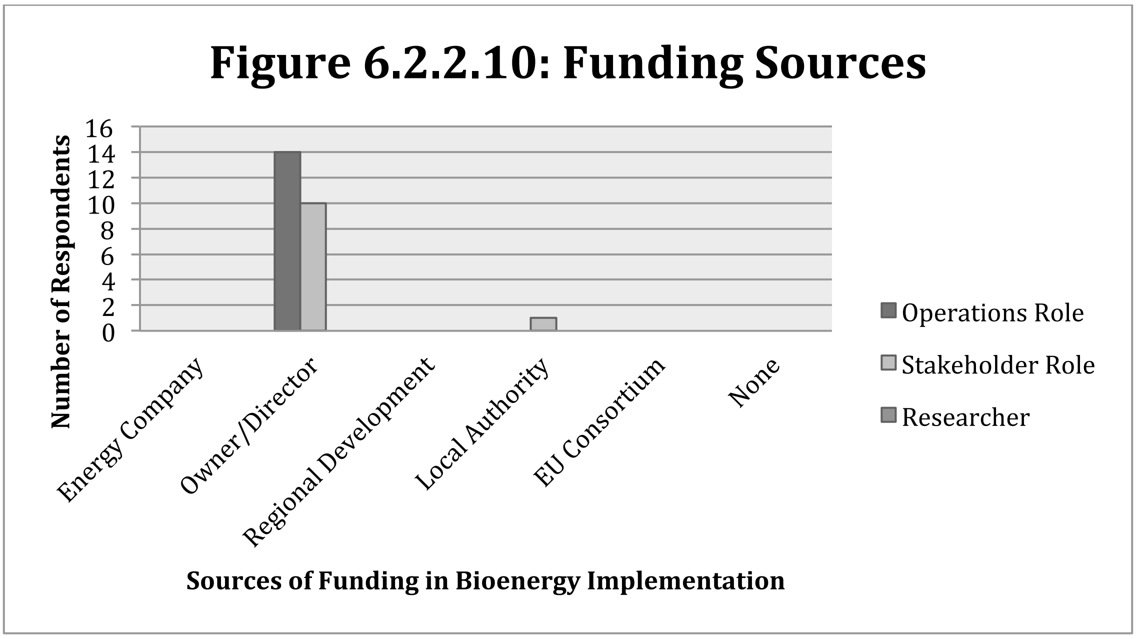


Figure 6.2.2.10: Funding Sources

Comments from respondents' added further meaning to the survey data:

Logistics Plant Manager: 'We are funded by the Director and shareholders'.

Stakeholder Legal Firm: 'Our work is funded by the clients and other funds are available through Government incentives such as FiT schemes'.

In contrast to funding sources from operator and stakeholder viewpoints, questions that researchers were asked were linked to sources of funding aligned to applications typical of research bids. The findings shown in Figure 6.2.2.11: Sources of Research Funding on p. 168 show that the majority of researchers selected EU funding (8 researchers) as their main funding source. Research Council grants (e.g. Engineering and Physical Science Research Council, British Council – 3 researchers) and National Government Funding (e.g. Technology Strategy Boards –TSB – 2 researchers), did not feature highly amongst the majority of researchers.

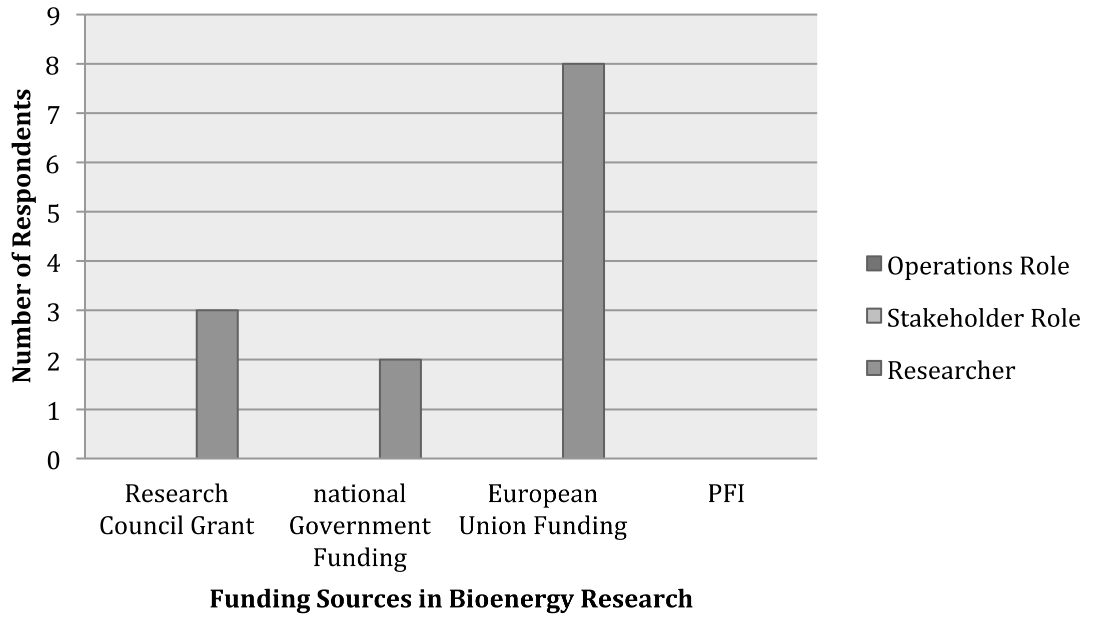


Figure 6.2.2.11: Sources of Research Funding

It was assumed that researcher responses were different to operator and stakeholder responses and comments have been separated in consideration of this distinction in funding decision with the majority of researchers referring to EU funding via stakeholder parties:

Research Assistant: ‘University senior leadership, Regional Development Agency and Research Centre Director is responsible for funding’.

Post Doctoral Researcher: ‘Funding is via the sustainability agenda and our links with the automotive industry’.

Post Doctoral Researcher: ‘I’ve no idea as I wasn’t here at the time’.

Bioenergy Research Director: ‘Our lab is funded for investigating and exploring biomass options for industry’.

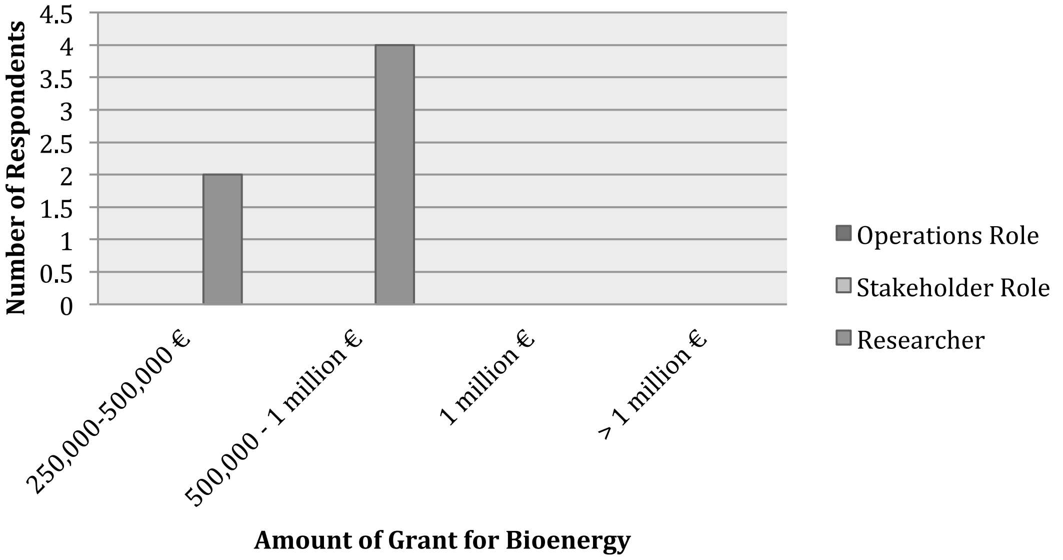
The response from survey data confirms development of European alliances and partnerships, dependent on the European Union research funding bodies, (Roos et al., 1999). The Director of one of the bioenergy research centres wrote in an editorial of how important European research networks and collaboration are to successful bid applications and dissemination of bioenergy research:

'Progress was influenced by a number of additional EU instruments launched during the project including European Industrial Technology Platforms and ERA-NET Bioenergy. Those led to the EIBI (European Industrial Bioenergy Initiative) and particularly EERA Bioenergy (European Energy Research Alliance'. Bridgewater, (2012). Biomass and Bioenergy, 2012, Vol. 38, p. 1.

The final section of survey questions relate to stakeholder factors in bioenergy research because as the previous figure indicates how important networking is in this regard. Figure 6.2.2.12: Amount of Grant and Figure 6.2.2.13: Importance of Bioenergy Research.

The first figure shows the majority of research respondents indicated 500,000 to 1 million € in the amount of grant received. However, this figure may not be accurate because low numbers provided this figure would indicate that they were not party to the financial management of their research centre and, furthermore, such sums would refer to specific projects that employed these individuals.

Figure 6.2.2.12: Amount of Grant



In Figure 6.2.2.13: Importance of Bioenergy Research was the combination of two sections of the researcher questionnaire. One of the sections queried the reason for developing the bioenergy research centre and the second section related to importance of bioenergy research. In the first instance the researcher participant responding indicated that their research centre was specifically established for research into bioenergy, (6 respondents) and that this was important, (10 researcher respondents). However, 12 researcher respondents indicated that a specific centre for bioenergy energy research was not important to promoting bioenergy. This is rather a contradictory response and it may be that either the respondents did not fully comprehend the question, or that their role in bioenergy research was not influenced by research centre objectives. However, it does come back to the fact that the majority of researchers were early career comprising 16 researchers in this category compared to 4 senior research staff.

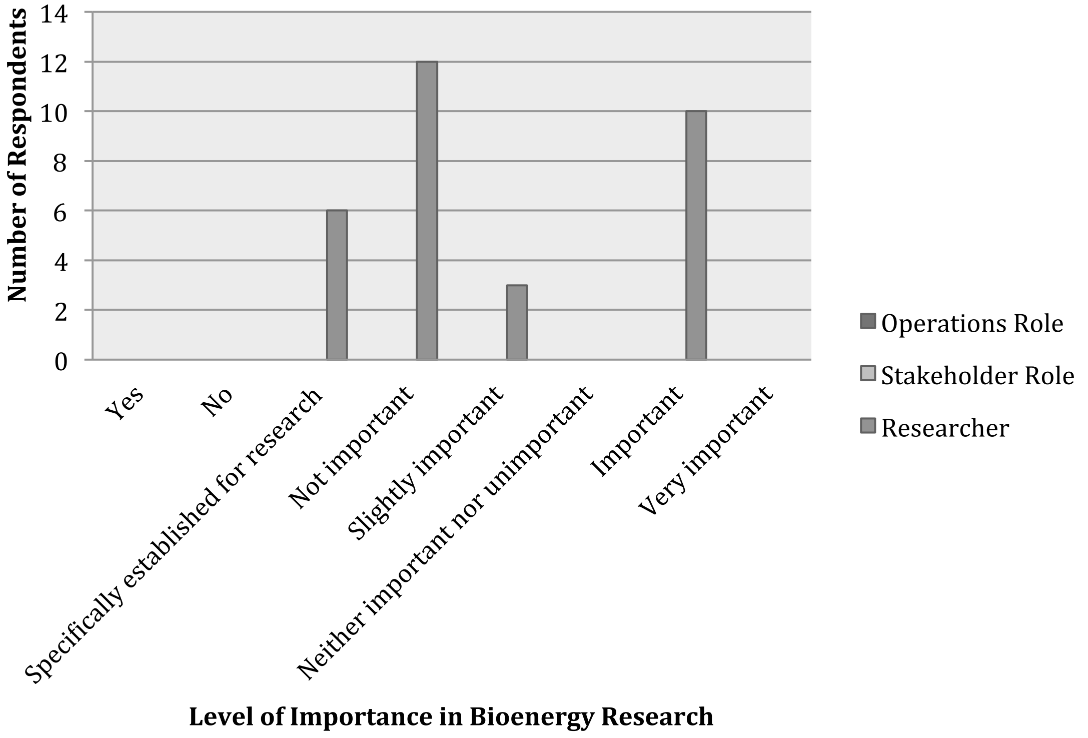


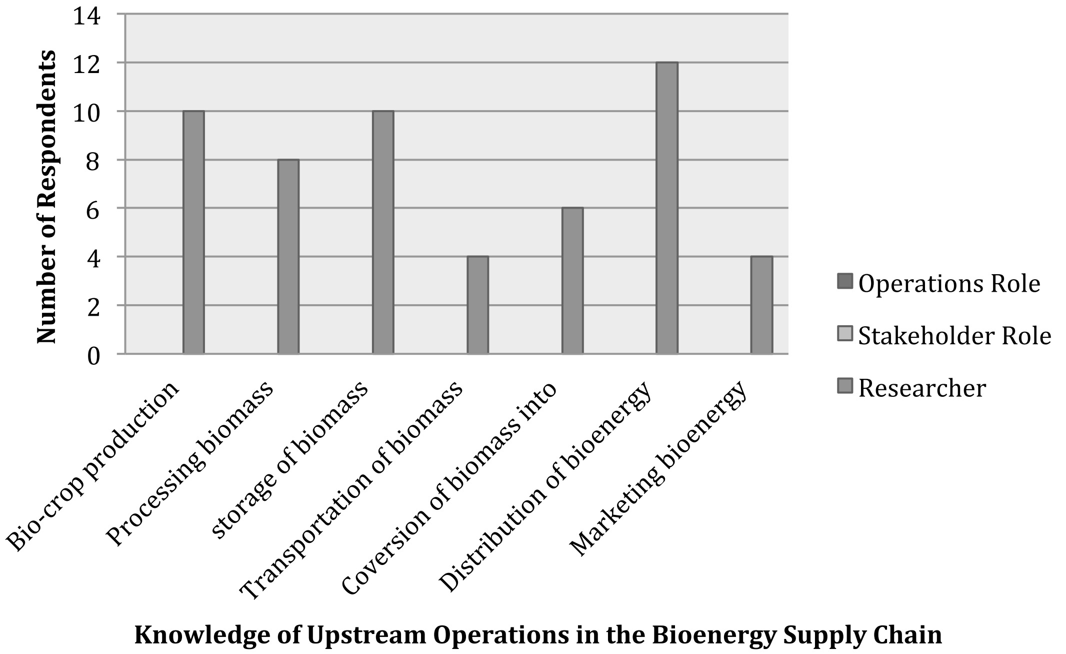
Figure 6.2.2.13: Importance of Bioenergy Research

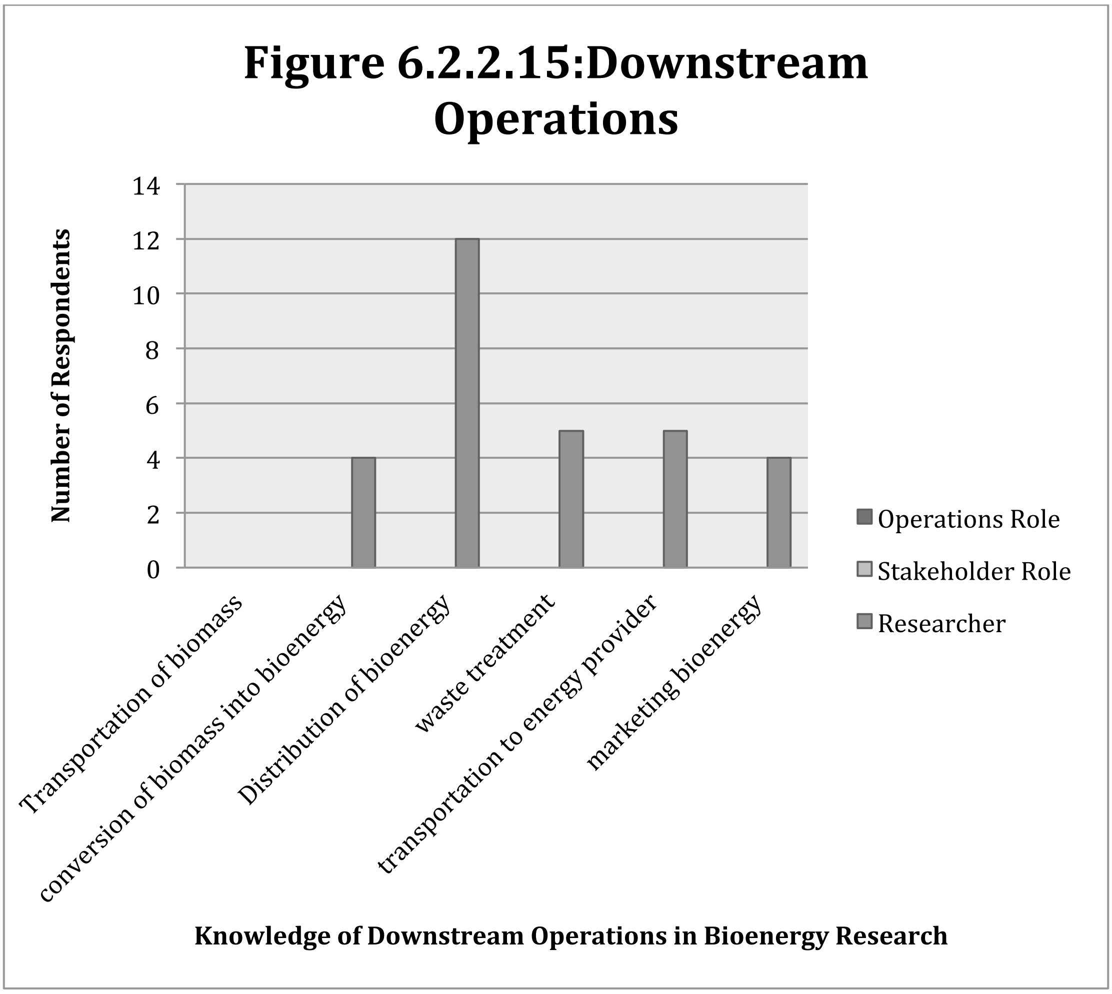
One Post Doctoral Researcher added:

‘Bioenergy research is very important to investigate efficiency and costs of the system’.

The questionnaire aimed at research into bioenergy also obtained data on researchers’ understanding of what is meant by upstream and downstream characteristics of bioenergy supply chains. The findings will confirm whether or not research is focused on technological and feedstock aspects of bioenergy rather than studied from a supply chain and business perspective. Figures 6.2.2.14 and 6.2.2.15 show researcher’s understanding of upstream and downstream operations in the bioenergy supply chain.

Figure 6.2.2.14: Upstream Operations





Upstream operations in this study were concerned with the production of feedstock and conversion processes, including transportation to a conversion facility, (point of origin to point of conversion). On the other hand, factors concerned with downstream operations were attributed to distribution of energy to customers and post-conversion waste. The findings show that the majority of researchers perceived upstream operations as ‘distribution of energy’ (12 researchers selected this option) followed by production and storage of biomass, (10 researchers each selected these options). In addition, findings from Figure 6.2.2.15: Downstream Operations also show the majority of researchers selecting ‘distribution of energy’, (12 researchers). The lowest values assigned to upstream operations in bioenergy were transportation of biomass (4 researchers) and marketing bioenergy (4 researchers). In downstream operations the lowest ranked scores were conversion (4 researchers) and marketing (4 researchers). The findings confirm that business and commercial organization of bioenergy is not a priority in bioenergy research. Furthermore, it is important to ensure that marketing and communications about bioenergy is disseminated through appropriate mechanisms and to the right parties, who will, determine the future of the industry, (Roos et al, 1999). Whilst, it is assumed that funding for research in this area is technology-driven rather than commercially driven there is a concern that the gap will grow wider rather than strive to a common goal amongst all parties. Identification of stakeholder characteristics in bioenergy supply chain integration are important to the study because of the role such actors play in determining the bioenergy industry, particularly in the Region. Initially, it was important to ascertain the level of understanding of supply chain and business processes amongst researcher participants if the results from the Bioenergy Research Questionnaire are valid and that they can make a contribution to the development of commercial-scale bioenergy? The emphasis of the next section is concerned process characteristics from operators and stakeholders with some input from researchers. Analysis and discussion is provided in the following order of presentation in this chapter as general information in relation to the number of years in production to specific operations' attributes in supplier selection and relationship, logistical operations, supply chain performance, IT applications, waste management and finally, marketing and communications' attributes in bioenergy production.

It was not clear whether bioenergy researchers fully understood the distinction between upstream and downstream characteristics in bioenergy supply chain operations. However, they did provide additional comments on areas for further research:

Post Doctoral Researcher: 'Harmonization and standardization of rules and a level playing field. The approach at present is not standardized and this affects credibility of bioenergy research. It is essential that we gain National Government buy-in and are seen as separate us academics from commercial aspects of bioenergy. There is a need to understand and progress the scientific aspects of bioenergy'.

Reader in Bioenergy: '1. Develop understanding of logistics and supply chain processes and operations in bioenergy and 2. Understand existing practices of logistics operations either on or off-site in bioenergy'.

Bioenergy Research Centre Director: 'To understand existing supply chain and logistics practices that can be adapted for bioenergy.

To understand what is meant by logistics. Renewable energy sites are co-located and how can current technologies and processes be adopted for bioenergy. To disseminate more effective pre-treatment and processing technologies'.

PhD Researcher: 'Resource availability (India). The price of electricity is not compatible with conventional fuel, (coal). CHP is key and close to the source, which will encourage utilization of heat. Renewable energy is close to the consumer, competition with grid electricity price is low. Biomass used by other industries, e.g. paper. Therefore we need to think of a range of biomass from other agricultural residues'.

Research Assistant: 'Contracts in bioenergy, particularly for biomass. Any type…there should be a trade agreement between suppliers and customer and a trade description'.

In the context of their comments it would appear that there is a gap in research for logistics and supply chain management, which would integrate knowledge and understanding of bioenergy technologies with commercial applications. Contracts were identified from the last comment in this section but also all the comments allude to integration of supply chain processes to link parties active in bioenergy development together. The next section presents findings from a process perspective in bioenergy.

6.3: Process Integration Characteristics in Bioenergy Supply Chains

This section presents survey findings that relate to production processes in the day-to-day operations of a bioenergy firm and its supply chain. Similar to questions on stakeholder characteristics in bioenergy, respondents were given a series of multi-choice questions on aspects of procurement, supplier selection, logistics operations, production performance, finance, marketing and communications. Most of the respondents in this section were operators and stakeholders rather than researchers.

Figure 6.3.1: Bioenergy Production and Figure 6.3.2: Number of Employees in Bioenergy Research Centre.

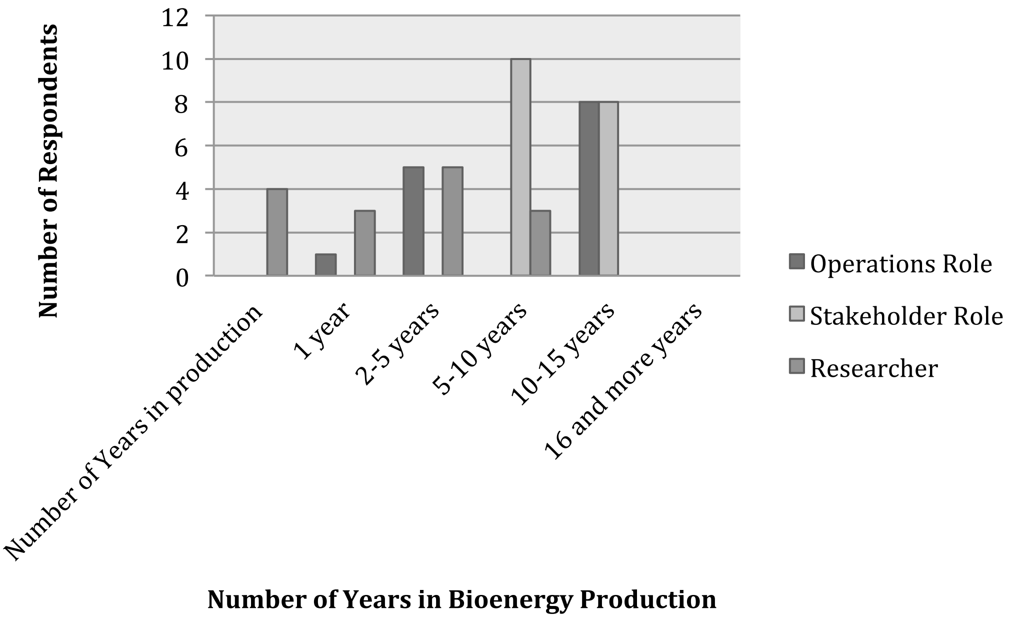


Figure 6.3.1: Bioenergy Production

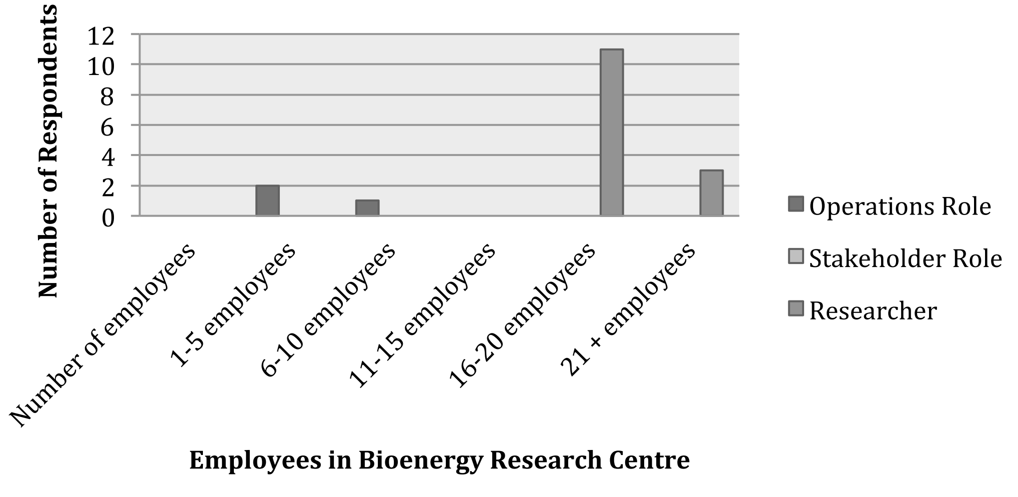


Figure 6.3.2 : Number of Employees in Bioenergy Research

Figure 6.3.1 shows the majority of stakeholders in bioenergy production had been involved between 5-10 years (10 stakeholders). However, both stakeholders and operators each had up to 10-15 years in bioenergy production. Compared to similar energy sectors, both stakeholders and operators had been involved in bioenergy production from a relatively short timespan. To date, there has not been any definitive research that can confirm this assumption. However, this suggests that the question should not have queried length of time in commercial production but should have queried:

‘How long does it take from bench scale to commercial production in bioenergy?’

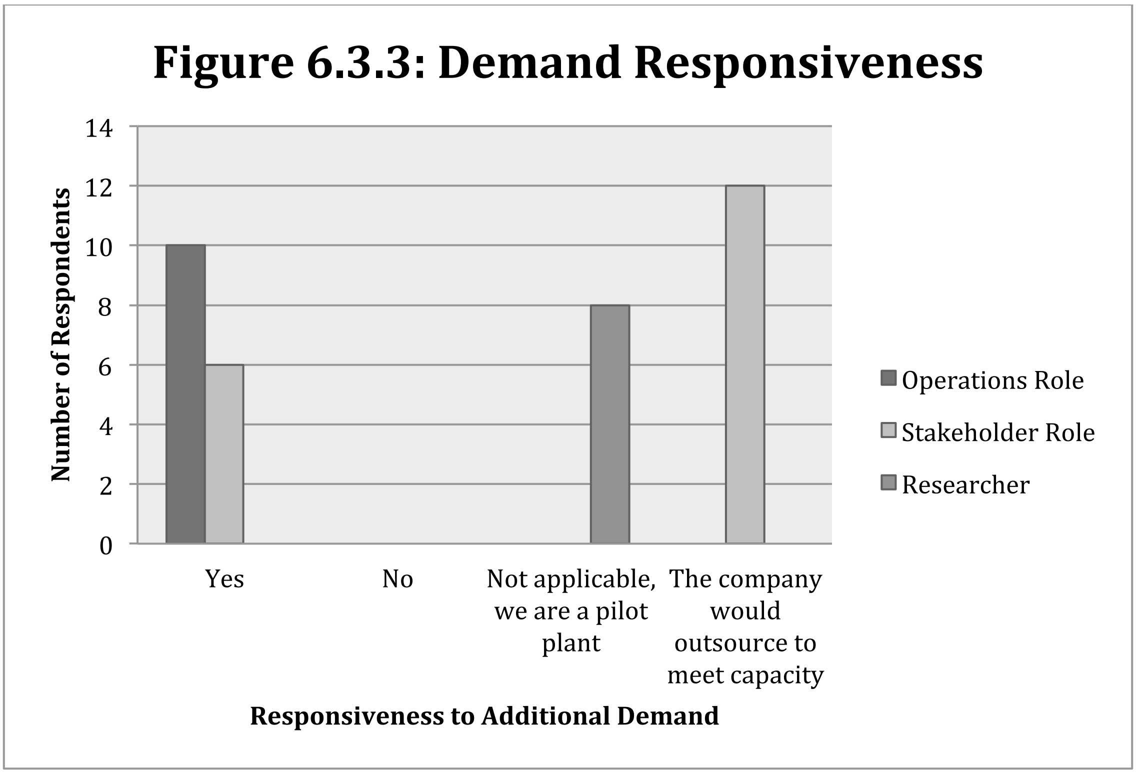
Such a question is of course, determined by the characteristics of feedstock and technology.

Researchers indicated shorter time frames in bioenergy production. One operator and 3 researchers had been involved in bioenergy production for a period of 12 months and others indicated between 2-5 years, (5 operators and 5 researchers). In relation to researchers, this is not unusual because many full-time PhD studentships are 3 years in duration and also, fixed term employment contracts for post-doctoral and research assistants are aligned with the duration of research funding term. No respondents indicated 16+ years involvement in bioenergy production. This finding confirms the novelty of the sector by shorter time spans in terms of production and also number of employees, (see Figure 6.3.2: Number of Employees in Bioenergy Research). From a research perspective there were 11 researchers who indicated 16-20 employees in contrast to operators who indicated 1-2 operators in bioenergy research. Interpretation of such a finding would indicate that staff had either been seconded to work on specific aspects of bioenergy, or were employed within their company to gather performance data. A plausible explanation for this finding would appear to be secondment of staff. In table 6.2.1: Role of Participants in the Study, p. 162 there were 2 project managers, and other staff of whom had been seconded into a stakeholder role to work in bioenergy research. Comments from operators and stakeholders who were not asked this question but nevertheless commented on recruitment of skilled staff stated:

Stakeholder Legal Firm: ‘There is a real concern of skill shortages in this sector’.

Plant Manager: ‘Colleges do not run the type of course we need to run the plant’

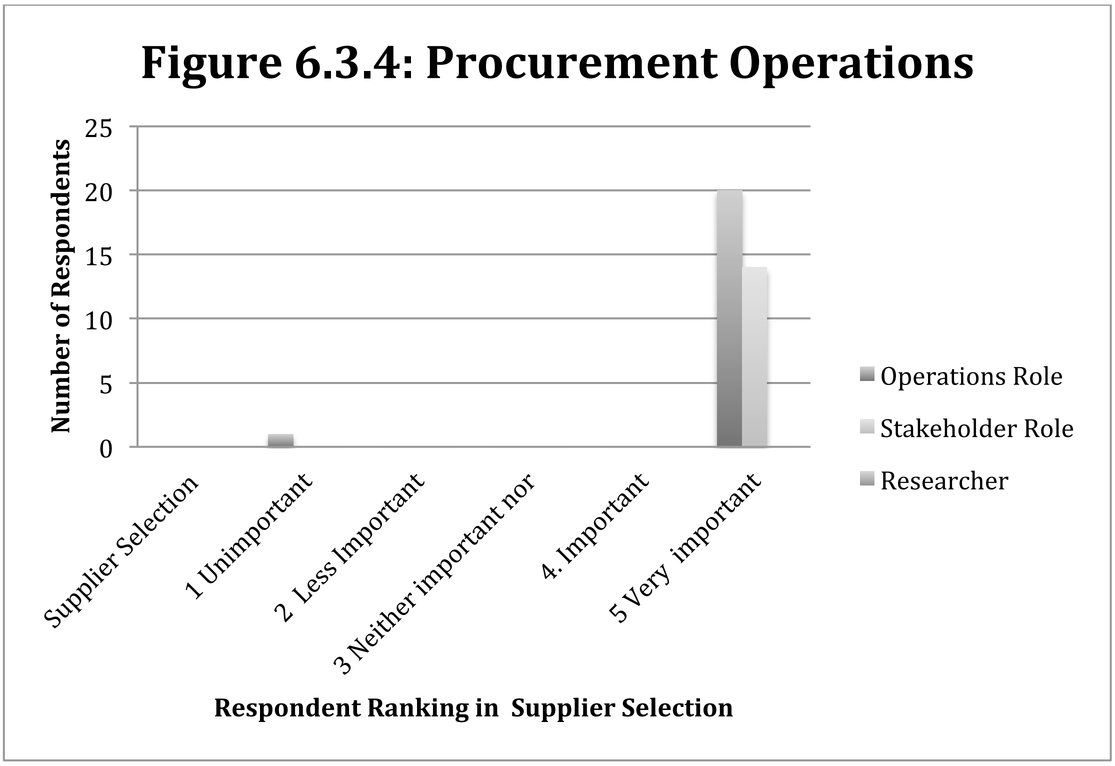
There is a tension between research-scale operations in renewable energy and the imminent requirement to scale up to commercial production, but as the findings show, this is indicative of an emergent rather than a mature industry sector where there are not the skills and people flow across the supply chain as might be anticipated in other industries. Again the research is limited in this area but Domac et al, (2005) find that employment in bioenergy is likely to grow from 449, 928 jobs in 2005 to 642,683 jobs by 2020, which is an estimated increase of 192,755 employees in bioenergy (global figures). The next figure shows if bioenergy companies in the Region are able to scale up to meet increased demand, (Figure 6.3.3: Demand Responsiveness and an additional view of this is given in Figure 6.3.21 in Finance and Performance of bioenergy Supply chains). Here, the figure demonstrates a dichotomy between bench-scale and commercial provision in bioenergy.



Both operators and stakeholders report that they are able to respond to increased demand, (10 operators and 6 stakeholders), but would have to outsource increased demand to other conversion facilities, (12 stakeholders). Whereas researchers indicated that this was not applicable as they worked at a pilot plant, (8 researchers). This could either mean conducting investigative experiments in feedstock or micro-scale testing of technology under laboratory conditions. Like the previous figures (Figure 6.3.2.) this finding reiterates the lack of maturity in this sector and the gap not only between research and commercial scale activities but also, from the stakeholder perspective that indicated that companies would have to outsource to meet any increase in demand for energy. None of the operators reported that they would outsource production in order to meet additional demand. Therefore it can be assumed that gaps exist between the research and commercial practice in terms of business strategy and production. Supply chain attributes cited in the literature originated from supplier-to-customer transactions. Altman et al, (2007, p. 107) cite:

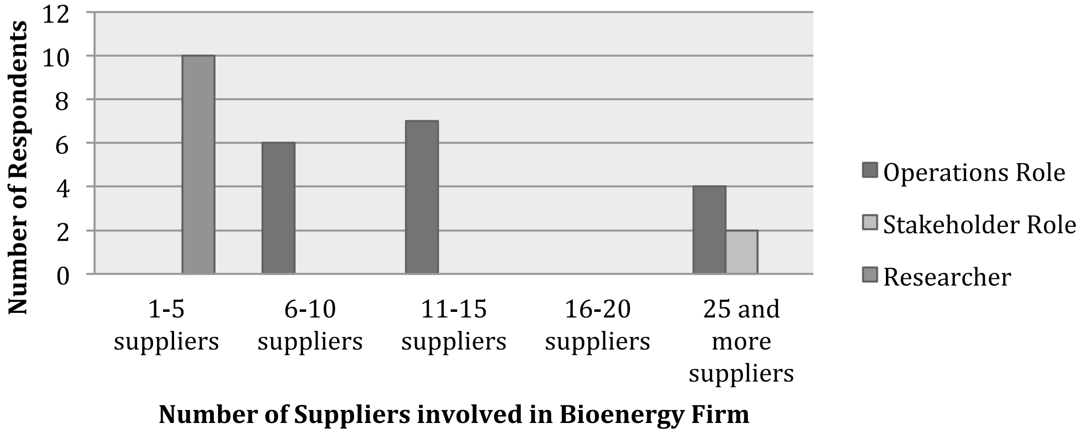
'…transaction costs from organizing biomass exchange may be an important non-technical barrier to commercial development'.

Procurement in bioenergy in the questionnaire is divided into eight supplier attributes. The first figure relates to procurement operations in bioenergy, (Figure 6.3.4: Procurement Operations) of which the data confirms that both operators and stakeholders rank procurement operations in bioenergy production are highly important, (20 operators and 14 stakeholders). Researchers did not respond to this section, as their role did not involve procurement and any supplier-customer transactions.

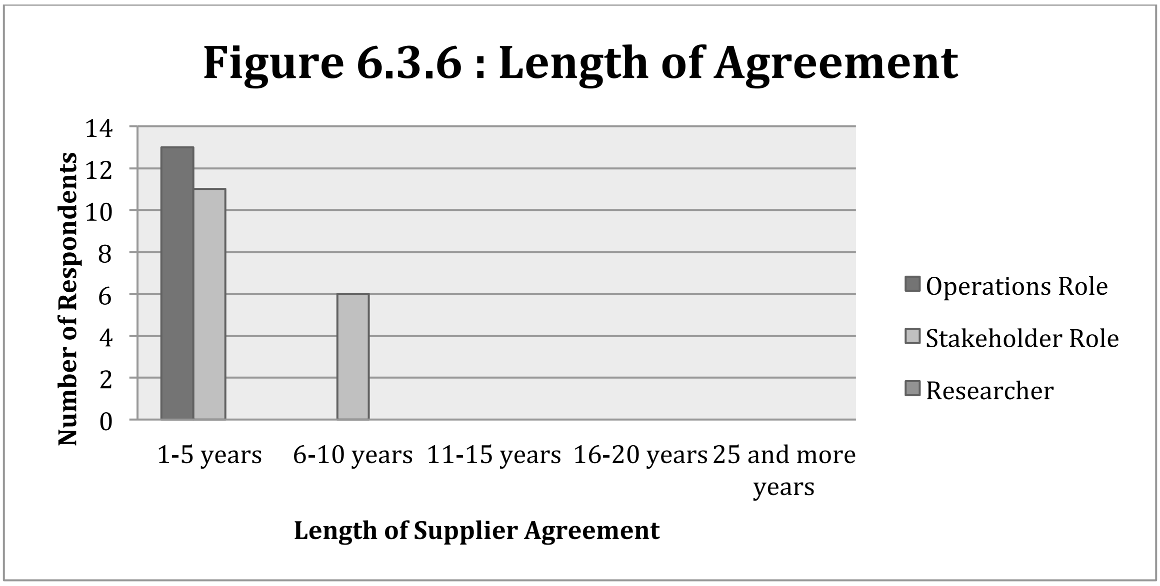


Having established from the survey that procurement is highly important it is necessary to understand what factors were important in procurement operations in bioenergy firms. Respondents were asked how many suppliers were involved in Figure 6.3.5: Number of Suppliers. With the exception of researchers responding to this query, the majority of operators (7 operators) selected 11-15 suppliers in bioenergy production. There were a minority of responses amongst operators and stakeholders selecting 25 and more suppliers in bioenergy production, (4 operators and 2 stakeholders). Researchers on the opposite end of the scale ranked the lowest number of supplier involved. Ten researchers selected '1-5 suppliers', which were attributed to scientific equipment rather than commercial suppliers such as feedstock and logistics companies involved in the biomass-to-bioenergy supply chain. The number of suppliers involved in this process is determined by scale and technology. There were direct links with feedstock producers and transport providers. In addition, such firms had engineering contractors on-site who were sub-contracted to oversee the plant maintenance. Amongst, engineering contractors on-site, there were also sub-contractors responsible for maintenance of specific equipment, such as boilers for example.

Figure 6.3.5: Number of Suppliers



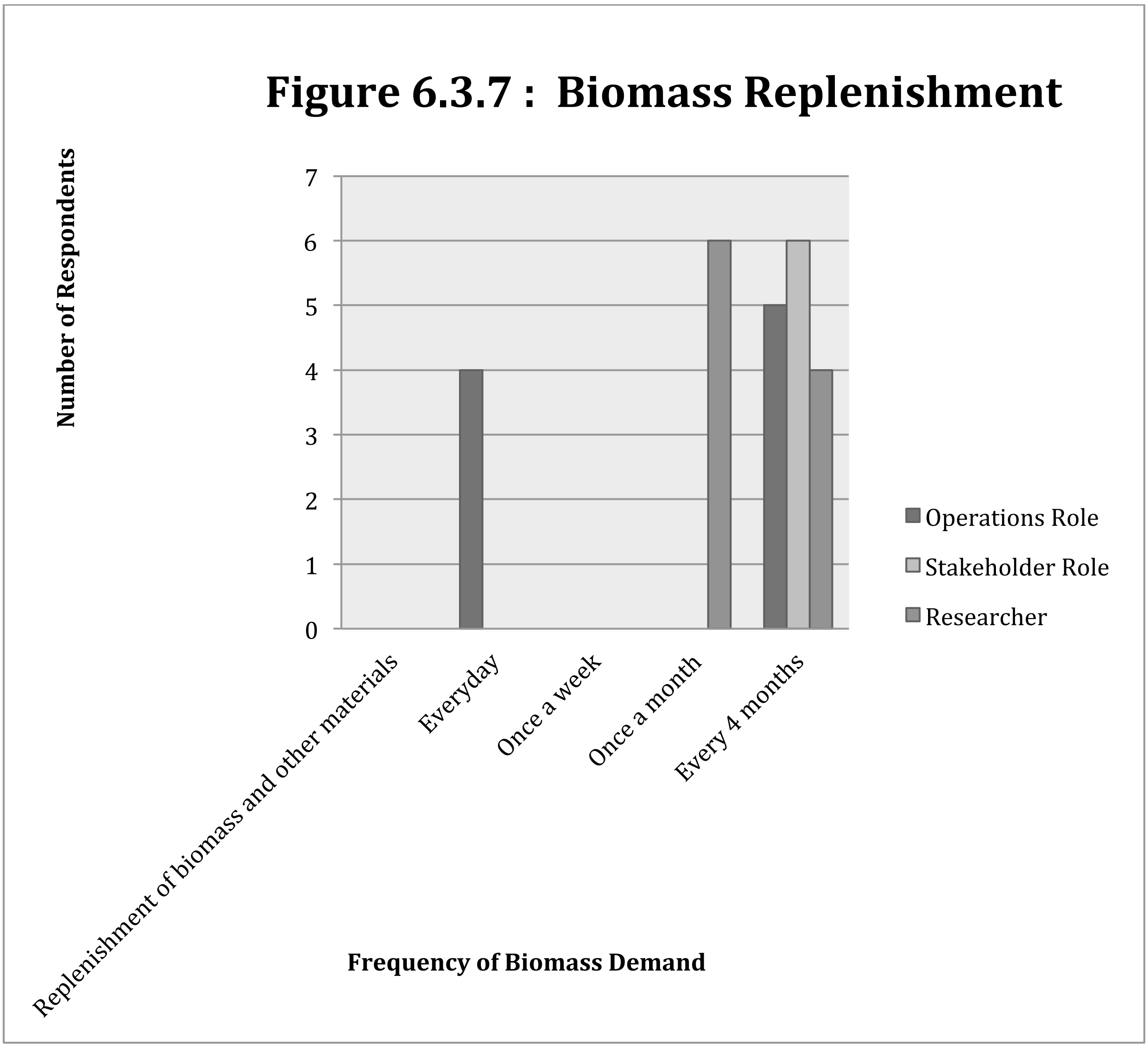
There was in evidence a hierarchy of suppliers available on site during day-to-day operations. This involved legacy contractors that remained on site as a result of turnkey arrangements where engineering contractors have to remain on site for equipment maintenance, contract engineers for general maintenance, biomass and logistics providers. Therefore there is a distinction between legacy contractors and current suppliers deployed in bioenergy firms. This is borne out by length of agreement shown in Figure 6.3.6. The findings shown in figure 6.3.6 confirms that the majority of stakeholders and operators selected length of supplier agreement of 1-5 years (13 operators and 11 stakeholders). None of the participants selected supplier agreements longer than 15 years. Six stakeholders selected 6-10 years. This contradicts findings from the scoping study where bioenergy operators indicated contracts of up to 25 years. Glithero et al., (2013) find that small-scale producers favour contracts of 3-5 years in duration, which provide a balance between stability in relation to fixing costs and greater flexibility to change compared to longer-term contracts.



A comment from one of the participants provided further meaning to survey data and confirms assumptions arising from the survey results in the context of contractual arrangements in the biomass-to-bioenergy supply chain. The respondent clearly states that contractual agreements operate on a number of different levels confirmed in the literature where tier one suppliers and customers had longer term agreements compared to sub-contractors, (Altman et al., 2006).

Project Manager: 'Depends on role within the industry. Waste plants require more cost capital investment. Therefore supplier needs to agree with the company to provide technology maintenance over longer terms. Feedstock supply on the other hand depends on payback period. For example, AD feedstock is paramount but needs contracts of at least 5 years, preferably contracts of 5-10 years. Contracts with waste companies require 3-4 years duration. Investors need longer term contracts to ride the risks'.

In addition to number of suppliers and length of supplier agreement, respondents were also asked how often they replenished feedstock. Figure 6.3.7: Biomass Replenishment shows a cluster of replacing feedstock every 4 months (5 operators, 6 stakeholders and 4 researchers).



However, 4 operators reported that they replenish stock every day. It should be noted that demand scheduling in biomass is determined by feedstock characteristics. For example, woody biomass is stored until it reaches moisture content up to 30%, whereas MSW is delivered everyday into their conversion facilities. Written responses were also provided from all parties to add to the survey data:

Research Assistant: 'During operations we replenish biomass solids every week and liquids between 1-3 months intervals. We have limited storage space'
Post Doctoral Researcher: 'Every 2 weeks'.

Logistics Plant Manager: 'The question is not applicable really. We are a biomass producer and supply up to 1 million tonnes biomass per annum'.
Bioenergy Plant Manager: '50,000 tonnes'.

Logistics Company Biomass: 'We deliver in ranges of 5-10 tonnes, 51-100 tonnes, 101-500 tonnes and 500+ tonnes'.

Sales Administrator Bioenergy Company: '500 kg to 2.5 tonnes and we can scale up 10+ tonnes per day'.

Stakeholder Legal Firm: 'Pellets cost £200 per tonne and can deliver 1.5m^3 per truck. Transport further requires a bigger margin on cost per delivery to be cost effective. Biomass boiler that produces 350 KW demands 200 tonnes of pellets. A 1 million KW/h requires 2300 tonnes pellets. A 2 MW AD plant requires 14,000 tonnes maize'.

Engineering Contractor: '50,000 tonnes per year'.

The comments identify specific quantities of biomass, cost in one case and time frame. This is not untypical of supply chain operations between material suppliers and scheduling demand by the conversion facility. There is a lack of literature that covers replenishment of feedstock. Most literature points towards feedstock characteristics and calorific value. For example see Chatterjee (2013) who considers costs of feedstock production from bio-crop yields.

Risk in supply of biomass shown in Figure 6.3.8 provides categories of risk linked to procurement operations. Both operators and stakeholders (12 operators and stakeholders, including 5 researchers) confirmed that quality of biomass was a risk in supply, particularly if they are sourcing feedstock through third party arrangements. In addition, 8 operators identified competition from other bioenergy companies as a further risk in supplying biomass. Transportation, safety and security of supply were not seen as a risk amongst operators.

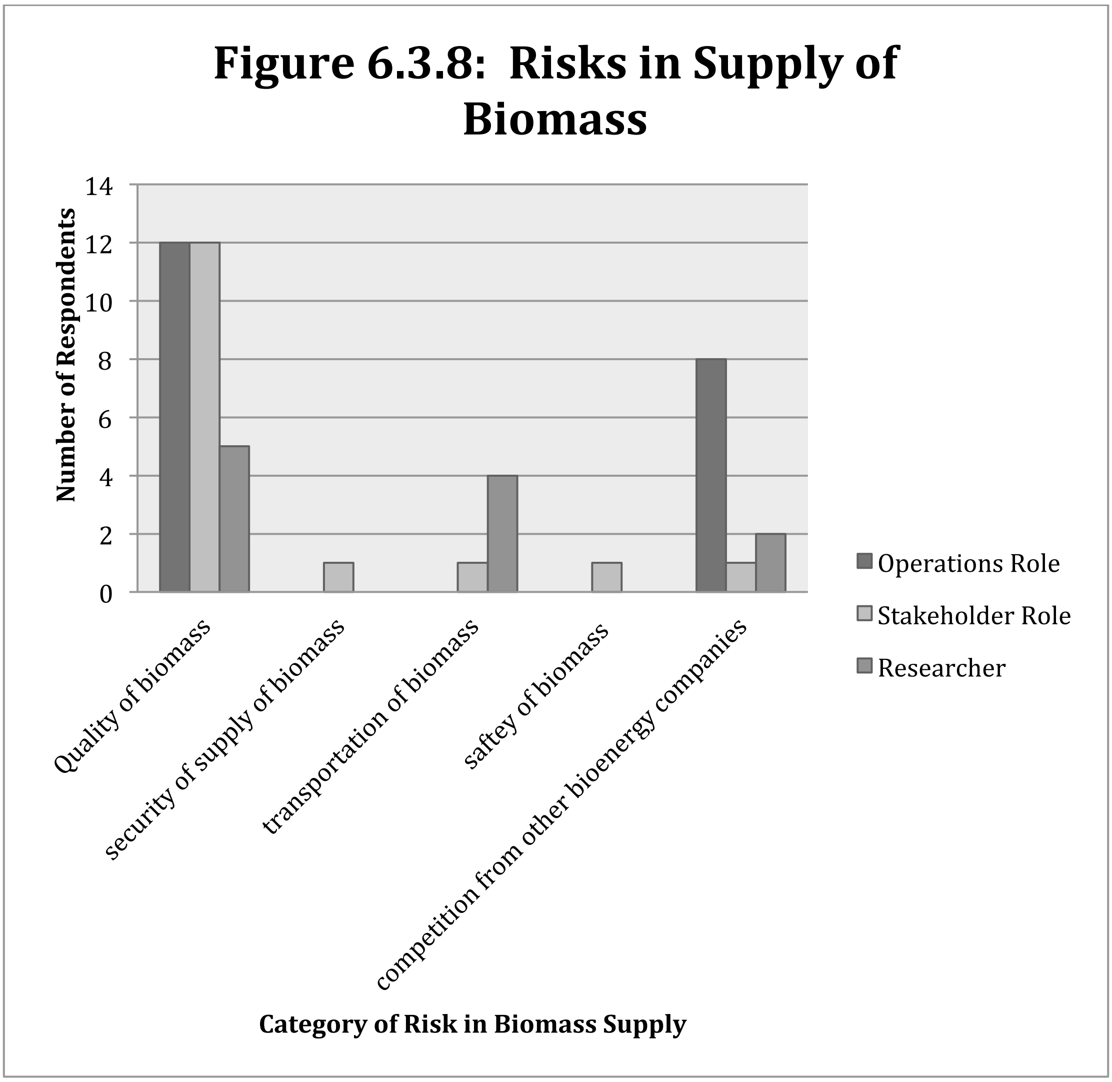


Figure 6.3.8: Risks in Supply of Biomass

Additional comments from respondents provided more information of risks associated with biomass:

Engineering Contractor: ‘Weather affecting crop yield’.

Stakeholder Legal Firm: ‘With reference to transportation, distance once the supply chain has been set up it’s a question of can they afford it? Also storage issues in the plant, packing it into the plant can be unsafe. There are areas where CO_2 poisoning. There needs to be good ventilated storage facilities’.

Biomass Producer: ‘Weather affecting yield’.

Research Assistant: ‘Supplier risks are irrelevant because we are a bench scale facility’.

PhD Researcher: 'Quality of biomass. If wet, it will increase the weight and transport on no proper roads (referring to road transport in India) and there is competition with other bioenergy industry'.

Post Doctoral Researcher: 'Liquid issues and from solids as we do not have a wood pellet silo. The boiler is on the third storey and adds a further 30% to cost as we need a winding hoist to deliver material from ground level'.

There were issues highlighted by some of the researchers regarding the design of their research facility. However, operators and stakeholders identified issues concerning quality of biomass and disruptions to supply that are confirmed from the survey data. There were single numbers of stakeholders selecting these categories but low numbers would suggest that these could not be confirmed as risk to supply of biomass. However, the findings show that quality is an issue in supply. Sokhansanj et al., (2006) suggest that better visibility between producers and transport providers would alleviate degradation of biomass.

Interaction between suppliers and customers was the final area of investigation in procurement section of the survey. These set of questions queried the type of relationship between bioenergy firms and their suppliers and customers. Findings are given in Figures 6.3.9 to 6.3.10. There was a contrast between operators and stakeholders in operating through consortia, (majority of stakeholders) compared to operators who selected interaction with biomass suppliers. Stakeholders tended not to have any relationship with suppliers.

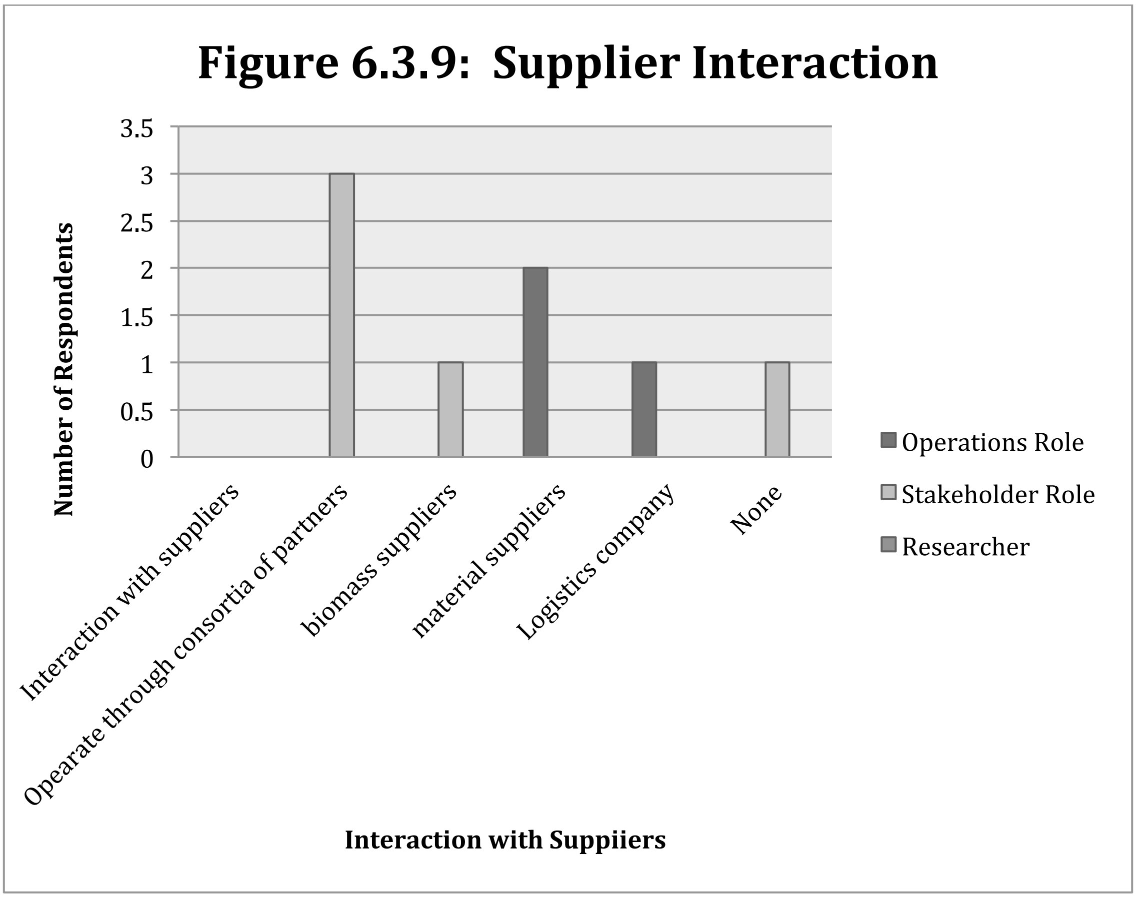


Figure 6.3.9: Interaction with Suppliers. Operators selected interaction with logistics companies and material suppliers (1 and 2 respectively). Stakeholders selected consortia on the other hand, (3 stakeholders selected operate through a consortia). This would confirm findings from Figure 6.3.6: Length of Supplier Agreement where contracts were of sufficient length to provide a level of stability.

Comments from respondents gave further information on supplier and customer interaction to identify how bioenergy companies developed relationships with other businesses:

Engineer Contractor: 'Companies in the biogas sector such as AD developers, plant suppliers and gas grid owners'.

Stakeholder Legal Firm: 'Technology suppliers, biomass suppliers and material suppliers. In relation to customers we deal with end users of energy, waste products and farmers who use digestate. Biomass suppliers and developers who are also our customers, banks for finance'.

It can be assumed from the comments that robust relationships are developed alongside formal contractual agreements.

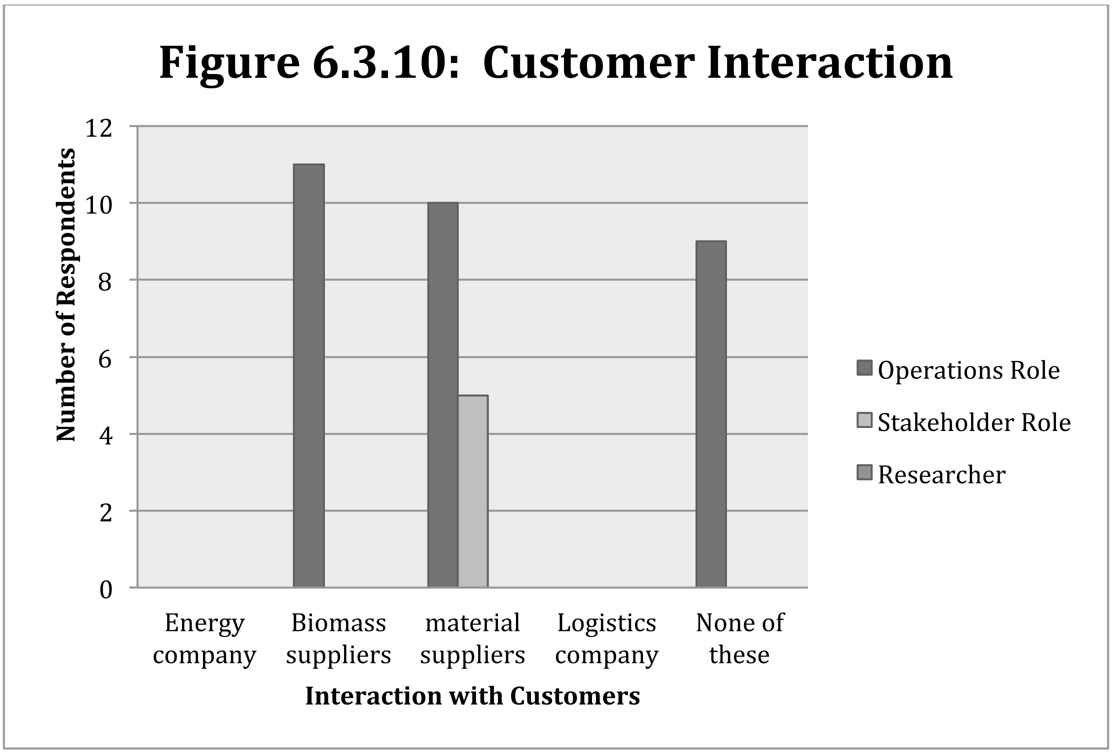


Figure 6.3.10: Customer Interaction

The findings from Figure 6.3.10 show that operators view biomass suppliers and material suppliers (11 and 10 respectively) compared to 5 stakeholders who selected material suppliers. None selected ‘energy company’, for either supplier or customer interaction. Both parties demonstrated confusion in understanding the difference between the term, ‘suppliers’ and ‘customers’. It could be assumed that customers and suppliers mean the same. However, the findings from both figures confirm that the supply chain is defined from biomass-to-bioenergy and not from point of origin (feedstock producers) to point of consumption, (energy users).

Logistics provision is generally outsourced amongst bioenergy producers. Therefore one of the sections in the survey referred to how logistics operations linked into bioenergy production and its supply chain. There is a distinction between transport and logistics functions in the survey. Transport refers to vehicle selection (haulage) and logistics refers to storage and warehousing operations including selection of transport, where the logistics company outsources transport. Figures 6.3.11-6.3.15

show findings from logistics and transport from a process perspective. The first figure 6.3.11: Transport Mode in this part of the survey demonstrates predominance of road transport in the UK and biomass does not deviate from this. Eighteen operators, 12 stakeholders and 8 researchers selected road transport compared to other transport modes such as rail, sea, inland waterway and pipeline. Bioenergy tends to be a rural industry therefore road links are important for delivery of biomass to conversion facility. Infrastructure for road transport is well developed in the UK which reduces risk in ability to supply, (Rogers and Brammer, 2009).

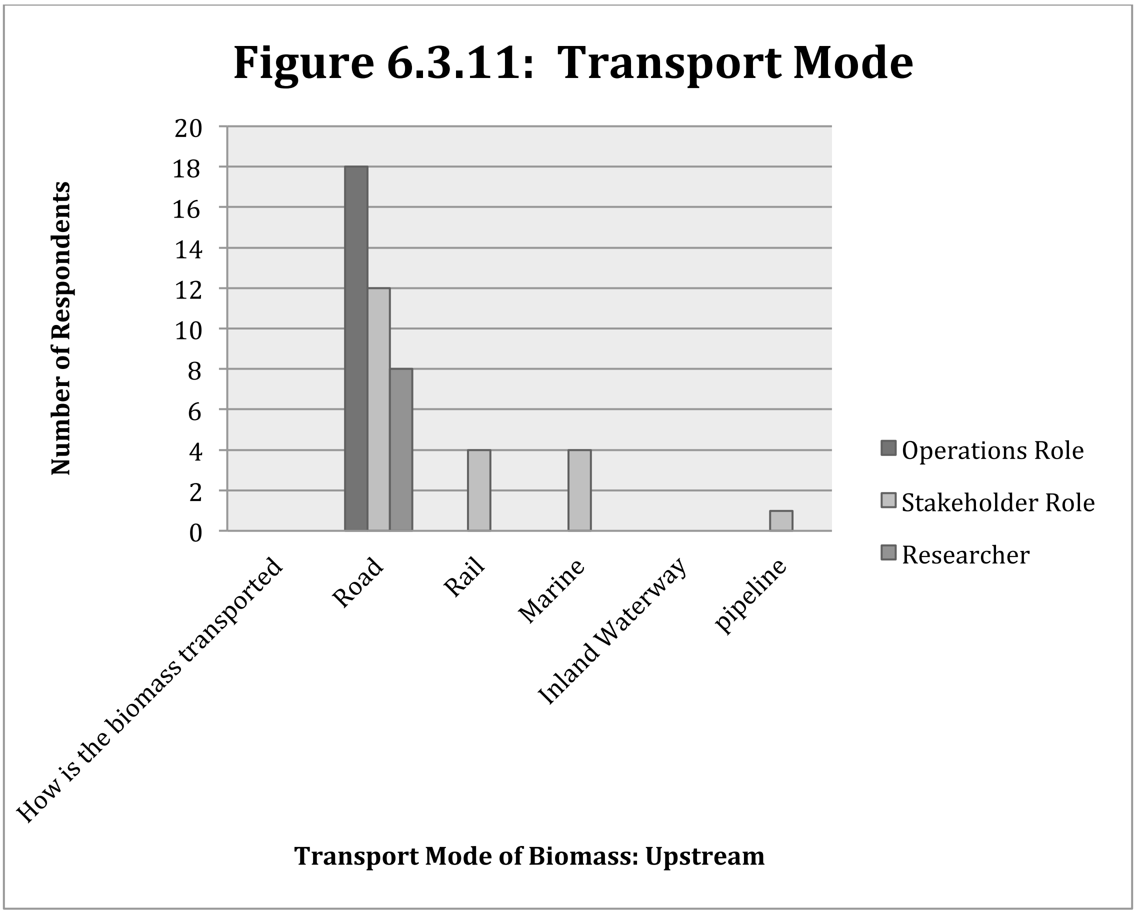
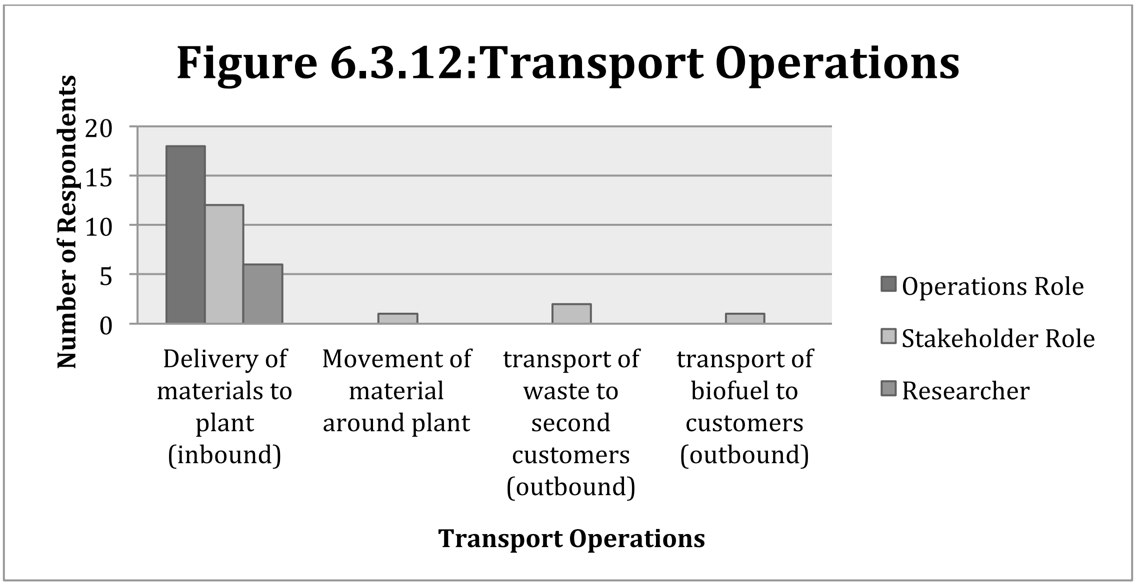
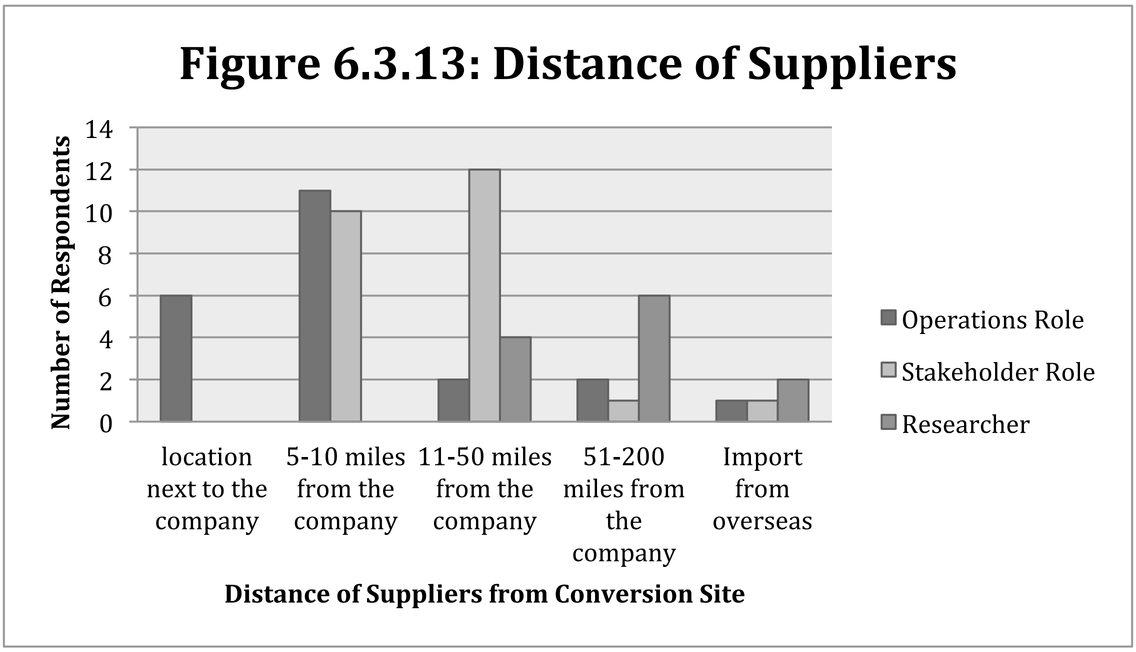


Figure 6.3.12: Transport Operations show the role of transport in logistics. Here the findings confirm a cluster from all participants that transport operations are deployed for delivery of biomass to the plant, (18 operators, 12 stakeholders and 6 researchers). This places emphasis of process integration in the bioenergy supply chain on upstream operations as opposed to downstream operations. Numbers of participants selecting downstream transport functions were negligible. One stakeholder each

selected movement of material around the plant and outbound transport. Only two stakeholders selected transport of waste (post-conversion) to second customers. The next section of 'Logistics Functions' queried distance between conversion facility and supplier locations seen in Figure 6.3.13: Distance of Suppliers.





The majority of respondents selected from 5 miles up to 50 miles their suppliers were located from the plant. There were a number of comments from respondents regarding supplier locations:

Sales Administrator in Bioenergy: ‘Waste is localised nearby to AD site location and components are sourced globally’.

Technical Project Manager: ‘All within 15 miles’.

Technical Manager in Bioenergy: ‘15 miles’.

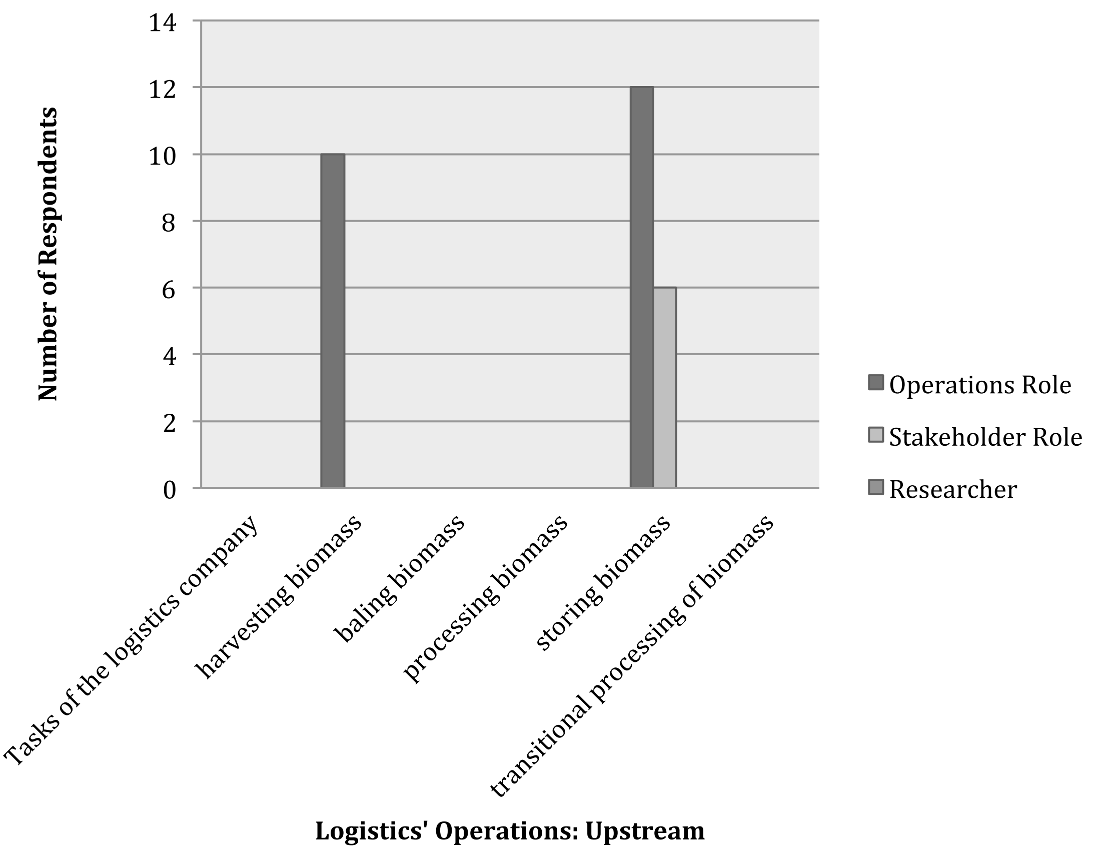
Logistics Manager Biomass: ’50-100 mile radius’.

Equipment manufacturer, Bioenergy: ‘We are a manufacturer of technology so only buy specific components which we do not manufacture in-house’

Bioenergy Stakeholder: ‘Distance depends on cost of feedstock. Road transport costs are too high for low value crops. Woody biomass is £85-£100 per tonne to transport. Biomass chip of 3 m^3 -3.5 m^3 is limited to how much can fill a truck. Yet pellets are more expensive but more compact. More importantly, viable distance depends on value of feedstock and would consider value of £3000 per tonne in value as viable to transport by road’.

Logistics operations comprised questions on what in-house and outsource functions amongst firms in the bioenergy supply chain. The first figure, (Figure 6.3.14: Logistics Operations) required participants to select specific logistics’ operations performed in bioenergy organisations. Twelve operators selected storage of biomass and ten from the same group selected harvesting biomass as part of logistics’ operations. Of the stakeholder group, the only category selected was ‘storage of biomass’, (6 stakeholders). Evidence in the literature suggests that biomass producers are also responsible for transport and in addition, local supply chain do not require long haul distances and multi-modal transport systems, (Scott et al., 2012; Hillring, 2002). Contrary to the literature, logistics providers and commercial operators in this study had contractual agreements in place to perform conventional logistics operations of storage, quality control and delivery of biomass to customer (conversion facility). Figure 6.3.15: Outsourced Operations shows participants show that only 2 stakeholders responded by selecting ‘transportation’ as logistics functions that are outsourced.

Figure 6.3.14: Logistics' Operations



Comments from participants included:

Project Manager Stakeholder: 'Farmers who produce feedstock may also do logistics. Biomass needs specific types of transport such as trailers with moving floors and blowers. There is a potential risk as conversion plants are held to ransom by logistics companies with specialist trucks'.

Technical Project Manager: 'We need transport for delivery of digestate'.

Sales Administrator Bioenergy: 'Energy recovery from biomass waste'.

Business Development Consultancy: 'We transport AD technology to site for installation for our customers'.

Logistics Manager: 'Transporting biomass to the end user'.

One of the stakeholders alluded to logistics' companies' customers to ransom due to ownership of specialist vehicles to transport biomass but most identified dependence on transport and logistics companies to deliver biomass to conversion sites. This would confirm survey findings which find outsourcing logistics to third party providers in order to focus on either biomass production or bioenergy conversion. According to Scott et al., (2013), decision to outsource functions that are not core to the business are part of the firm's strategic supplier sourcing strategy. Further operational processes also confirm this factor in Figures 6.3.16 and 6.3.17 show performance indicators attributed to bioenergy firms in the survey. Figure 6.3.16: Performance Factors in Bioenergy show a contrast between stakeholders and operations. The majority of operators selected 'on time delivery' (12 operators) followed by 'cost of material and labour' (10 operators) and quality of biomass (10 operators). Stakeholders, on the other hand selected 'cost of material and labour' followed by 'quality of produce', (10 stakeholders selected both variables in Performance Factors).

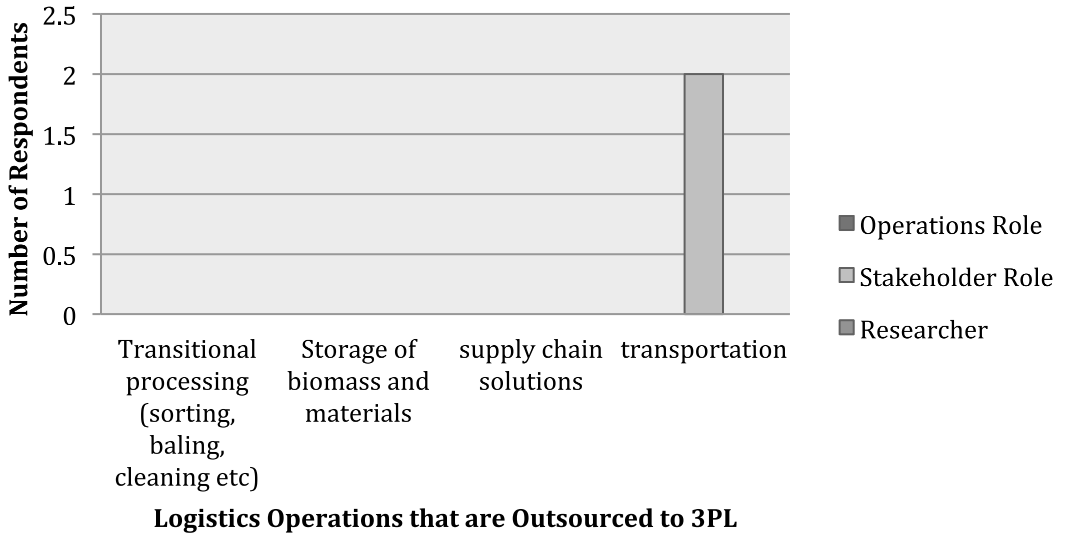


Figure 6.3.15: Outsourced Operations

The majority of operators selected 'on time delivery' (12 operators) followed by 'cost of material and labour' (10 operators) and quality of biomass (10 operators). Stakeholders, on the other hand selected 'cost of material and labour' followed by 'quality of produce', (10 stakeholders selected both variables in Performance Factors). Operators reiterated in most of the meetings with them that quality of biomass was a key issue and procedures had to be in place to ensure that suppliers met with their criteria. The same issue arose from logistics providers, particularly if they outsourced transport to ensure integrity of feedstock to the point of delivery.

Logistics Manager stated: ‘ *It’s the quality of feedstock that’s really critical’* and a plant manager in a rural AD plant also confirmed: *‘It’s a problem where foreign bodies have not been sorted from the biomass because it breaks the machinery’*

The logistics manager elaborated that they were reliant on achieving critical moisture levels in biomass they processed on site prior to delivery to conversion site.

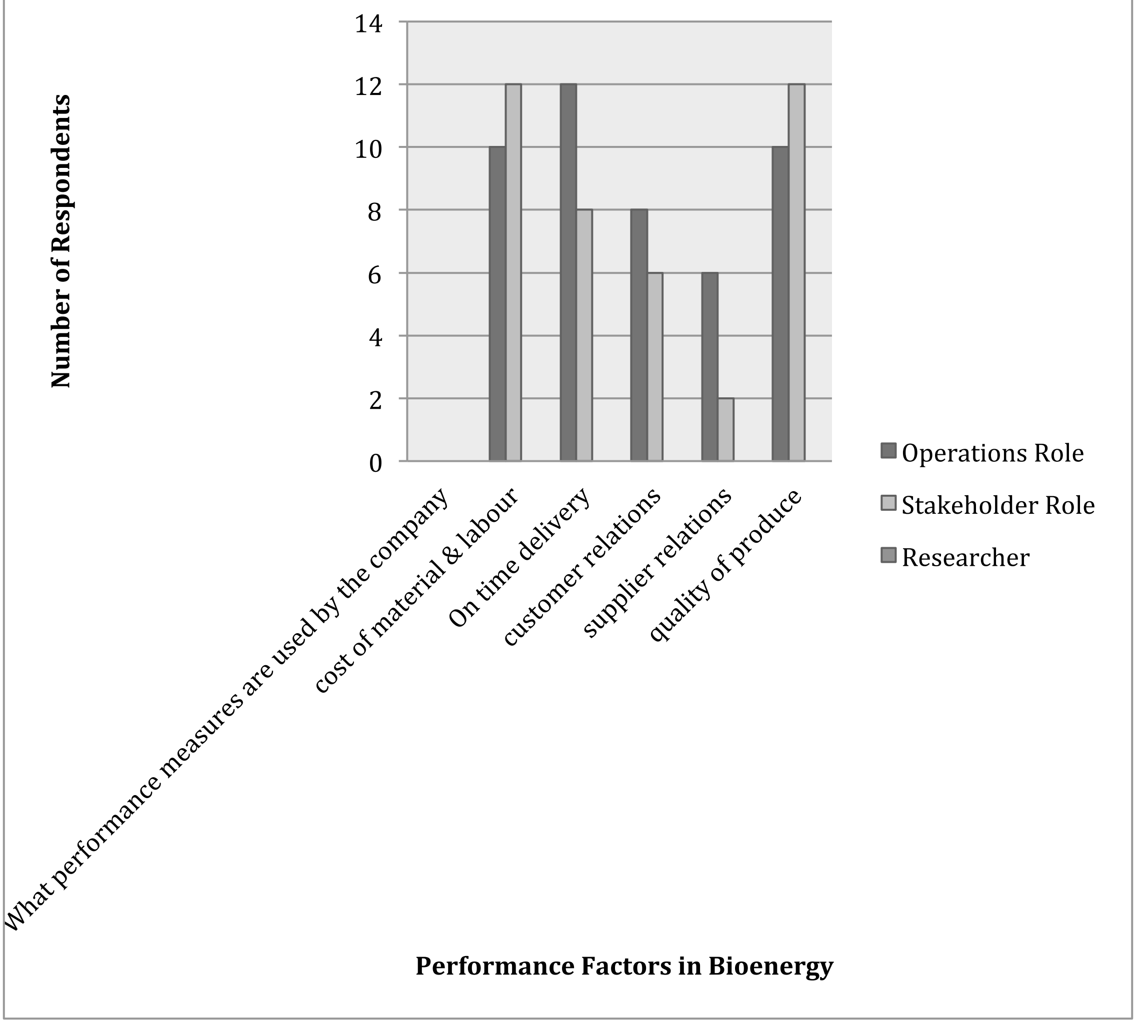
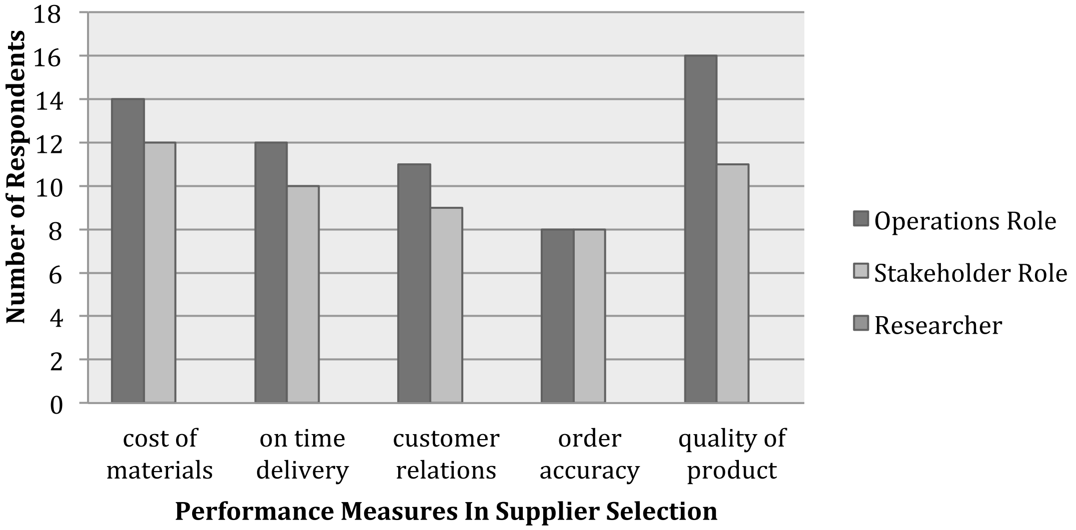


Figure 6.3.16 : Performance Factors

It is evident from the findings in the survey that standard quality criteria should apply across the bioenergy supply chain in order to optimize processes and reduce costs. Figure 6.3.17: KPIs in Supplier Selection

Figure 6.3.17 : KPIs in Supplier Selection



There is limited evidence in the literature of application of performance indicators to bioenergy supply chain management and integration, (Puigjaner et al., 2015; Scarlat et al., 2015) and as Altman et al., (2008, p. 108) cite:

'...biomass supply chains are under-researched'.

The survey findings show that performance indicators are utilized in measuring performance of suppliers and processes across the supply chain. Despite supply chain novelty in bioenergy and localization, such firms apply KPIs to key features in the production system, (Findings from the survey clearly demonstrated KPIs in a number of areas from operator and stakeholder perspectives. There was an interesting similarity in choices made by operators and stakeholders in prioritising KPIs in bioenergy as well as differences. Firstly, most of the operators (16 operators) selected quality compared to stakeholders (11 stakeholders selected quality of biomass), whereas the majority of stakeholders selected 'cost', (12 stakeholders). This was the second highest score amongst operators (14 operators selected cost). In order of ranking, third highest score was the same amongst operators and stakeholders for 'on time delivery', (12 operators and 10 stakeholders). Both groups ranked the same choice for customer relations and order accuracy, (8 operators and stakeholders per variable). Application of KPIs is intrinsic to contractual agreements, production planning and control irrespective of the size of organization. Such performance indicators can be adapted to suit the organizational dynamics and it can be assumed that KPIs were developed to conform to the requirements of all parties. Customer relations are important to supplier selection and also in communications and marketing of bioenergy. There is an overlap of numerous factors in supply chain integration. Not only can this be confirmed in the findings from supplier selection, KPIs and logistics functions. The one over-riding factor between the variables that links them together is the funding and planning approval between parties in bioenergy. Figures 6.3.18: Compliance and Regulations. Stakeholders rather than operators selected options in compliance and regulations. However both stakeholders and operators selected 'EU Directives', (13 operators and 14 stakeholders) and the remaining selected variables were from stakeholders. EU Directives were at the forefront of concern amongst operator and stakeholder participants. There were many changes in UK Regulations that were a result of changes in EU Law governing renewable energy. During the period that the survey was conducted, (2013-2014), both groups were aware of imminent changes and how this would impact on their business, in relation to financial incentive and biomass, and strategic planning bioenergy in the case of stakeholder roles. The UK Government through the Department of Climate Change introduced measures to reduce subsidies to renewable energy in order to reduce dependency on renewable energy subsidies so that bioenergy adopts appropriate business conventions to ensure viability. Changes in national renewable energy policy are also cited in Chapter One, (p. 13). Figure 6.3.19: Forecast of Subsidies in Renewable Energy in the UK to 2021 shows the cost of subsidies if continue at current rates, which show forecasts for the distribution of the Levied Control Framework between Contracts for Difference (CfDs) Feed-in Tariffs (FiTs) and Renewables Obligations (RO) up to 2020/21 based 2011/12 figures.

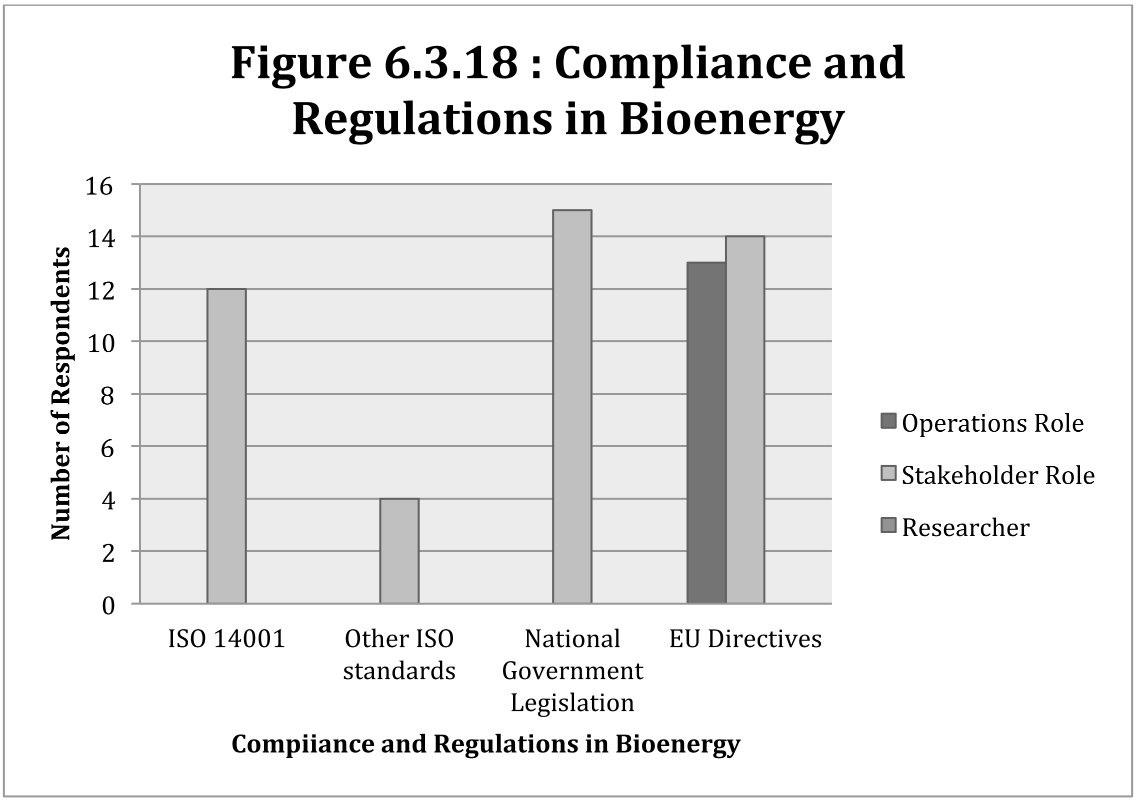


Figure 6.3.18 : Compliance and Regulations in Bioenergy

Comments from respondents provide:

Engineering Contractor: ‘ISO 9001’.

Stakeholder Legal Firm: ‘The EU can be obstructive. The ISO 14001 is optional. Directives that apply concern those from the Environment Agency, Waste Incineration Directive is applicable on a large scale, e.g., burning chicken waste, HSE[4], WID cannot do small scale because of costs. Farmer biomass producers tend to apply for exemption certificates’.

Government and EU Directives add risk where such a novel and emergent sector require stability.

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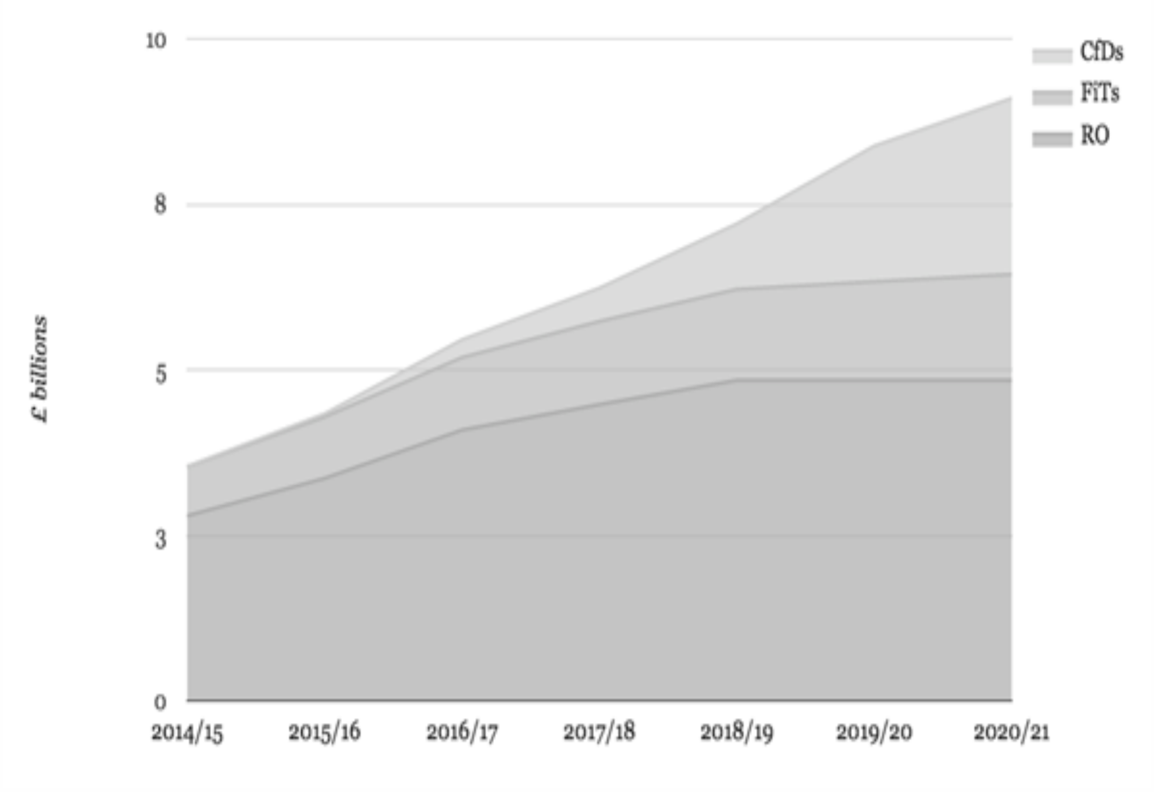
[4] Health and Safety Executive

Figure 6.3.19: Forecast of Subsidies in Renewable Energy in the UK to 2021.



Source: Office for Budget Responsibility/DECC. Chart by Carbon Brief.

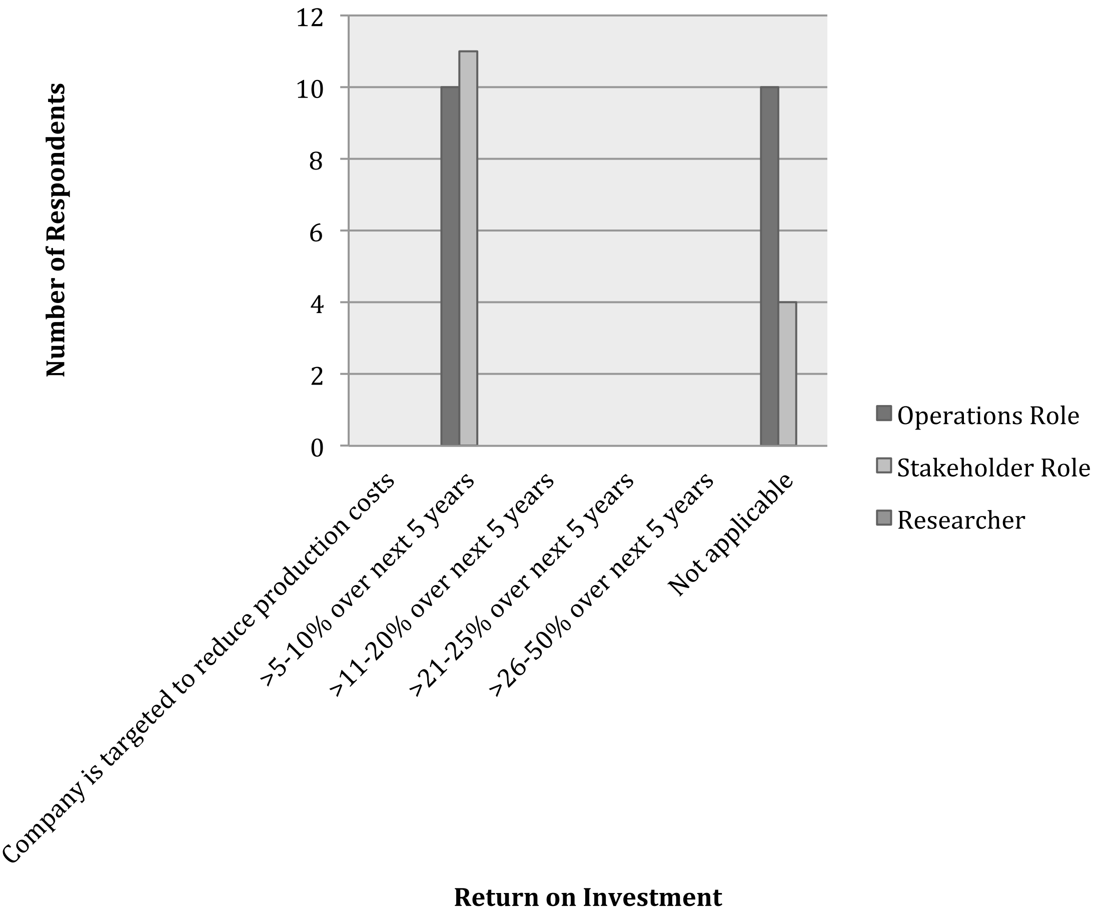
The Levied Control Framework (NFC) is a National Government tool to control cost of energy schemes and therefore place a cap on any subsidies, (National Audit Office). A Contract for Difference is defined as a contract between the investor and investment bank. At the end of the contract parties exchange the difference between opening and closing, closing prices for the financial investment, including shares and commodities, (lexion.ft.com). Thus the CfD market reform for supply chain projects over 300 MW was introduced during May 2015, (www.gov.uk) and thus not adversely affect small-scale projects in the UK but it provides a strong assumption that all new market entrants establishing bioenergy businesses cannot depend on UK Government subsidy. Amber Rudd, Secretary of State for Energy and Climate Change, said:

'Our support has driven down the cost of renewable energy significantly. As costs continue to fall it becomes easier for parts of the renewables industry to survive

*without subsidies. We're taking action to protect consumers, whilst protecting existing investment', (*www.carbonbrief.org).

Whilst at the same time, the European Union aim to increase the production of energy from renewable sources through the SET Plan (15th September 2015 and to be delivered in the European Parliament 29.09.15), which commits National Governments to actions established in the EU Renewable Energy Directive (2009/28/EC). In the UK, the National Plan is referred to as the National Renewable Energy Action Plan for the UK, Article 4 of the Renewable Energy Directive. The plan establishes targets for increasing energy production from renewable sources from planning, developing and implementing renewable energy systems from a range of sources. Financial performance provided in Figure 6.3.20 shows forecast business performance in relation to reduction of costs. The figure shows 10 operators and 11 stakeholders forecasted between 5% and 10% reduction in costs over the next 5 years. This would be in line with current National Government spending cuts in renewable energy subsidies. However, similar number of operators (10 operators) selected 'not applicable' in financial performance but this was ranked lowest amongst stakeholders, who responded to financial performance questions, (4 stakeholders).

Figure 6.3.20: Financial Performance



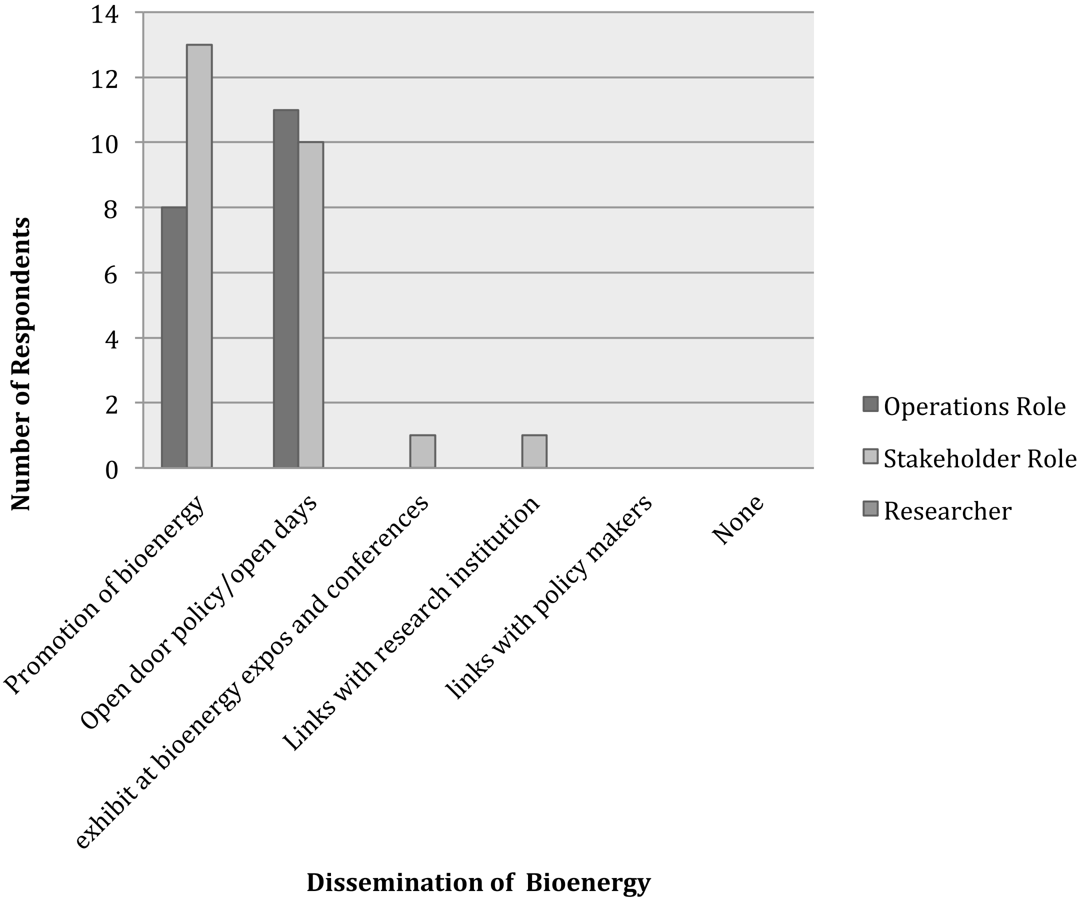
The findings confirm that the respondents involved in survey were aware of the National Government changes in renewable energy policy and were implementing business strategies that would circumvent such change.

Corporate social responsibility (CSR) is important if organizations are to promote good practice, Lähtinen et al., (2014). Many respondents reported, ‘open door’ policies to promote and widen public knowledge in renewable energy. Figure 6.3.21: Marketing Bioenergy illustrates findings of how such companies developed their marketing and communications to enhance their public image. The highest scores amongst operators and stakeholders were ‘promoting bioenergy’, (8 operators and 13 stakeholders) followed by, ‘open door policy’, (11 operators and 10 stakeholders).

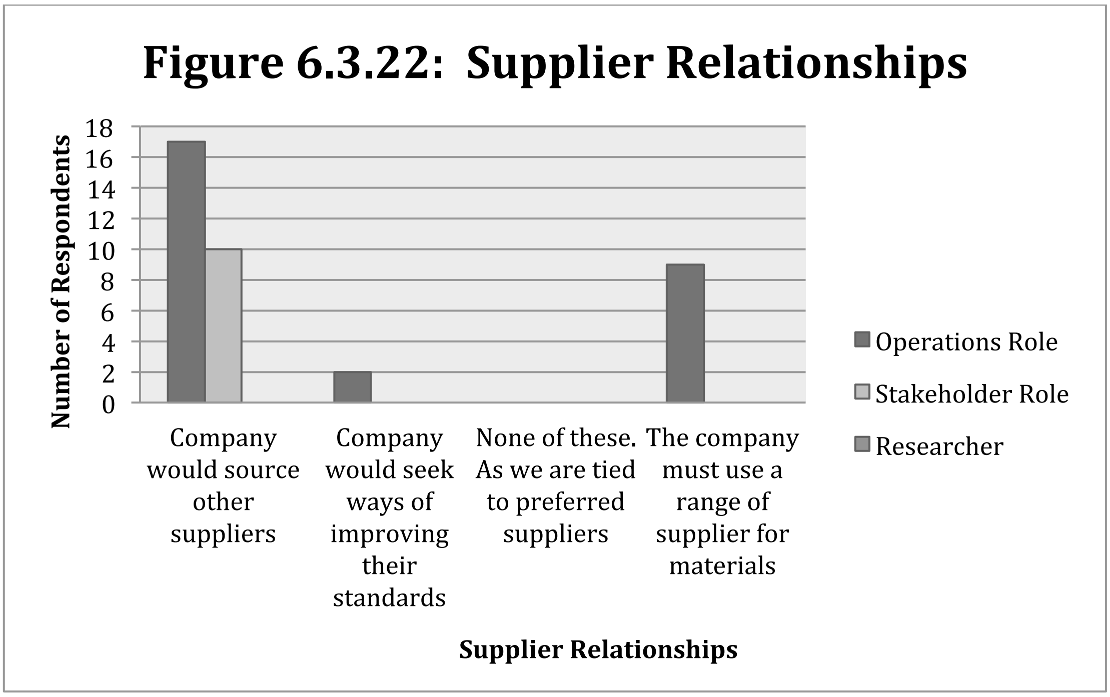
The lowest ranked scores were from stakeholders with just one stakeholder each selecting, ‘attending exhibitions’ and ‘links with research organizations’. One stakeholder expressed concern at the gap between industry needs and the apparent lack of research focus in developing a viable alternative to current provision.

Stakeholder from a City Authority: ‘*We helped set up the bioenergy research centre and we have not seen any evidence of how they can scale-up the technology…the contract with ‘X’ company runs out in 4 years time and I’m afraid that we are faced with having to renew their contract because there is no viable alternative’.*

Figure 6.3.21 : Marketing Bioenergy



Aside from marketing there are other forms of intra-firm communications, which related to supplier relationships. The literature is limited in this area and is biased towards conventional supply chain contexts as cited by Lambert and Cooper, (1998). Mainly the literature identifies technical and economic relationships in location and feedstock selection. In this context, however, respondents were asked how they deal with their suppliers in Figure 6.3.22: Supplier Relationships. The majority of operators ranked, 'sourcing other suppliers' if quality standards were not met, (17 operators and 10 stakeholders). Just 2 operators would work with their suppliers in an attempt to improve standards amongst their suppliers and 9 operators identified they had to work with a range of different suppliers outside their organization.



This latter finding confirms that a supply chain in bioenergy exists and is process integrated. Information technology, one of the integration constructs identified in the literature was also included in the survey and findings are illustrated in Figure 6.3.23: Information Technology. Where communications are a key factor in developing relationships, accuracy of information also optimizes operations and improves visibility in the supply chain, (Gunasekaran and Smith, 2001). The figure shows just researchers responded to application of IT for 'location decision'. Most researchers were aware and familiar with Geographical Information Software (GIS) in modelling optimal site location for conversion facilities. More notably, operators and stakeholders responded to the range of IT functions in bioenergy production systems. The majority of operators selected, 'quality management of feedstock' (12 operators), followed by, 'environmental auditing', (10 operators). In contrast, the majority of stakeholders selected, ‘order management’, (12 stakeholders). ‘Environmental auditing’ was not ranked highly by stakeholders, (8 stakeholders compared to 10 operators). Their comments provide an insight to the reasons why there was no consensus amongst stakeholders and operators.

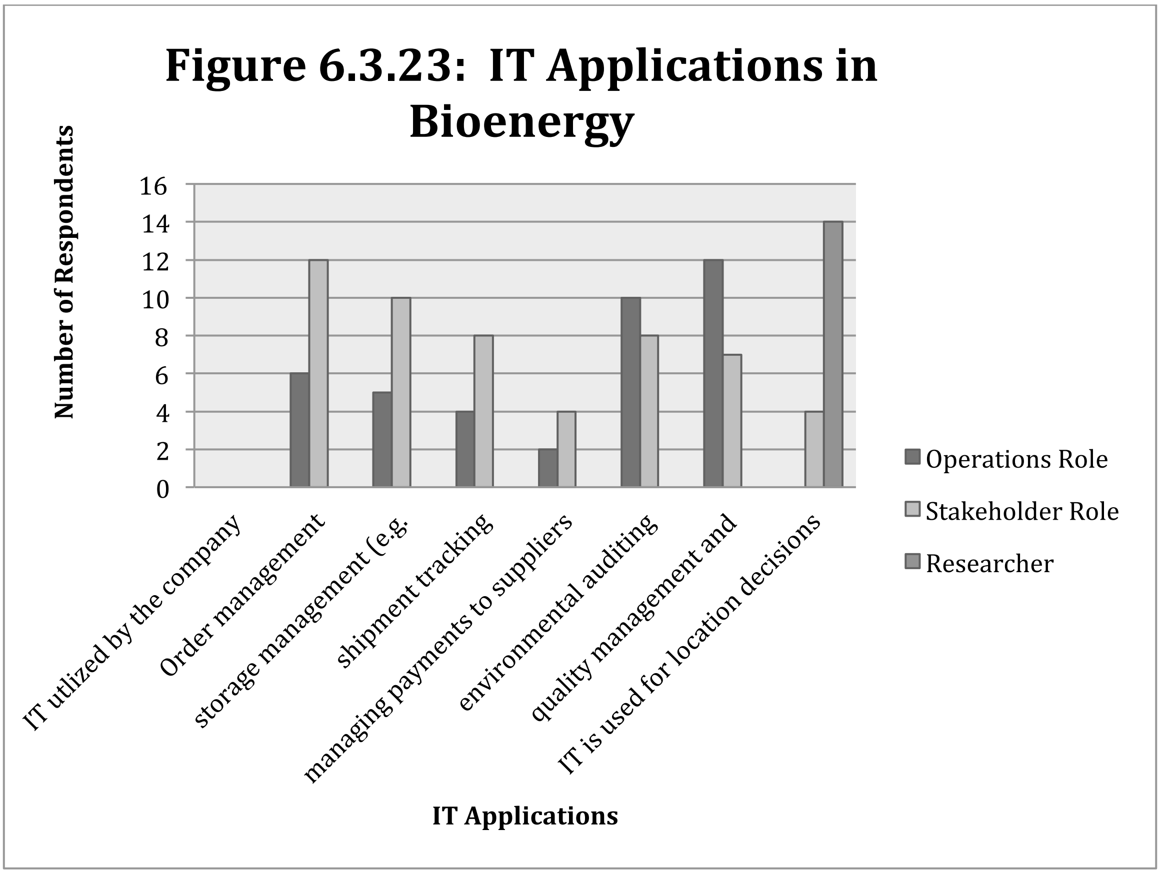


Figure 6.3.23: IT Applications in Bioenergy

Engineering Contractor Bioenergy Facility: ‘MS Office, CAD Software, Google Drive and Dropbox’.

Stakeholder Legal Firm: ‘May not be this specific. IT is used for measuring the performance of engines used in processing and administration’.

Logistics Manager, Biomass: ‘Mircosoft’.

Stakeholder, City Council: ‘Microsoft Office Suite’.

There were more stakeholders than operators and researchers embellishing responses to application of IT in the biomass-to-bioenergy supply chain. The majority utilized generic software that is found in everyday use. Bespoke software tended to be legacy programs that had already been in use by the core company. For example, bespoke systems were used by the logistics firm and also by CHP and AD plants seen in the case studies provided in this chapter. The literature tends to refer to modelling technological and socio-economic characteristics of bioenergy rather than investigate specific applications that help optimize the supply chain.

The final part of the survey referred to waste management in the context of how spent-waste is either disposed or, recycled into biomass within a closed-loop system. Figure 6.3.24: Waste Management presents the findings from respondents in relation to how they treated post-conversion material. The findings confirm that very few participants in the survey sent their waste to be treated and disposed of by other companies (1 operator). The majority of respondents recycled their waste into other products, (10 operators and 8 stakeholders). Eight operators selecting this category reinforced this factor, ‘waste is recycled to produce bioenergy’.

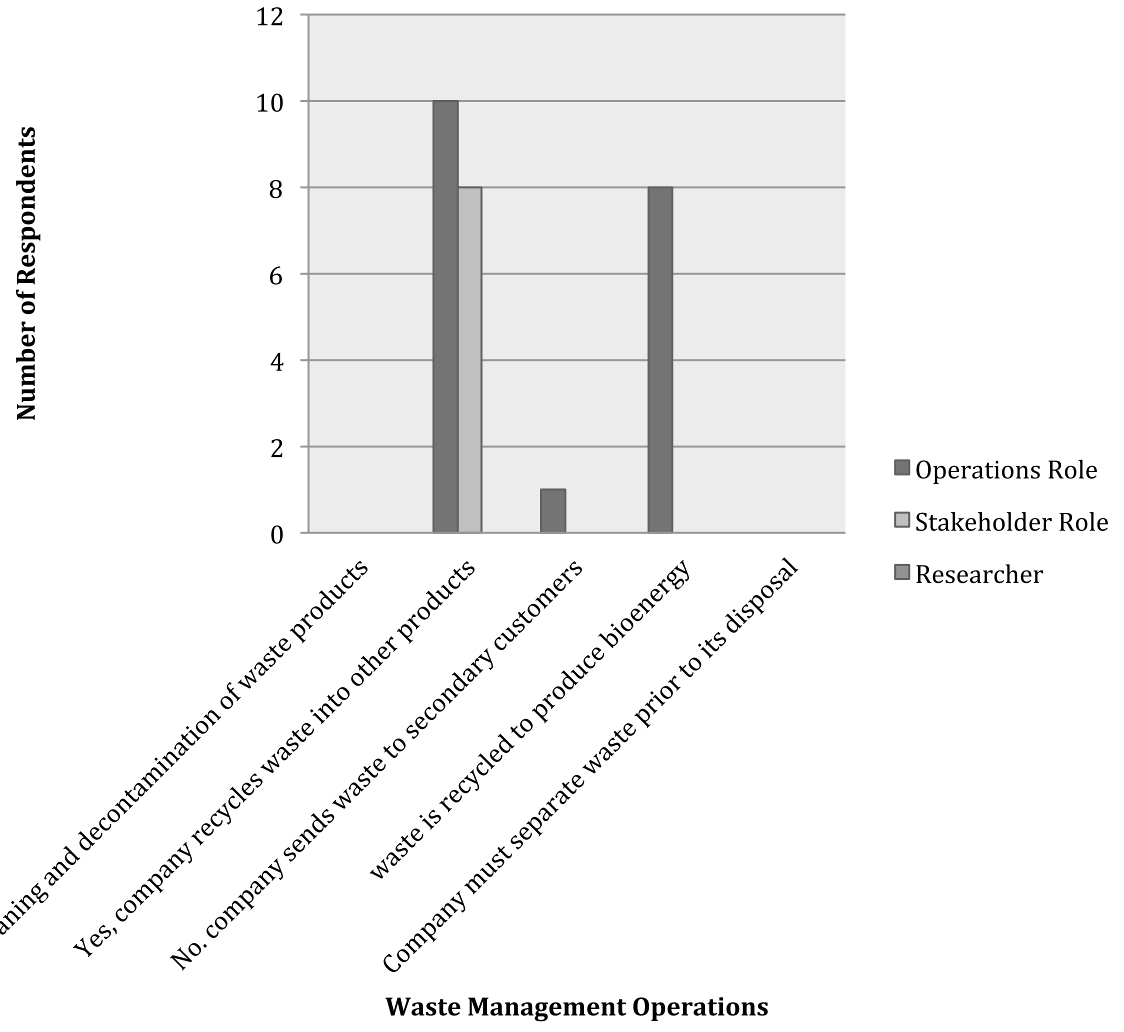


Figure 6.3.24: Post-Conversion Waste Management Operations

It is likely that these findings result from legislation that restricts waste being sent to landfill. These refer to the Waste Incineration Directive (WID) 2000/76/EC. Environmental Permitting Guidance on The WID For the Environmental Permitting (England and Wales) Regulations 2010, and, ‘Derogation from the Animal By-Product Controls under Regulation (EC 1069/2011) and European Commission Regulation EU 142/2011’. With such Regulations being in place in the UK and European Union, it can be assumed that technological processes in conversion could minimize post-conversion waste such as bottom ash for example, and re-use the waste within a closed-loop system. Therefore it is assumed that there is a relationship between regulations and technological selection in bioenergy.

There was one comment from a stakeholder with involvement in bioenergy development:

Project Manager Stakeholder: 'Woody biomass produces minimal waste, a small percentage. Most is put back into fertilizer as potash or to be mixed in with other fertilizer material. AD digestate from waste is different and requires a permit to send to third party waste plants. The farmer subsidises the cost which is convenient to the farming cycle either on the land as a fertilizer, or used in food production'

AD Plant Manager: 'Waste is used as fertilizer; it goes back on the land'.

The comments provide an insight is to how closed-loops are developed. Here the sample shown describes the way in which spent material is re-used which is not recycled as biomass but used to add value to other products and processes. This would ascribe to the assumption that bioenergy production and supply chain integration more effective in a rural environment.

Surveys produce interesting results in a structured way and benefit from data collection of high numbers of respondents. However, in this case the number of participants (54) would not conventionally be considered a high response rate but all participants including those from the case study companies were based in the West Midlands and covered all aspects of the biomass-to-bioenergy supply chain from researcher, stakeholder and operational factors. The latter sub-sections of these chapter present case studies that were also representative of organizations in the biomass-to-bioenergy supply chain

6.4: The Logistics Company: A Case Study in Biomass Transportation.

This is a new logistics company based in North Gloucestershire close to the borders of the West Midlands. Their headquarters are based on the same site as a sawmill and building suppliers. The company has been in operation since the beginning of 2014, (12 months at the time of writing). Prior to supplying woody biomass to conversion plants the company-supplied materials to the construction sector. Aside from its fleet of vehicles, they also store and chip wood to convert to bioenergy. Wood types they supply are mainly logs and brash, which is a residue from arboriculture arisings. This comprises low-density forestry material consisting of tops of trees and small branches. Biomass is collected mainly from tree surgeons and municipal parks in the County. The trucks travel from their depot to collect wood from such suppliers. The brash material including any logs are stored and sorted on site, shredded and chipped into different sizes depending on the moisture content required by the end-user, (CHP facility). A moisture content of 40%-45% is where the end user requires more sensitive range whereas other end users are satisfied with a moisture content of <20%. Such ranges are determined by the technical specification of the boiler utilization during combustion. Pre-processing operations are performed on site and it is rare to find contamination from foreign bodies such as plastic and metallic objects in the biomass, because the material is sourced from usually 'clean' wood residues. They are waiting for sorting machinery and driers to be installed.

'Most of our suppliers are clean'

The company has a comprehensive list of tree surgeons willing to provide their material from felling and, the Forestry Commission supply logs and brash not used in other competitive sectors.

'Our tree surgeons are only too happy for us to take it off them because they have nowhere to dispose of it and no further use for it'.

The tree surgeons supply branches from felling and logs. The Forestry Commission supply larger trunks. None of their suppliers take payment from the company because of their need to dispose of the material from their respective sites. In this respect synergistic relationships have grown between the logistics company and their suppliers. This is because the company makes their money from the bioenergy conversion sites, which purchase the material from them.

*'We take their timber as payment, also buy in from other suppliers but not often. There is no need, but we use them (*other suppliers*) on rare occasions'.*

There are few contractual arrangements based on guaranteed need of product quantity, price and specifications. Payment terms and the ability to supply continually are the most important criteria. The company constantly sources potential suppliers in the area and visit them to ascertain if they are suitable to their needs. As a third party logistics provider they need to ensure that they can achieve sufficient volume of biomass to deliver to conversion facilities throughout the UK. Suppliers are based around the County within a 100-mile radius but the company delivers biomass throughout the UK. They have five vehicles with walking floor trailers of 140 ft^3 with the facility to increase their capacity if required. They deliver up to a 25 tonne biomass but depending on moisture content. This may increase and decrease actual volume of biomass loads. They use a weighbridge but as weight can vary they are to ensure that the total weight, including load weighs a maximum of 75 tonnes. A copy of the weighbridge ticket is given to their customers at the conversion site so that they can receive payment and any FiT/REC fees apportioned to them.

Contractual arrangements are built on a 'gentleman's agreement' but this depends on whether they have a long-standing relationship with the supplier and customer. Usually, they have more formal agreements in place for suppliers who provide less than 10% of biomass, such as poultry farmers for example. Sourcing suppliers they have no initial knowledge of is more risky due to inconsistencies in the performance and quality of biomass.

'Shopping around leads to inconsistency in the product, for example ash content can vary. Most of our biomass is from softwood'.

Potential biomass suppliers have to apply for accreditation from the Biomass Suppliers List (BSL), which provides information about suppliers. The amount of information required is extensive from felling licences, carrier's licence, waste types etc.

Their customers pay around £100 per tonne for biomass they deliver. This amounts to £2000 per trip. They rarely take on incentives, especially with farmers. However, contractual agreements can become inflexible and affect their profit margins because of fluctuations in price of biomass and fuel costs. The company use ABC accounting methods in MS Excel and use a matrix based on distance, time and material grades. The company does not offer discounts irrespective of volume of biomass ordered.

‘We don’t offer discounts especially if the job is costed properly’.

There are regulations that affect all levels of the business. Accreditation is imposed on all wood specialists. In particular regulations are obligatory in relation to ethically sourced wood. Record keeping is kept up-to-date because they have to be available for inspection. The company has up to four audits a year. Inspections look at the suitability of their location, how the biomass is stacked and stored and where it is stacked.

‘Visibility is critical in a constantly changing scenario’

Competition comes from Herefordshire and north of Birmingham but none undertake the range of businesses offered by this company. There are no restrictions on the number of vehicles inbound and outbound due to the rural location. Drivers are familiar with their drops, approximately 60%-70% of the customer base is part of a regular delivery. Empty running of vehicles depends on the distance of a particular trip and

‘The main variable in costing any trip is the price of diesel’.

From a stakeholder point of view the company is independent of the conventional boundaries imposed on new developments. Firstly, as a logistics provider the company does not have the usual restrictions in terms of the number of vehicles delivering biomass to the site due to its rural and isolated situation in the north Gloucestershire. It shares the site with a building suppliers and had previously been involved in the construction sector prior to diversifying into collection, storage, pre-processing biomass prior to distribution. As a logistics company they provide an important link between biomass producers and conversion facilities that could potentially increase costs in bioenergy production because the cost of transport is higher than the value of biomass and bioenergy output. Their contractual arrangements were relatively simple and were not hampered by the extreme levels of bidding and formal contractual arrangements that are typical of the public sector. The company found a unique opportunity and gap in the biomass-to-bioenergy supply chain by sourcing material from suppliers who had no means of generating further value from their waste. By offering to take the material from them freely provided a favourable relationship between local tree surgeon and the forestry sector. The essence of their contractual agreements stemmed from costing that were, either informal or formal depending on level of trust between the company and their suppliers. Such costing models meant demand for feedstock was pulled by the customer rather than pushed from suppliers. It was evident from the site visit that the company did not have much external competition but filled a gap in the market to supply biomass and that suppliers comprised a network of forestry and tree surgeons that benefitted from their relationships with the logistics company because they were able to collect biomass, store and pre-process material on-site. The logistics company in this case had not co-located with a bioenergy conversion plant but were in close proximity to appropriate suppliers. Gloucestershire has a total area of woodland of 29,752 hectares according to the National Inventory of Woodland and Trees published by the Forestry Commission, 2002. At the time of writing (August 2015) there was not much competition for the woody material and as clean wood there were few restrictions on its uses as biomass. However, the company were mindful of the fact that this was likely to change in the near future due to competition from other sectors and increase in the value of woody material.

6.5: An Anaerobic Digestion Plant: A Case Study in Rural Diversification.

The plant is sited in a disused quarry in the North Cotswolds, Gloucestershire. It is a farm estate of 20,000 hectares and one other farm estate on adjacent land. It is a 1 MW AD plant that was commissioned in October 2010, and formerly utilized agricultural residues that formed the main feedstock that comprised silage, maize silage, grass, farmyard manure and grain from land owned by the estate. However, grain and wheat is no longer used due to increase in prices, and because of this factor it was decided to introduce liquid and solid food waste. For example coffee residues as the site, although in a rural location is close to the proximity of a coffee plant in Oxfordshire. Since sourcing food waste from Gloucestershire and Oxfordshire and also Yorkshire, the company organizes a ‘milk round’ of collections from supermarkets and restaurants, including food waste from Gloucestershire County Council in the form of domestic waste, prepared food that has reached obsolescence, restaurants and canteens. The logistics for food waste collection depends on whether the supermarket-owned and waste is collected from a central point, or from smaller local stores such as metro stores where food waste is collected in small trucks. The plant currently sources most of its feedstock from food manufacturers. One of the main reasons to decide to develop relationships between food manufacturers in this case was due to the consistency in volume of feedstock that has a high gas value during the AD process. There are 4 tanks on the site with capacity of 2500 m^3, 3500 m^3 and the largest at 4100 m^3. Gas production (methane 60%-70%) from feedstock is a rapid process and the company can depend on good quality biogas. One of the main problems they experience is the amount of plastic used in food packaging, which must be separated from the feedstock. Plastic tends to wrap itself around mixers causing machine failure and disruption to biogas production. Approximately 18 tonnes of digestate from farmyard manure, coffee residues and 60 tonnes of pasteurised liquid are fed into the AD tanks each day. Animal bi-products, including dairy requires pasteurisation under the Derogation from the Animal By-Products Controls Regulations, (EC 1069/2009) and Commission Regulations EU 142/2011. Enforcement came into the UK during 2011, which places a requirement for a monthly visit from veterinary surgeons in order to ensure that they do not use animal bi-products (carcasses) in the AD process. Such compliance may appear draconian but this Regulation is to ensure that feedstock does not threaten the safety and integrity of national livestock and that their pasteurisation processes in the production of biogas will not cause a future outbreak of foot and mouth disease for example.

‘We have a clean site’: Plant Manager.

The plant location is in an area of AONB in the North Cotswolds, yet despite this, the company did not experience the usual restrictions. Permission to locate an AD facility on disused quarry land, out of view of any residential areas and its isolated rural location is beneficial to the number and timing windows for delivery of feedstock. The main A44 between Stratford-Upon-Avon, Evesham and Oxford is under a mile (1.3 KM) from the site. Additional food waste delivered from North

Birmingham, West Oxford, Swindon and Wales have implications for transport costs because the value of the feedstock is less than logistics' costs. Food waste requires pre-treatment, (pasteurisation) and this increases gate fee (FiT rate) charges. Separating the food waste from its packaging adds an additional cost and is compounded by the fact that low-grade packaging waste cannot be recycled. Instead, it is fed into a shredder that de-packages the contents from its container. Such waste is sent to landfill but the food waste contents are fed into tanks including 25 tonnes of water so that pasteurisation can commence. It takes 4 hours to process 8 tonnes of food waste, which is then discharged into a feed tank. From this point, biogas is pumped into a fermenter where it resides for 40 days. Biogas is produced in all four tanks. Two CHP units burn gas for electricity production that requires 375 m^3 gas/hr., per engine. This amounts to 22,000 m^3 per day during conversion (CHP processes). Two MW is transformed to feed a 12.5 MW solar park and distributed into the National Grid.

The plant cost £5 million to develop but the pay-back is financially beneficial due to the ROC and FiT rates.

'AD is expensive and it cost £5 million to set up the plant but the payback is good': Plant Manager.

At the time of writing ROC fees were sold at £40 MW/hr. The plant sold 2 ROCs for every MW/hr produced, which equated to 96 ROC per day as:

24 x 96 x 2 =
24 x 96 x 80 = £4608 per day from biogas production

Additional ROCs could be obtained from sewage gas and the company were considering this during the time of the visit due to new threat of competition for feedstock from food waste and reduction in the value of gate fees in the UK. However, providing the company could utilize MSW from kerbside collections they would continue to utilize solid feedstock rather than slurries from domestic and agricultural waste.

Contractual agreements developed by the company are based on medium to long-term arrangements. For example, they have contracted with BIFFA to provide feedstock from food waste over 5 years and their public sector contracts (i.e. Local Authorities) over a 7-year period. The company has formed close relationships with local hauliers for their feedstock. However, they do not control their collection of AD material, as the feedstock provider is responsible for delivery to their site. All contracts contain penalty clauses if a contractor fails to comply with the agreement.

'All contracts have break clauses': Plant Manager.

Other contractors off-site include lab-testing facilities that are required to check the micro nutrient levels of the digestate. This includes a check run every two to three weeks to measure acidity of the tanks; copper, zinc and iron levels in the digestate.

The bi-product from the processed AD is spread directly in estate land as fertilizer. This conforms to PAS 110 regulations because the digestate is not sold outside and is overseen by the Environment Agency.

The company developed from rural diversification by realizing a business opportunity to utilize agricultural waste from its estate lands and produce an independent source of heat and power for the estate. It has sought further business opportunities from the local area in addition to providing heat and power on their estate.

The previous case study provided logistics support in transport, storage, sorting and pre-processing woody biomass. Capital outlay was high during the initial set up but recovery of the investment had led the company to seek business opportunities with feedstock providers and biogas distribution. It is a dedicated bioenergy facility situated on estate-owned land therefore did not have the number of restrictions on land-use (sited in a dis-used quarry), noise and congestion due to its isolated location. Utilization of spent digestate could be spread as fertilizer on their land.
Similar to the logistics provider, this rural AD plant was located in a rural area, therefore the number of deliveries per day were not duly restricted to specific time periods and thus, the company was able to optimize delivery of biomass from food and agricultural waste. However, in contrast, to woody biomass, food waste is

heavily regulated. The AD plant operates formal contracts with Local Authorities and food manufacturers and is likely to be the reason to instigate more formal arrangements in addition to public sector protocol in procurement rules and competition from similar AD companies in the area for food waste biomass. Agreements of 3 to 5 years were in place. Despite robust agreements with feedstock suppliers the company did not have any contractual arrangements with the logistics providers as these were between the logistics and feedstock suppliers.

Synergies with other bioenergy producers in the area had developed to distribute biogas into the National Grid and therefore the company could benefit from ROCs, FiT as well as RECs from MW/h of bioenergy produced.

6.6: A Case Study in Business Spin-Out Investment: A Water Treatment Plant.

Two separate meetings were arranged between the Head of Renewable Energy and Plant Manager at a water treatment works that had diversified part of its business in renewable energy. This is an AD plant that utilizes biomass from sewage sludge. They operate on several sites, which covers the West Midlands and includes parts of the South West and Northern England shown in Figure 6.6.1: Map of the Area Covered by the Water Treatment Company. This site was commissioned in 2010 and the company has plans to expand their AD business by commissioning more three sites throughout their area. The company has a guaranteed supply of feedstock but operates as a separate cost centre and thus pays for its biomass.

Figure 6.6.1: Map of the Area Covered by the Water Treatment Company.

Source: Severn Trent Water Supply Area.

The company has a 1000 sewage treatment works throughout their catchment area and the site where this meeting took place was based at one of their larger sites of which there are 35 large sites with AD conversion facilities. The company were able to divest into biogas production into the National Grid because they are able to produce sufficient volume and in addition, use their core business to deflect risk if their AD plant is not running at optimal levels. Government incentives from ROCs and RECs to produce bioenergy provided the company with business opportunities in the renewable energy sector. Its current infrastructure and supply chain was adapted to provide biomass from a spin-out investment.

Historically, sewage treatment requires de-watering to convert to dry matter (cake). Sludge digestate was taken to landfill (formerly 600,000 tonnes of cake p.a.). Public perception of their disposal of bi-product into landfill was not seen in a positive light. Other risks include the effects of the weather as excessive rainfall causes the sewage to become too 'wet' and the company can experience problems of leakages from over-flowing drains and sewage outlets. Extremely dry weather risks the AD business because the sewage sludge becomes too dry and water has to be added during AD process. Aside from the technical characteristics of sewage biomass, the company is considering expansion into collection of other biomass resources such as garden waste and agricultural residues. However, they benefit from a guaranteed supply of biomass, particularly around large centres of population. Selection of technology is sourced from overseas companies to provide their AD plant equipment because as the Renewable Energy Manager explained:

'It tolerates a wider range and is robust'.

Experimental conversion technologies such as pyrolosis and pyrofab are considered highly risky at this stage because the company has not seen them in full-scale commercial operation. The Plant Manager expanded on the application of renewable energy technologies in order to improve the end-to-end process to gain most gas. One of the key criteria in adoption of technology is reliability and increased output of biogas, thus generate more profit. Water scrubbing technology can generate 1200 m^3 of biogas but the company has not seen any evidence of adoption of membranes for the same process. Any increases in efficiency of gas to grid can off-set fluctuations and risk in future electricity prices. The Government is likely to approve adoption of technology in this case and, thus provide further incentives.

From an operational perspective, sewage sludge is heavy and expensive to transport requiring specialist tankers for the journey. Due to their AD being seen as a separate cost centre, the costing model has to include costs of transfer between the usual sewage delivery and gate fee as the material arrives at the AD plant. There are also other competitors in the Region that also demand similar biomass particularly food and garment waste. Their main competitors are landfill sites, composting and CHP industries.

Key drivers for renewable energy divestment were to reduce their dependence on energy from the National Grid. Increased demand and costs from energy providers made the company consider bioenergy as a viable investment and by producing biogas from their sites they are able to sell surplus energy back to the grid. Capital costs were not passed on to the customers but financing the AD business came from resources and assets already available in the company. As a PLC the risk is borne by their shareholders and not their customers. Their business model is developed around the following criteria according to the Renewable Energy Manager:

1. *' Is renewable energy aligned to company strategy? The energy prices and corporate social relations are important to the company.*
2. *Is the financial model viable? Identification of costs to build and run the plant.*
3. *Is feedstock available and reliable? Volume required and the mechanisms in place to collect biomass.*
4. *Expertise in place to operate the AD plant? Recruitment of sales and marketing teams but the remainder of the workforce was already in place'.*

Biogas has already been proven as commercially viable in European Countries where gas to grid injection is commonplace. However, this is not the case for the UK (at the time of writing August 2015). This is perhaps partly due to economic subsidies available in Europe which are not available in the UK. They have considered distribution of biogas into CHP but lack of infrastructure in the UK means that they are not prepared to risk commitment to CHP. Biogas is economical to transport and the AD plant is based in a good location in the West Midlands to seek opportunities for expansion into other technologies and feedstock supplies. The current RHI provides 75% of income and are in receipt of £42 MW/h. AD process at the site is expensive due to the cost of treatment of the biomass (sewage) and increase in decarbonising energy to the National Grid.

'Any proportion that can mitigate against the grid is valuable', Plant Manager.

The company have another site based in the West Midlands where there is a large amount of contaminated farmland therefore there is the potential to use food crops as biomass.

Contractual agreements depend on the supplier. Most suppliers agree 5-year contracts and use a standard framework agreement. Their contracts operate on different levels but mainly to ensure that costs are fixed and parity is attained between the parties.

'Pain and gain sharing contracts', Plant Manager

Flexibility is compromised due to the need to realise the investment in the AD business. Any new investments have a high level of shareholder and director involvement where all new projects have to seek approval by the Board of Directors prior to acceptance and funding. Their activities are heavily regulated but the energy market is highly competitive, therefore the company is financially-driven.

Constraints they face are availability of skills and expertise in renewable energy production. In distribution there are not enough traders who are interested in bioenergy because levels of production are not high enough. There is a need to fix the wholesale price of electricity so that they are able to compete in these markets. In the future, RHI and FiT incentives will decrease by 2016 but the company can take advantage of the Renewable Transport Fuel Obligation (RTFO). The supply of biogas requires a similar netting arrangement.

'By comparison gas-to-grid prices in France are fixed, thus supply greater stability', Plant Manager.

Whilst the biomass-to-bioenergy supply chain is considered a robust model in their case there were a number of uncertainties in the bioenergy-to-distribution due to centralization of energy markets and price fluctuations. Gas-to-grid can be transported economically and the company has sufficient area coverage to benefit from central gas hub where gas can be transported rather than piped directly from individual sites.

Both the Renewable Energy Manager and Plant Manager provided views and their experience of this AD facility. They were asked similar questions but responded from different perspectives due to their role of responsibility within the company. The Renewable Energy Manager responded with a better overview of stakeholder perspectives because his role concerned renewable energy projects throughout the Water Treatment Company, whereas the Plant Manager provided more technical information in relation to the specific site. Their core business is water treatment of domestic and industrial sewage sludge and the company made a decision to divest into renewable energy and had AD, CHP, solar and wind farm to demonstrate commitment to the international and national renewable energy agendas to reduce dependence and consumption of energy from fossil fuels. It appears that the company considered a range of bioenergy technologies to produce renewable energy, each provided different FiT and ROC rates. Such a range could decrease risk from dependence on one type of technology. There were 35 renewable energy facilities run by the company (at the time of writing). This particular site was commissioned in 2010 to produce biogas in an AD process. Finance from the project came from company assets. Approval was sought from shareholders and the Board of Directors. The investment into renewable energy from the core business operated on a financial model based on full operational costs. The Plant Manager remarked:

'Our core business is considered more important than renewable energy. Therefore if there is a problem in our core business, all efforts are focused on that business'.

All key decisions were based on level of viability such as technology selection was based on a tried and tested criteria and the technology used at this site was imported from Germany and Denmark.

Drivers in renewable energy were initially to seek independence from energy companies due to increased and fluctuating energy prices, and at the same time, realise divested business opportunities in this area. Reliability of feedstock from sewage sludge and proximity to feedstock provided a considerable advantage in control of supply. Location is quantified in terms of cost effectiveness of gate fees, which they must pay to back to the main company. An efficient logistics infrastructure was in place but there were concerns in biogas-to-grid infrastructure. Contractual agreements were based on a standard framework agreement. A framework agreement is defined under Directive 2004/17/EC, which states:

'An agreement or other arrangement between one or more contracting authorities and one or more economic operators which establishes the terms (in particular the

terms as to the prices and, where appropriate quantity) under which the economic operator will enter into one or more contracts with a contracting authority in the period during which the framework agreement applies', (Office of Government Commerce, 2008, p. 3).

As a water treatment company they are bound by such agreements and this has influenced their contractual behaviour in renewable energy projects. Their quality assurance map is provided in appendix 4, (p. 356). Income from biogas comes is partly composed of 75% income from the Renewable Heat Incentive and £42 MW/h per ROC which amounts to approximately a third of their income from biogas. The Government FiT tariffs have a 20-year incentive, which reduces initial financial risk but also provides a higher profile to their customers in terms of improving the environment.

The next case study uses a different technology but also based in an urban setting in the West Midlands. This particular company utilizes CHP technology and municipal solid waste as feedstock, (MSW). It was selected due to the site being based in a city location and there was a direct relationship between stakeholder (Local Authority) and process integration.

6.7: Waste Recovery: A Case Study of CHP in an Urban Setting from a Process Perspective.

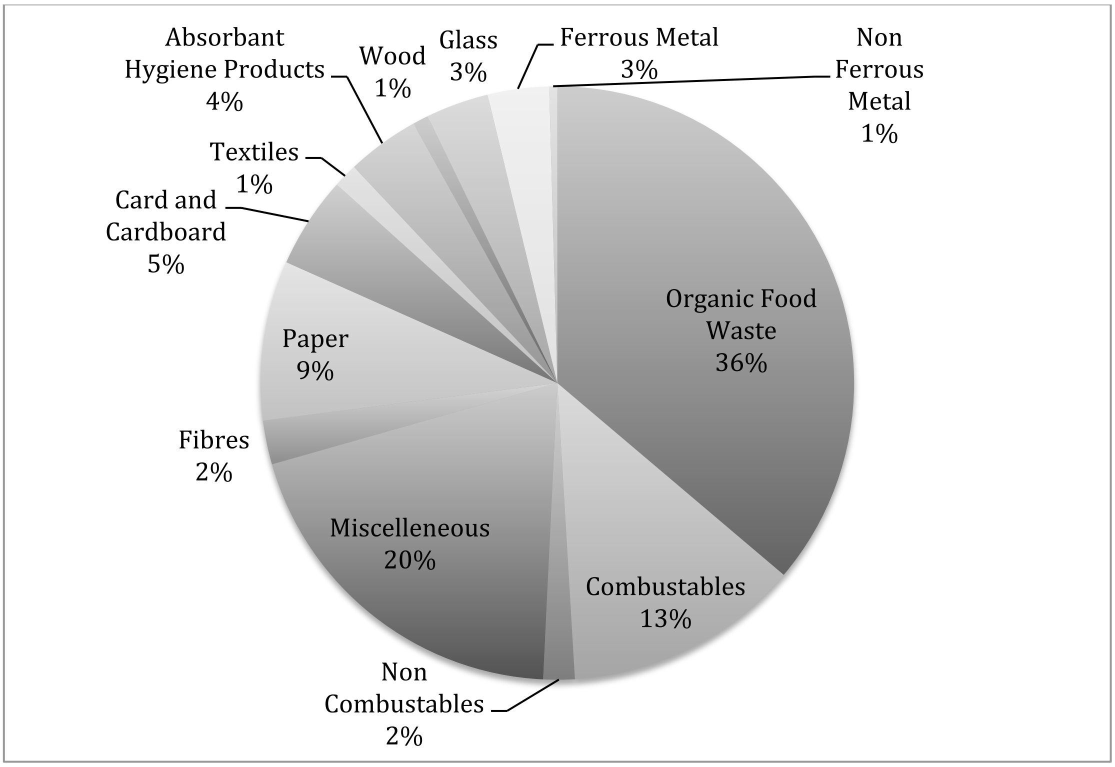
This meeting was arranged with the Plant Manager at the site, which is based on a municipal waste recovery site for both domestic and municipal solid waste. Individual residents deliver domestic waste but MSW is delivered from kerbside collections from around the city and within the Local Authority area. It was initially established during 1975 to feed energy from CHP technology into a former car manufacturing plant adjacent to the site. In recent years the car plant has ceased to exist so energy from the plant is fed into a district-heating scheme for the City Council, Metropolitan County Council and County Council Authorities since 2000. Currently there are 68 employees of which 13 are employed at the adjacent civic amenity site. They work a shift system of which approximately there are 30 employees per shift. Since taking over the site, the company has invested £7 million on improving performance within the plant. It takes 250,000 tonnes pa of municipal solid waste and commercial solid waste (MSW and CSW) of which 115,000 MW/h is produced by the plant from which 95,000 MW/h is exported to the National Grid. The remaining 20,000 MW/h is fed into a district-heating scheme for which they receive Levy Exemption Certificate (LECs). However, since this time the UK Government's summer budget 2015 have removed this exemption with effect of 1st August 2015. The plant utilizes homogeneous waste of which 40% is collected from the City Council and Metropolitan Council, 20% comes from the County Council and the remaining 40% is from Local Authorities located north of the region.

Contractual agreements are long term and devised between their main contractors who are the Local Authority stakeholders until 2041. Despite such long-term Principal Contracts in place, the company also requires flexible arrangements with sub-contractors through annual contracts. Long-term contracts on the one hand provide stability but on the other place the company at risk particularly where there are changes in regulations and levies from National and European Governments. The Plant Manager eluded that:

'Relationships tend to become 'political' and PFI contracts are not an efficient way forward'

Local Authorities are responsible for collecting and delivery of commercial and municipal solid waste to the plant. Figure 6.7.1: Composition of Commercial and Municipal Solid Waste illustrate the type of biomass utilized by the company.

Figure 6.7.1: Composition of Commercial and Municipal Solid Waste Feedstock.



Source: Adapted from the Case Study Company Website, (Percentages have been rounded up).

It is usual practice for PFI contracts to be long-term of up to 25 years. The waste recovery company have used this structure to organize their contracts in a similar way by dove tailing all other contractual agreements with parties over the same term.

'Most PFI arrangements are long term contracts of 25 years that tend to be back-to-back contracts over the same time', Plant Manager.

However, there are other contractual terms that cover different lengths of time, which are illustrated in table 6.7.1: Lengths of Contractual Agreement in the Case Study Company.

Table 6.7.1: Lengths of Contractual Agreement in the Case Study Company.

Contract Party	**Length of Agreement (Years)**
Bottom Ash	12 months (annual)
Lime	12 months (annual)
Chemicals	12 months (annual)
Engineering Support[5]	4-5 years
Training [6]	3 years
Logistics	25 years
MSW & CSW feedstock supply	25 years

One of the main risks surrounding their contractual arrangement is the level of uncertainty in UK and EU Government legislation in renewable energy. To a certain extent regulations provide stability in the context of equity for similar industries but sudden changes as for example in emission levels interrupt operations across the biomass-to-bioenergy supply chain. Similar to changes in the regulations on exemption levies such as LECs disrupt the supply chain, there have been changes in legislation for bottom ash waste that, according to Air Pollution Control (APCr) Regulations during 2015 was categorised as hazardous waste, (Environment Agency, February 2014).

Local Authorities are responsible for collecting and delivering biomass to the plant and this is contracted with BIFFA. Contracts between Local Authority and logistics provider are also long-term from seven to nine years.

To summarize the main factors arising from this site visit to the company there were a number of key points. The first is in relation to change of supplier from heat and power into a car manufacturing plant to supply heat and power to the City Authority's District Heating Scheme. Although the company possessed existing infrastructure to

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[5] Engineering maintenance is run with minimal crew, approximately 6 employees per shift.

[6] Apprentices are sent to Ratcliffe Power Station on a 3-year programme and are mainly recruited from the Power Industry and Armed Forces.

change from one customer to another, their location meant that they are locked into provision for the area. Currently, their site is dissected by a road network to and from the City and close proximity to a residential area. However, it was noted that for the foreseeable future there was no direct competition from other providers due to the nature of their contractual agreements between main contractors, namely their feedstock suppliers and logistics provider. They operated a range of contracts from one to twenty five years dependent upon type of supplier. There were risks involved in their longest-term contracts (25 years), due to inflexibility and inability to respond to changes emanating from EU and UK Government legislation. For example, bottom ash could no longer be sent to landfill due to changes in UK Government Regulation on reclassifying hazardous waste. Whilst at the same time such long-term contracts provided them with a degree of stability in relation to supply of feedstock and this corresponded with similar long term contracts with logistics providers. Apart from main contractors there were also medium-term contracts with maintenance engineers and training providers of three to five years duration. This gave the company a degree of flexibility to change maintenance contractors. However, their contractual obligations with training providers were part of their company strategy to ensure employees received appropriate skills to perform their tasks. Annual contracts were with chemical suppliers and incinerator waste. The latter arrangement would ease disruption to changes in legislation in this case and provide them with the flexibility to respond to any modification necessary.

The final case study investigates the biomass-to-bioenergy supply chain from a stakeholder perspective within an urban setting and presents a strategic view rather than that from technical and operation-driven factors.

6.8: District heating: A case study in an urban bioenergy scheme from stakeholder perspectives.

There were two meetings arranged with stakeholders concerned with establishing bioenergy in the West Midlands. One of the respondents was a City Council Regeneration Manager responsible for developing bioenergy and the other respondent, from a firm of consultants, was a Project Manager who was party to developing a university renewable energy research centre.

The role of the City Council's Regeneration Manager was to divert MSW from landfill and incineration into renewable energy. Such a role was to develop a supply chain by developing a network of district heating schemes. One of the projects concerned a stake hold in a university-based renewable energy research centre and a number of district heating schemes throughout the former West Midlands Metropolitan County comprising Birmingham, Sandwell, Coleshill and Walsall in this case. The Regeneration Manager spoke of difficulty with gaining public acceptance in sorting domestic waste into appropriate categories for heat and power conversion. Separation of waste at conversion site increased costs of production, particularly where waste collections were financed by each Local Authority and feedstock procured by waste recovery facility. For example, a site within the area utilized food waste as biomass was continually breaking down due to contaminants in the feedstock. As a result of a 24-year contract in place to utilize food waste, as biomass feedstock, they could not change suppliers from kerbside waste collections to food manufacturers where packaging and other foreign bodies contaminating the feedstock did not present risk.

'We have to rely on the goodwill of residents to recycle waste properly but local residents do not adopt recycling behaviour': Regeneration Manager.

The Regeneration Manager identified three main considerations in relation to feedstock collection from residents as firstly, where feedstock originated from and secondly, distance travelled between kerbside collections and delivery to waste recovery site and finally, the purity of feedstock. If Local Authorities could not meet these considerations MSW was not viable, particularly not on a commercial scale. Research into bioenergy does not appreciate volume and scale potential of MSW as feedstock and the Regeneration Manager insisted that any research centre must be able to operate at scale if the City Council is to propose alternatives to current provision. The contract for waste disposal will end in 2019 after 25 years. Selection and development of new technology at the university bioenergy research centre has not delivered a viable alternative to utilize MSW from the status quo. Costs of converting waste into a useful substance has to be factored into an economic equation that includes the machine operating requirements for each category of feedstock. In addition, there are logistics and managerial issues associated with bioenergy development and proposals for a Environmental Enterprise District would overcome negative views of a dedicated research centre. The Environmental Enterprise District would have a practical output based on full operational costs of a commercial facility. The proposed Development Plan would comply with Thematic Policy 8 - Environment and Climate Change and 'City Authority' Total Waste Strategy (January 2011) commissioned by the City Council in March 2010, which is based on City Council Waste Capacity Study, completed February 2010. The plan is a £48 million investment to regenerate a former industrial district in the City for new business in renewable and sustainable sectors. This requires Local Authorities to collaborate in development of strategic planning and infrastructure to provide sufficient land for waste management facilities and reduce waste disposal through landfill. The city's Environmental Partnership target was to be reduced from 50% of all waste produced to be sent to landfill by 2015 to no waste to landfill by 2026. Currently, there are 3.2 million tonnes per annum (Waste Capacity Study (2010) which comprises municipal solid, commercial and industrial, construction, demolition and excavation and hazardous materials and is unlikely to reduce by 2025. Their proposed Environmental Enterprise District would comply with the UK Government's Green Commission Vision statement March 2013 that considers reduction of GHG emissions as the Department of Climate Change Statute, Climate Change Act, (2008) commits the UK to an 80% reduction in carbon emissions by 2050. The City aspired to become a leading 'Green' City as a result of a target of 60% reduction in total carbon dioxide emissions by 2027. Out of the total CO_2 reduction, 40% of carbon emission would be from the commercial sector. The population in the City is 1,028,700 and is projected to increase to a further 150,000 from 2011 to 2031 in an area of 267.77 square kilometres (103 square miles). Their Road Map published November 2013 refers to the "scale" of the challenge in which there are five themes for action in relation to renewable energy are as follows:

- To become a leading green city
- To improve energy efficiency in buildings
- To improve and optimize energy consumption from recycling and re-use
- To improve existing transport infrastructure so that more people use public transport and,

- To realise potential from City's natural resources (parks and recreation).

At the time of writing the City produces 350,000 tonnes of municipal solid waste produced per annum that is exclusively processed at a energy recovery facility. At this site they export 25 Megawatts of electricity to National Grid, which is sufficient to power 41,000 domestic properties but there is no re-use of waste heat and the contract with these Environmental Services expires in 4 years' time, (at the time of writing, August 2015). In a closed-loop system the City Authority could reduce all MSW and generate value from waste. This would create local supply chains for recycled materials. As the Regeneration Manager stated:

'Recycled materials need a market but the economics become negative when supply chains extended'.

The Enterprise District would provide an Information Exchange to identify opportunities for industrial symbiosis given the given bioenergy technologies from landfill and incineration treatment of MSW as biomass from:

1. CHP using woody biomass, anaerobic digestion from pure organic waste "feedstock",
2. Pyrolysis is thermochemical decomposition of organic material at high temperature in an oxygen-free environment. Efficiency in AD technology is subject to the quality of feedstock,
3. Gasification requires high temperature conversion of waste materials into synthetic gas ("syngas"), finally spent biomass post-conversion could be utilized as fertiliser (including paper and food waste)
4. Due to high costs for bioenergy production waste to energy is not as good as recycling but considered better than landfill. There were three scenarios proposed of how such an enterprise district could be organized. The first scenario involved and illustrated in Table 6.8.1: City Environmental Enterprise District Biomass Capacity on page 237.

Table 6.8.1: City Environmental Enterprise District Biomass Potential Capacity.

Case Study	**Biomass Capacity in Enterprise District**
Case Study One	**Waste survey in [redacted] Environmental Enterprise District (September 2013) - response from [redacted] Limited:** Volume (tonnes) of waste handled in August 2013: Wood waste: 700 Soil: 3,000 Bricks: 2,900 Hard plastic: 5 Cardboard: 17 Trees: 8 Plasterboard: 43 Landfill material: 766 Recoverable fuel: 311 **Total: 7,750**
Case Study Two	**Waste survey in [redacted] Environmental Enterprise District (September 2013) - response from [redacted] Locomotive Works:** Generates 10 tons per annum of "smoke box char" Sent to landfill
Case Study Three	[redacted] **- Advanced Plasma Power Limited** £35 million investment in "gasification" and "plasma conversion" technology Diversion of commercial waste from landfill A "game-changing solution for a zero waste future" Generate100 new jobs
Case Study Four	**Resource Technical Advisory Body (RTAB)** Waste management officers from local authorities in the West Midlands region Forum for the regional co-ordination of waste management Controls the supply and treatment of waste Supply not matched with demand Pre-occupation with responding to government policy directives

Source: Adapted from 'Making Birmingham Green', (November 2013).

Funding for bioenergy projects in the Environmental Enterprise District are determined by European Union grants for small to medium size enterprises, (SMEs). The City Authority has found it difficult to get SMEs in the District sufficiently interested in applying for grants. The Regeneration Manager concluded the meeting regarding their current issues in the City Authority's shortfall in utilizing MSW and

CSW effectively in renewable energy production. There were complex strategic planning issues because of locating their Environmental Enterprise District in a area of high density population.

'Resource recovery plants work best in an rural location due to isolation'; Regeneration Manager

There has been a shift in organization of MSW and CSW from waste management to resource recovery that has moved into how domestic and commercial waste can be either recycled or used for biomass.

'Current methods of managing waste have "outgrown" the narrow parameters of waste management': Regeneration Manager.

European rather than UK companies dominate the emerging bioenergy market.

'Alternative technologies based within the City Authority are not yet tested at scale, thus, landfill and incineration will remain the "default settings" for the treatment of volume household waste' Regeneration Manager.

The project manager role was involved in a EU bioenergy project funded by the Interreg IVB programme. Their consultation services provide a match-making service to bring together UK and European partners for specific projects. At the time of the meeting, the consultancy service was working with the University and City Authority to develop a district bioenergy scheme as well as facilitate the EU bioenergy project. From the onset there were more barriers to developing bioenergy in the UK than compared with Germany. For example, UK Government policy approaches tended to function at as a 'quick fix' rather than meet long-term objectives of carbon reduction in climate change. Thus subsidy to encourage growth of renewable energy conversion technologies and sites fluctuated according to political factors. This risked determination of technology and feedstock as both attributes are directly linked with one another. Security of supply was also at risk due to changes in Government subsidy for renewable energy. The Project Manager believed that no bioenergy company in the UK had formed a supply chain, not only because it is a novel sector, but also more importantly, it is a sector that is unstable. The

Consultancy also works closely with bioenergy companies in Germany and would like to develop similar models of best practice in the UK. In Germany, heat and electricity generation is based on a circular model as opposed to a linear model found in the UK. Geographical location and typology of the West Midlands restricts such development of bioenergy due to centralized rather than decentralized approach to energy production and distribution. Thus, energy production in Germany given in the Project Manager's example was designed so that each district could be self-sufficient. Whether based in either rural or urban areas without distribution into the National Grid, energy requires storage facilities therefore development of bio-batteries that can store energy and release according to demand. Long-term contracts add a degree of stability in a highly competitive and risky environment. Major companies that restrict the market from new entrants gaining access dominate Bioenergy production in the UK. This makes it difficult to introduce new technology in renewable energy conversion. Therefore, such stakeholders with a role in financing bioenergy projects are risk adverse and will revert to existing technologies in awarding contracts. His company's involvement with both the City Council and university renewable energy research centre shared the same view, and like the Regeneration Manager was sceptical on the ability of new and experimental technologies to scale-up to commercial operations.

'Any demonstrator unit needs to work and return the investment': Project Manager.

For renewable energy to act as a viable business unit there has to be a financial model in place that integrates into a supply chain in order to mitigate risk. Bioenergy businesses risk failure because they do not factor in policy change. The market for renewable energy technology is dominated by German and Danish technology because the UK does not have a UK-wide policy, which is why the Project Manager believes that renewable energy supply chains do not exist in the UK. The existing contract in the City for waste management is likely to be renewed due to lack of inertia in a small market that has potential to expand. Several questions were asked regarding the implementation of new technologies to produce bioenergy but the Project Manager returned to issues surrounding bioenergy contractual agreements, particularly where protocols for public sector procurement rules were involved. His particular role was to bring parties together and facilitate terms of agreement in order to:

'...come up with something workable'.

Contracts work at different levels and it is envisaged that SMEs will get more involved in bioenergy within the City, particularly with the City's proposed Environmental Enterprise District. At the time, SMEs lacked the confidence to support renewable energy and were risk adverse.

The stakeholders were involved in the same European bioenergy research and City Council projects. The first person was a City Council employee, and the second person was employed by a firm of consultants as a Project Manager. Both were responsible for developing appropriate networking and business opportunities in developing the renewable energy in the City. The Project Manager, however, had a wider remit and developed partnering arrangements in Europe and throughout the UK. In addition, both possessed a strategic overview of the City's Renewable Energy Roadmap, which was part of the strategy document in regenerating a former industrial district into developing industries that would align with the UK Government's Climate Change Act (2008) in reducing carbon emissions. Renewable energy was high on the agenda for the City Council. It was interesting to find that both stakeholders were critical of dedicated research initiatives because it was important for regeneration to provide a viable renewable energy alternative to current provision and also, develop a renewable energy economy. Key drivers in bioenergy were contract driven providing their criteria met with specific technical and performance objectives. Without meeting key business objectives, innovations in bioenergy technologies would not be adopted. Such risk aversion was primarily due to such new technologies lacking a robust business case. Location was also one of the factors presented to the stakeholders and urban locations were found to be at higher risk than rural locations due to restrictions in space, land use and public perception in relation to waste recovery. The Regeneration Manager, in particular identified problems with the City's residents not sorting waste prior to collection, which disrupted processes at the waste recovery plant. Lack of infrastructure and limitations in existing technology means that processes do not capture all the benefits from waste recovery, such as steam for heat utilization for example. This impacted on the City's ability to develop a renewable energy supply chain, partly due to bioenergy being an emergent sector but, also and more importantly, inertia from local businesses, namely small to medium size firms, (SMEs). Grants supported by the City Council were left unclaimed, as they could not promote sufficient interest from local businesses. Table 6.8.1 illustrates different scenarios and potential supply of feedstock from businesses in the Environmental Enterprise District, an area that has received £48 million in regeneration funds. Renewable energy technology is dominated by German and Danish equipment manufacturers and, likewise for engineering support. Addressing skills shortages in the energy sector is important if the City were to realise its 'green' potential. Results from the survey and case study are analysed in chapter seven to devise a priority framework in bioenergy supply chain integration.

6.9: Summary and conclusion of results from the surveys and case studies.

Analysis of results is provided in the next chapter but this summary highlights the main findings from survey and case studies undertaken in the main study between 2013-2015. Organization of survey results followed the line of enquiry identified from the constructs ascertained in the literature review given in chapter two as technical, stakeholder, process and procurement constructs. The latter characteristic of supply chain integration is an interesting attribute because it has a foothold in both camps of stakeholder and process integration constructs. Findings from the researcher bioenergy survey were added in order to ascertain any similarities and differences. It was envisaged that information from researchers would help gain an insight into how their research programmes could potentially drive future bioenergy policy and direction.

Central to both survey results and case studies was to what extent did the fieldwork address the main research question? It was evident that the literature helped to define contemporary views of supply chain integration in bioenergy and also identify the key constructs from both stakeholder and process aspects. In turn, the results from the main study confirmed the parameters of the bioenergy supply chain, which can be defined as the point of origin to the point of conversion. There is limited data on bioenergy supply chain integration extending to the point of consumption, therefore the study does not confirm factors attributing to the impact of bioenergy production on consumer behaviour. Bioenergy supply chains are essentially horizontally integrated from B2C rather than vertically integrated from B2B. Evidence of this is seen in the extent of stakeholder intervention across bioenergy business in relation to planning approval during the early stages to financial management and environmental monitoring during operational phases. From a technical perspective, both stakeholder and operators selected CHP and AD and this also determined selection of biomass such as municipal solid waste, agricultural waste and wood biomass. None selected algae, except researchers. Technology decisions were risk adverse with selection of tried and tested conversion technologies. Location decisions varied between stakeholder and operator owners. As bioenergy production tends to be based in rural locations, proximity to feedstock and ease of access of conversion sites were more important to being located near consumer markets. Both stakeholder and operators identified EU and National Government Directives as drivers for developing and implementing renewable energy but ownership tended to be locally based due to the rural nature of the business. It was found bioenergy firms do not depend on renewable energy subsidy. Financial incentives were perceived as a risk as dependence on such initiatives were short-term and energy production requires long-term commitment. Information and communication technologies tended to be part of legacy systems rather than development of bespoke bioenergy software. Survey data was limited in this respect as most respondents reported IT applications in use of environmental auditing and vehicle scheduling. Logistics companies had made considerable financial investment in specialist equipment such as walking floor trailers, blowers and chippers for wood biomass. There were comments from the case study companies that such companies could hold bioenergy firms to ‘ransom’ as a result. Nevertheless, there was evidence of synergies between logistics providers and conversion sites where logistics providers and feedstock producers co-located either near to or at a bioenergy conversion site.

Marketing was seen as important from both stakeholder and process perspectives for promoting bioenergy, thus generating wider public understanding and acceptance of alternative forms of energy. However, it is debatable whether such marketing strategies played a role in supplier selection. It can be assumed from both the literature and fieldwork that this is a novel and emergent sector.

The survey results show that contractual agreements play an important role in the integration of the supply chain. Supplier relationships were seen as highly important. Contractual arrangements ranged from long to short-term and tended to overlap one another in relationships that were mutually beneficial from B2C in a horizontally integrated supply chain such as feedstock producer to logistics provider and conversion facility. Here contractual arrangements tended to work in parallel to each other.

Chapter Seven: Analysis of Results of the Literature, Bioenergy Survey and Case Study Data.

7.0: Overview of Chapter, Purpose, Method and Contribution.

The purpose of chapter seven is to provide an analysis of the results from the primary research given in the previous chapter (chapter six) and compare the analysis with the main findings from the literature review in parts I and II, (chapter two). Whilst emphasis remains focused on the biomass-to-bioenergy supply chain this chapter starts to discuss the end-to-end attributes of the bioenergy supply chain in terms of distribution but in the context of contract–led integration characteristics.

In the first instance analysis of results from survey and case study data confirms the constructs identified in the review of the literature in relation to technological, social, economic and environmental constructs and ascertains if they relate to the survey and case study results. The findings also identify a fifth construct that plays a central role in bioenergy businesses and this is the ‘legal’ construct.

The method of analysis itself that is presented in this chapter is qualitative where each construct arising from the primary research is compared with the same constructs identified from the literature review. From this it is possible to rank each construct in terms of its importance from the consensus of results. Analysis of data is presented in a tabulated and diagrammatic format, which at first is divided into stakeholder and process constructs. The final table combines both stakeholder and process higher ranked constructs in order to demonstrate factors that integrate supply chains in bioenergy. Tabulating and ranking results in this way helps to develop a framework for identification of the most viable characteristics of supply chain integration in a bioenergy business and for an emergent sector.

7.1: Introduction and Confirmation of Research Questions in Supply Chain Integration in Bioenergy.

It is often argued that the main driver for bioenergy is policy-driven from Directives emanating from European and National Governments. Without detracting from renewable energy polices that are key to reducing GHG emissions, it is proposed that development of bioenergy businesses cannot be realised without the design and development of a robust supply chain. This chapter aims to address the main aim to ascertain if constructs of supply chain integration apply to the bioenergy industry. In addition to the aim three research questions investigate and analyse the definition, constructs, issues and challenges and finally, identify the factors that encourage the viability of bioenergy SCI and business performance.

It was apparent from findings in the scoping study, main survey and case studies that different contract arrangements determined supply chain integration in bioenergy. Whether agreements were either formal or informal were not without some risk, particularly in long-term contracts identified from case study data, but there were also benefits arising from longer-term contracts. Length of contract term extended across the supply chain between the bioenergy firm and main contractors such as feedstock producers and logistics companies for example. There were two main categories of risk associated with longer contractual agreements and these were firstly, third party transport providers could hold the conversion site and feedstock producers to ransom because they possessed specialist trailers required to transport biomass and secondly, such agreements tend to operate between the buyer, (biomass) and seller (transport provider), and not the customer (conversion plant) in this case. There are, however, advantages to third parties where long-term contracts provide a degree of stability to develop the business. For example, the logistics firm from the case study company in the previous chapter had invested in new equipment such as walking floor trailers, blowers and chipping equipment and was considering further investments due to resilience in their supply chain.

Stakeholder intervention plays a prominent role in decision-making, not only in planning and development of bioenergy but their roles are blurred where they have a considerable involvement in the day-to-day operations of bioenergy production. There was evidence of collaboration and ‘match-making’ services amongst stakeholder actors in both the scoping and main study. Co-location is frequently cited in the literature but it tends to give examples of rural companies. Such supply chain configuration is mutually beneficial to parties and reduces complexity in the biomass-to-bioenergy supply chain. However distance to customer markets risks the robustness of this approach. Historically, renewable energy, re-use of resources and recycling obsolete products were placed in corporate social responsibility paradigms. Whilst, it is still the case that companies can seek to improve their corporate image by developing 'green' credentials evidenced in the CSR literature, the rate of change in developing alternative forms of energy drives the sustainability agenda. Influential in finding alternatives to fossil fuel use, there are many examples of companies developing independent heat and power units with such units serving as independent cost centres.

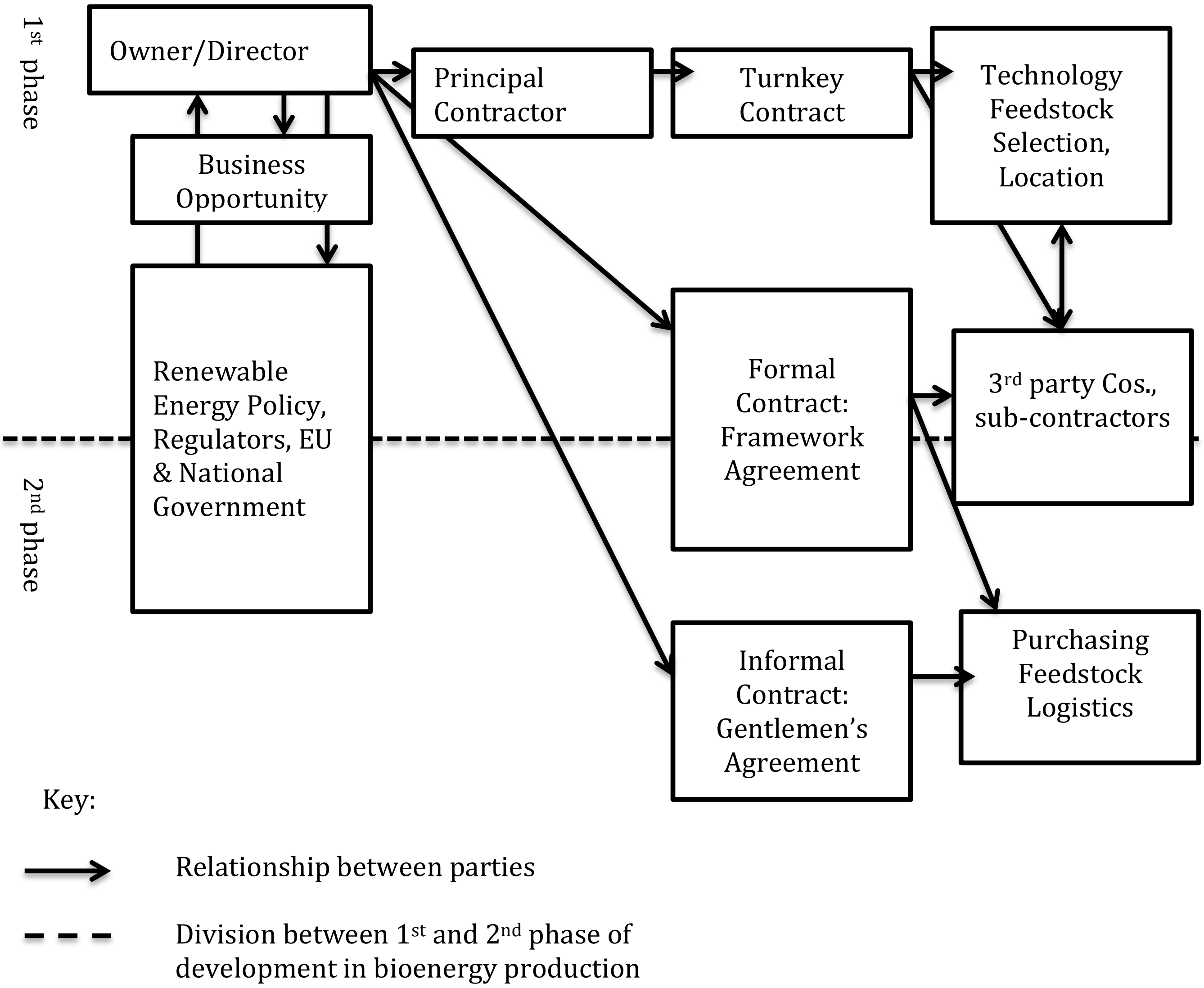
Testing the research questions against theoretical approaches presents challenges in the context of this research topic. Firstly, supply chain management is regarded as a process that adopts and adapts theories from other disciplines. Secondly, bioenergy supply chain organization is not only relatively novel but the supply chains cited in the literature and primary research suggest that biomass-to-bioenergy supply chains are local to their region and do not extend beyond their country of origin. Finally, recent trends in operations management research support the fluidity of bioenergy organization and structure. Actor-Network Theory is applied to information systems but bias towards social interventions from social, organizational and technical constructs that belong to the same network is also true of supply chain integration, (Walsham, 1997). Trends in operations management for new theory building are based on action research methods from semi-structured interviews, survey and case study methods, (Voss et al., 2002). Reliability of qualitative data is based on aggregation of the number of agreements and disagreements from respondents taking part in interview and site visits to gather case study data, (Drejer et al., 1998). Analysis from results presented in the previous chapter is developed into a framework of supply chain constructs to demonstrate a hierarchy in the level of integration and relationships between stakeholder and process factors in bioenergy.

7.2: Analysis of Stakeholder Constructs in Bioenergy Supply Chain Integration.

Chapter two, part I identified supply chain constructs and how such factors determined contractual agreements. Stakeholder attributes are illustrated in figure 7.2.1: Relationship between Contract and Stakeholder Characteristics in Bioenergy.

Figure 7.2.1: Relationship between Contract and Stakeholder Characteristics in Bioenergy.

Stakeholder Characteristics and Integration Factors



The figure helps position the factors involved in stakeholder activity that are pertinent to bioenergy development but the question remains what factors from a stakeholder perspective integrate the bioenergy supply chain. Table 7.2.1: Hierarchy of stakeholder characteristics in bioenergy identifies the main related and sub-linked factors using a Likert scale 1-5 of factors showing level of importance as: 1: Not Important to 5:Very Important.

Table 7.2.1: Hierarchy of Stakeholder Characteristics in Bioenergy

Characteristic	**5: Very Important**	**4: Important**	**3: Neither Important nor Unimportant**	**2: Less Important**	**1: Unimportant**
EU Directives	✓				
Renewable Energy Policy			✓		
National Government			✓		
Local Authority				✓	
Regulators		✓			
Pre-Contract	✓				
Planning Approval	✓				
Framework Agreements	✓				
Location	✓				
Technology	✓				
IT			✓		
Supplier Agreement Long-term		✓			
Supplier Agreement Short-term			✓		
Supplier Agreement Mid-term			✓		
Quality Control		✓			
Finance: EU incentives		✓			
Finance: co. profits	✓				
IT			✓		
Compliance	✓				
Waste Mgt					✓
Brand Image				✓	
Communications				✓	
Research in bioenergy					✓
National Grid		✓			

From table 7.2.1: Hierarchy of Stakeholder Characteristics in Bioenergy data taken from survey and case studies identify the main constructs and order of findings from participants in the study. Table 7.2.2: Summary of Stakeholder Characteristics categorise factors in rank order.

Table 7.2.2: Summary of Stakeholder Characteristics in Bioenergy.

Characteristic	5: Very Important	4. Important	3. Neither Important nor Unimportant	2. Less Important	1. Unimportant
	EU Directives	Regulators	Renewable Energy Policy	Local Authority	Research
	Pre-contract agreement	Supplier agreement L/T	National Government Initiatives	Brand image	Waste Mgt.
	Framework Agreement	EU Incentives	Supplier Agreement S/T	Communications	
	Location	Quality control	Supplier Agreement Mid-term		
	Technology selection	National Grid Connectivity			
	Compliance				
	Finance: Company Profits				
	Planning Approval				

The table summarises stakeholder characteristics that are very important to bioenergy supply chain integration followed by descending order of factors that were explored in the literature and fieldwork. Evidence shows EU Directives as being ranked of the highest importance identified from survey and case study data. One of the main policy documents driving the agenda for renewable energy in the UK is The Renewable Energy Directive, also cited in chapters one, two and five, which establishes targets for reduction of GHG emissions and development of renewable energy and fuel. From a supply chain perspective there is a gap in the academic literature, which considers stakeholder factors from partnership, collaboration and trust attributes, but it is these characteristics that determine the design of the bioenergy firm, (Gold 2010). Governance in bioenergy is key to stakeholder integration (Cannon et al., 2007), and this is confirmed from the scoping study and case study data.

There was an overlap between first and second phase, bioenergy site construction to bioenergy operations, (see Figure 7.2.1). Initial length of contract through Principal

Contractor and turnkey arrangements is primarily seen in large-scale projects and not used for small-scale projects. In this context, stakeholders have a role in technology selection and location decisions (McCormick and Kåberger, 2007). Relationships between stakeholder and bioenergy firm are important to decision making and even such examples were confirmed in farm-led bioenergy models. Contractual agreements during the second phase (operational stage) were found to be either formal or informal. Large-scale bioenergy installations used framework agreements whereas the example shown in the logistics case study reported use of a 'gentleman's agreement between feedstock providers and their firm. This was conditional on level of trust towards their customers. Where the supplier was less well known to the company, more formal arrangements were in place. This basis of trust contradicts the literature cited in Mirata et al., (2005). Inflexibility of long-term contracts seen in Chen and Paulraj (2004) confirms the findings in the case study companies that identify long-term contracts can also risk a firm's ability to respond to changes in technology, feedstock categories and new regulations. Profit from robust agreements rather than dependence on financial incentives from National Government initiatives encouraged more effective supply chain design and resilience. Participants regarded National Government incentives as high risk. There were also negative responses from stakeholder and operator participants on research in bioenergy. Stakeholders, particularly those taking part in the main study were party to bioenergy research centre development and projects. It was evident that there was a lag between bench-scale bioenergy testing and the time research in bioenergy takes to become commercially viable.

7.3: Analysis of Process Constructs in Bioenergy Supply Chain Integration.

The second part of analysis considers process integration factors in bioenergy to demonstrate relationships between contractual arrangements in Table 7.3.1: Relationship between Contract and Process Characteristics: Links between Constructs and Process Characteristics in Bioenergy. Process integration occurs on a number of layers in the organization due to the number of actors that comprise the biomass-to-bioenergy supply chain. The table includes stakeholder characteristics and integrates their respective role in bioenergy processes to demonstrate the relationship between them. Table 7.3.2: Hierarchy of Process Characteristics in Bioenergy on page 252.

Table 7.3.1: Relationship between Contract and Process Characteristics: Links between Constructs and Characteristics in Bioenergy Supply Chain Integration.

Stakeholder Characteristics	**Contract (Legal Construct)**	**Process Characteristics**
Regulators *(Economic and Environmental Constructs)*	Owner/Director of Bioenergy Firm *(Legal & Social Constructs)*	Conversion Technology (*Technological, Economic & Environmental Constructs)*
EU/National Government *(Economic, Environmental, Social Constructs)*	Framework Agreements 1 year, 3-5 years & 25 years *(Legal & Economic Constructs)*	Procurement Operations *(Legal, Economic & Environmental Constructs)*
Financial Incentives *(Financial Construct)*	Maintenance Contract *(Legal Construct)*	IT Operations *(Technical Construct)*
Principal Contractor (*Legal Construct and Stakeholder Characteristic)*		Marketing *(Social & Environmental Constructs)*
Customer: National Grid, In-house heat and power supply *(Economic, Social. Legal & Environmental Constructs)*		Feedstock Suppliers *(Financial & Social Constructs)*
		Logistics *(Legal & Economic Constructs)*
		Marketing *(Social & Environmental Constructs)*

Table 7.3.2: Hierarchy of Process Characteristics in Bioenergy.

Characteristics	5. Very Important	4. Important	3. Neither Important nor Unimportant	2. Less Important	1. Unimportant
Technology selection	✓				
Biomass Volume	✓				
ROC rates		✓			
FiT rates		✓			
Supplier Agreement L/T		✓			
Supplier Agreement Mid-term			✓		
Supplier Agreement S/T			✓		
Formal Contract	✓				
Informal Contract				✓	
Quality Control	✓				
Performance Measures		✓			
Relationship Mgt.	✓				
Co-location		✓			
EU Directives	✓				
UK Government Directives			✓		
Local Authority					✓
Regulators		✓			
Regulations	✓				
Transport	✓				
Logistics Pre-processing		✓			
Logistics: storage		✓			
IT Applications				✓	
Training			✓		
Recruitment		✓			
Investment			✓		
Brand image			✓		
Communications			✓		
Research					✓
Demand responsiveness			✓		

Table 7.3.3: Summary of Process Characteristics

Characteristics	**5. Very Important**	**4. Important**	**3. Neither Important nor Unimportant**	**2. Less Important**	**1. Unimportant**
	Technology selection	ROC rates	Supplier agreement Mid-term	IT applications	Local Authority
	Biomass Volume	FiT Rates	Supplier Agreement S/T	Informal contract	Research
	Formal contract	Supplier agreement L/T	Training	Waste management	
	Quality Control	Performance measurement	Investment		
	Relationship mgt.	Co-location	Demand responsiveness		
	Regulations	UK Government Directives	Brand image		
	Transport	Logistics: pre-processing			
	EU policies	Logistics: storage			
	Financial Model	Recruitment			

The literature confirms that national and EU Directives and regulations underpin organization and development of bioenergy (van Dam et al. 2010; Perry and Rosillo-Calle 2008). Such guidelines determine technology and feedstock use. Technology selection plays an important role in bioenergy supply chain integration. From a contractual viewpoint, Principal Contract agreements overlap the handover period where for a short time run in parallel with standard framework agreements found in the day-to-day operations of a conversion facility (Spekman et al. 1998). Technology requires robust contractual agreements seen in a bias towards the higher rating awarded to long-term contracts illustrated in tables 7.3.1 and table 7.3.2, (pp. 252 and 253). However, this contractual relationship between handover period and full commercial operations were found in large-scale bioenergy firms. Small and micro-bioenergy business units such as farm-based could by-pass principal contractor arrangements providing they had gained planning approval before hand. Such farm-led models operated bioenergy conversion through closed-loop systems to provide heat and power in-house and gained benefits from RHI schemes by selling the surplus to the National Grid via the Distributor Network Officer, (DNO). Small scale bioenergy schemes in this case were at most risk because of inability to expand the business as they had not undertaken initial planning and development phases from the onset. Other risks included inflexibility in technology selection linked with the inability to expand and utilize different ranges of feedstock. It can be assumed that small-scale micro-bioenergy schemes require modular, easy-to-assemble conversion technologies.

Stakeholder and operator participants were unconvinced by new technologies emanating from research centres that were involved in development of 4th generation technologies in bioenergy. Innovations in conventional manufacturing, for example automotive, personal computers deploy rapid prototyping methods so lead-time for incremental innovations adds value (Subroto et al. 2004). The payback period is built into new design and materials in standard components (Tuck et al. 2006). The lead-time for bioenergy technologies is considerable from bench-scale, pilot plant, demonstrator unit and finally as a commercial unit. With finance for bioenergy being modelled on full-operational costs the position of research amongst academic institutions at the other end of the scale cannot compete for technology selection.

Manufacturers in bioenergy technology, according to data from surveys and case studies came from German and Danish engineering companies. None of the participants reported UK manufacturers in bioenergy installation. This factor will also restrict technology selection, because bioenergy companies will not risk deviation from suppliers that have a reputation for effective delivery and on-time installation within the project plan. Secure financial models were ranked highly by participants, as opposed to reliance on EU and National Government incentives, which by their very transient nature will induce rather than deflect risk. The scoping study and main study data confirms how financial models are contract-driven, that in turn, are linked with performance measures to ensure the security the quality and integrity of feedstock. This is not to argue the case for transactional cost economic theory because bioenergy supply chains are more dynamic. Factors that appear key in phase one (construction and installation) lose their level of importance in phase two (commercial operations). The literature confirms UK incentives do not extend beyond pump priming bioenergy development (Adams et al. 2011). There is also a distinction between large-scale and small-scale economic incentives, for example recent National Government announced a reduction in FiT rates for renewable energy that affect solar and on-shore wind power technologies to encourage the trend towards full commercial costing models. In relation to biomass, the Derogation Waste to Landfill Regulations that came into force during July 2015 discourages post-conversion waste to landfill and use in fertilizer. Competition for feedstock from other sectors was a concern expressed by logistics and conversion companies. One concern originated from a co-generation company that participated in the scoping study and the others, a logistics provider responsible for transportation and pre-processing of woody biomass and AD plant manager using straw arisings from wheat crops. In the first instance, the Plant Manager and Head of Procurement expressed concerns at changes in feedstock directives as their biomass was reclassified as a food crop irrespective of the biomass sourced was not used for any other purpose. The logistics plant manager who participated in the main study reported concerns in the increased prices for wood biomass due to the likelihood of competition from other sectors. The plant manager from the estate-owned AD plant reported switch from wheat to food waste. Wheat straw has a low calorific value, but also competes with other uses such as animal bedding.

Contracts that drive bioenergy supply chains also centralize infrastructure because energy distribution is mainly centralized in the UK. The Carbon Trust (2013) is critical of this because it does not encourage development of renewable energy projects (Carbon Trust 2013; Wolfe 2008; Woodman and Baker 2008). Co-location, favoured by participants enabled them to overcome such a constraint. For example, the waste recovery plant that originally produced heat and power for a car plant currently produces heat and power for a Local Authority district heating scheme due to capacity and robust contractual model which ties in main suppliers to long-term agreements. From the data, the study found two approaches that defined co-location of bioenergy firms. The first approach is where conversion plants are situated on the same site and the second co-location approach is where third party companies are located in close proximity to either feedstock producers or conversion sites. Synergies between feedstock producers and transport providers were commonplace from examples taken from the scoping study and main study. Most firms co-located in rural areas.

Logistics companies in both the scoping and main studies found supplier relationships of mutual benefit. Survey data from the scoping and main study identified the importance of supplier agreements that were often defined as strategic within the firm (Çebi and Bayraktar 2003; Ghodsypour and O'Brien 2001). The literature cites effective supplier selection integrates the biomass-to-bioenergy supply chain (Weber et al. 2000), but criteria for contracts are not well documented in the contemporary literature. There was also evidence of informal contracts used by a logistics company who deployed 'gentleman's agreements'. These were based on a legacy of trust and cohesion and therefore relationship building in supplier-customer relationships formed a means for transactions to take place between parties.

Information Technology (IT) is documented in the literature in the context of supply chain integration, but mainly on a GIS research-basis for location decisions (Scott et al. 2014; Mitchell 2000). The study found evidence to suggest the contrary. Participants utilized 'generic' MS Office and bespoke packages inherited from legacy software where developed as spin-out businesses. According to Stallo et al. (2010) ICTs are pivotal to supply chain integration in order to secure visibility but the businesses surveyed in the study were highly localised in organization. Their supply chains were not global which is common amongst mature and complex supply chains in the manufacturing sector and including comparisons with vertically-integrated supply chains that are typical of conventional energy systems. Due to the limitations in ICT application the role of the contract is even more critical. Application of the semantic web to devise bioenergy ontologies is purely research-based and has been applied to bioenergy models for location decision (Solanki and Skarka 2013). Semantic web-based applications are more appropriate for fixed artefacts' and not the dynamic and changing environment found in bioenergy firms. Evidence in the literature frequently cites enterprise resource planning, scheduling and outsourcing decision (Ikonen et al., 2013). However, the study found examples for relatively simple costing formula based on ABC accounting practices. Such approaches assign the costs of products and services based on actual consumption. There was no evidence in the study of long-haul transport routes for collection of biomass. Transport routes tended to be restricted from 10-100 miles in radius for in-bound collections. Whereas deliveries to conversion sites were scheduled throughout the UK as identified from transport providers taking part in the study. Evidence from the field work confirm findings in the literature that transport is centred on biomass collection, volume, and distance constraints and in the case of wood feedstock, also includes pre-sorting and storage of biomass (Uslu et al. 2008). Due to low value of feedstock, reduction on National Government subsidy long-haul transportation was not cost effective.

Participants ranked marketing and communications low in importance. Such attributes are associated with improving public image as opposed to development of robust supplier-customer linkages. There were open door policies in operation that helped promote renewable energy. Participants could foresee the intangible benefits from social relations in addition to transactional relationships with their suppliers. It is the latter that was ranked highest amongst participants in the study to develop business opportunities. The study findings show differing contractual arrangements to stabilize infrastructure in the bioenergy supply chain. Contracts that are mid-to-short term were awarded to maintenance sub-contractors for example and were in use to increase levels of flexibility within the business.

Production operations more importantly include performance measurement systems that span across the supply chain. These differ in respect of biomass and technology selection and enforcement of regulations associated with technology and feedstock characteristics. Integration between stakeholder and operators suggest that systems are centralized. Tatsiopoulos and Tolis (2003) find the demand for contractual agreements are due to centralized energy systems but also depend on good relationships with farmers and third party transport companies. There was strong evidence of the range of contracts operating in parallel to each other. Procurement was ranked of high importance amongst stakeholder and operator participants. During the installation stage, there was high involvement from stakeholders compared to framework agreements in operations during production phases. Stakeholder role involved financial and environmental regulation. The main survey data confirms such interventions at this level but were also viewed negatively by participants who viewed such involvement as interference. However, robust contractual agreements linked into effective regulations and compliance mitigates risk (Piterou et al. 2008).

Grid connectivity depended on whether heat and power produced was part of an in-house configuration or established to compete with conventional energy markets to deliver energy from renewable sources. Although the study is centred on the biomass-to-bioenergy supply chain, evidence in meeting customer demand was identified from survey and case study data. Whilst, it is the intention of National and European Governments to utilize energy from renewables, the cost of grid connections restricted the market for renewable energy in the UK. The study found that companies did not have 'protection' of formal contracts between conversion and distributor as energy distribution is defined as a commodity and has to compete on the open market for best price. Here, energy suppliers attempt to get the best possible price within a 'package of generation' that is contracted to them in order to supply customers, (biogas.org.uk). Suppliers are responsible for using transmission and distribution wires but this is a very competitive market according to the Renewable Energy Association Energy Guidelines (n.d.). Every unit of electricity produced is managed by a Distribution Network Operator, (DNO), who pay a tariff fixed over a 20-year period. This is referred to as a, 'Generation Tariff', and includes payments made for ROC and FiT rates but payments awarded are dependent upon capacity. Every unit of renewable energy that is exported to the grid receives an extra 3p/KWh. The additional payment is referred to as, 'Export Tariff' and is negotiable at a higher price depending on the supplier. The application of transmission and distribution systems confirms support for a centralized energy system in renewable energy grid connection. The main stakeholder, Ofgem is responsible for the connection contract between conversion site and DNO. Distribution Use of System Contract (DUoS) entitles the conversion facility to use the distribution network to import and export electricity and gas. However, there is an obligation to pay 'use of system' charges. Adoption Agreement is with an independent connections provider rather than the DNO. The UK Renewables Energy Strategy published by the Department of Energy and Climate Change in July 2009 sought to simplify grid connectivity for bioenergy firms but this is an area that requires considerable policy change according to Jablonski et al. (2008, p. 649) state:

> *'Assuming most of the newly build were to use district heating and or CHP by 2020, the UK heat market structure remains very similar to that of the present, making penetration of bio-heat very difficult'.*

Here the bioenergy distribution is dependent upon stakeholder interventions, but as the study is centred on the biomass-to-bioenergy supply chain the next section identifies stakeholder and process characteristics to ascertain factors that integrate the bioenergy supply chain.

7.4: Stakeholder and Process Characteristics in Bioenergy Supply Chain Integration.

Characteristics identified from stakeholders and processes that were important to both groups are tabulated in table 7.4.1 to determine factors highly and fairly important to either group to ascertain similarities and differences and Figure 7.4.1: Stakeholder and Process Integration Characteristics in the Bioenergy Supply Chain illustrate the linkages and hierarchy of characteristics identified in the study.

Table 7.4.1: Integration of Stakeholder and Process Characteristics in Bioenergy.

Characteristics	**Stakeholder**		**Process**	
	Very Important	**Important**	**Very Important**	**Important**
EU Directives	✓		✓	
Regulations		✓	✓	
National Government Policies	✓		✓	
Technology selection	✓		✓	
Finance	✓			✓
L/T contracts	✓		✓	
Mid-term contracts				✓
S/T contracts			✓	
Quality of biomass		✓	✓	
Co-location				✓
Transport			✓	
Performance measurement			✓	
Supplier selection	✓		✓	

Supply chain integration characteristics applicable to bioenergy organizations that integrate both stakeholder and processes are: EU Directives, long-term contracts, technology and supplier selection. Of contrasting levels of importance similar choices from stakeholders and operators in the bioenergy study are: regulations, finance and quality of biomass. Solely, operators ranked choices were mid-term and short-term contracts, co-location, transport and performance measurement. The analysis confirms that both stakeholder and process integration rank of equal levels of importance were EU Directives which support the intervention of stakeholder drivers that promote and establish bioenergy in the UK. Technology selection also identified from both stakeholder and process integration perspectives. At the centre of technology selection and bioenergy development are a series of contractual agreements that lay the foundations for creation of a new energy sector, which is made viable through a robust supply chain. The literature confirms financial incentives from National Government and budgetary constraints are not beneficial to bioenergy but added risk. Financial models were key to supply chain integration and business viability and both groups acknowledged this factor. For larger, PFI bioenergy projects the long-term contract was critical. There was a blurring of stakeholder roles that were clearly identified at the installation phases but became more ambiguous during operational phases where there was a range of contracts instigated by the operator. Here, stakeholder involvement changed from co-ordinating principal contractor to that of monitoring and regulation.

Technology selection linked with location and biomass quality were important to stakeholders during installation phases but became more critical to operators during production phases.

The second category to both groups of differing levels of importance relate to financial model including relationships between suppliers, which confirms the importance of supplier selection that was ranked highly by both groups. Quality of biomass and integrity of feedstock as determined by technology selection are also linked with performance measures. These factors were more important to operators but not ranked as high amongst stakeholders. Other factors that were included by operators but not included by stakeholders were shorter-term contracts and transport factors. Contracts for logistics operations ran in parallel with the long-term contracts for technology and feedstock selection. Distance was constrained by cost and value of feedstock. Competition from other sectors and policy changes risk disruption in the supply chain.

Figure 7.4.1: Stakeholder and Process Integration Characteristics in the Bioenergy Supply Chain: An Illustration of Linkages Identified in the Study.

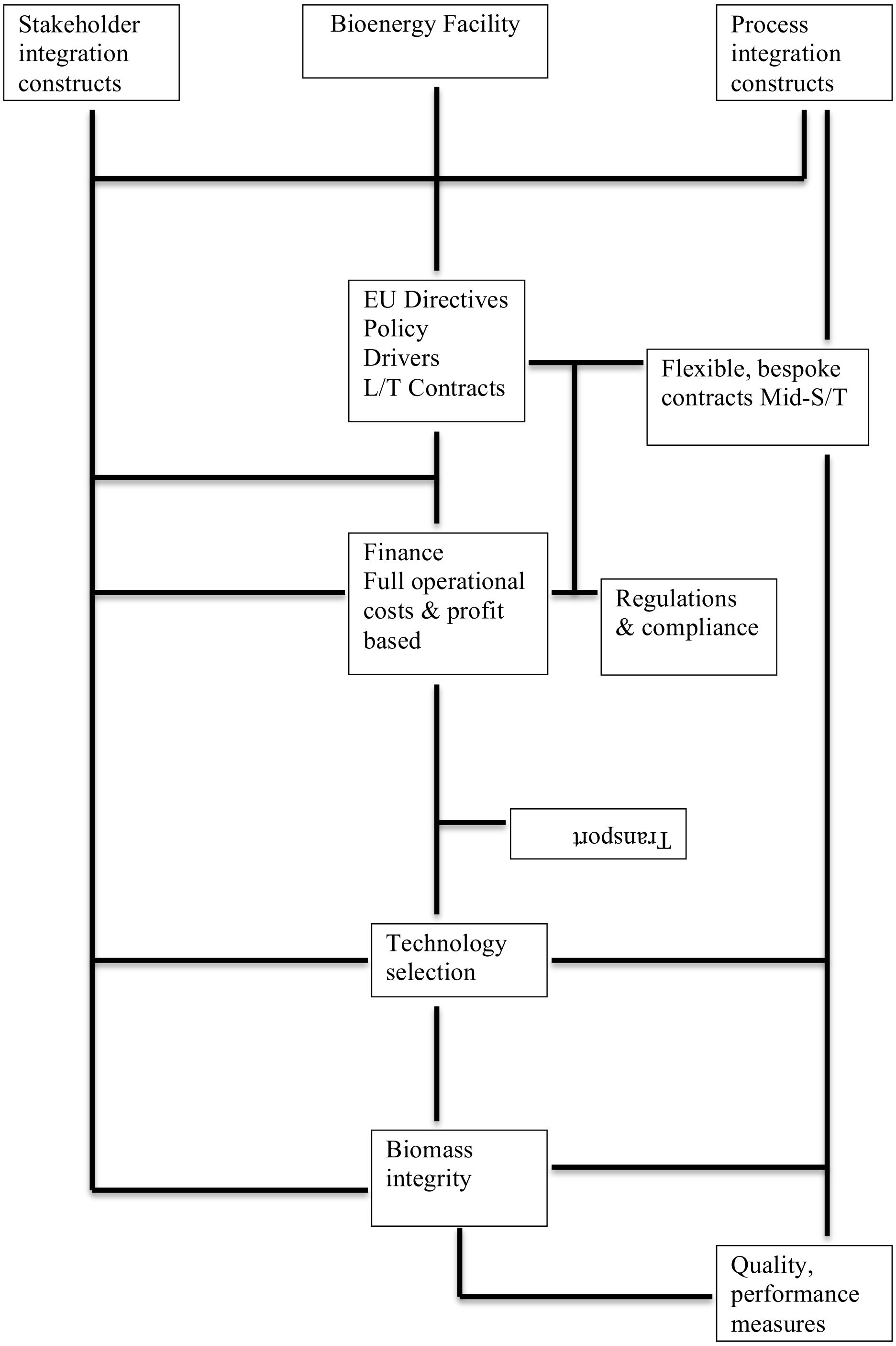


Figure 7.4.1 shows main integration characteristics appear to simplify the bioenergy supply chain but this is not the case because as often reiterated throughout this thesis is how emergent the bioenergy industry is in relation to conventional energy supply chains. The figure shows that bioenergy is not vertically integrated at this stage of its development but functions are vertical and horizontal due to critical relationships between stakeholder and process operations. Underpinning integration and critical to bioenergy business viability are contractual arrangements that co-exist from initial project development to commercial production.

The final chapter draws on the research questions, aim and objectives to address factors arising from the literature and field research. This is in order to contribute to academic and theoretical knowledge, in addition to demonstrating a model for best practice based on contract viable supply chain integration in bioenergy.

Chapter Eight: Discussion of Findings in Bioenergy SCI, Evaluation and Conclusion.

8.0: Chapter Overview, Purpose and Contribution.

The final chapter summarises the main conclusion and evaluation of the study. The format is presented in a systematic way by addressing each research question in turn based on primary and secondary research findings. This presents an effective and logical approach that helps expand knowledge from both practitioner and academic aspects. Motivation for this study does not deviate from the aim, which is to identify factors that enhance integration in bioenergy supply chains. Therefore the starting point is seen in the first research question, ‘what is meant by supply chain integration in bioenergy as a concept and set of constructs?’ and followed by the second research question, ‘what are the issues and challenges arising from supply chain integration in bioenergy?’

In summary, bioenergy supply chain integration is determined by the robustness of a contract that drives both stakeholder and process constructs of the businesses involved. Secondly, the main issues and challenges arising from the secondary research question consider supply chain integration from the point of origin to the point of conversion. The main issue here is that the supply chain in bioenergy is immature and is not supported by factors that integrate business linkages from a vertical perspective, (B2B) but is biased towards horizontal integration (B2C). In response to the issues and challenges identified as the study evolved, the third research question, ‘what are the integration factors that would help improve the performance of bioenergy supply chains?’ found that location, costs, terms of contract, National and EU Government renewable energy targets determined the scope of bioenergy businesses, in addition to their ability to distribute energy on to the open market. Energy distribution is centralised in the UK, therefore this determines how energy, including energy produced from renewables is sold through existing commodity markets. As stated in the previous chapter, the study does not fully scope research into energy distribution from renewables it is nevertheless worth including from the point of view of qualifying how bioenergy supply chains can successfully develop in the UK and this provides potential for further study. Leading on from the summary of the research and respective contributions is a short evaluation. This describes the research experience from a part-time mode of study and of access to fieldwork data and a limited number of practitioner companies, which in turn, provides an insight as to why so many bioenergy research approaches are based on secondary research that place emphasis on decision support systems and LCA tools for example. The last section of this chapter concludes with proposals for further research. It has been stated over a number of chapters that bioenergy is a developing and emergent industry. This in turn, gives the reasons why the supply chains are horizontally integrated from B2C because vertical integration (B2B) is yet to develop and evolve.

8.1: Introduction: Testing the Research Approach – Supply Chain Constructs in Bioenergy.

Chapter one presents the motivation for the study, its aim and research questions. First, it was necessary to define what is meant by supply chain integration in bioenergy and whether this is distinct from conventional supply chains. These are defined from the point of origin to the point of consumption whereas bioenergy supply chains are defined from the point of origin to the point of conversion. Therefore, for clarification the study and in order to identify and understand the role of SCI constructs in bioenergy, the study distinguished stakeholder and process characteristics from both the survey and case study findings given in table 8.1.1: Relationship between Bioenergy SCI Construct and Stakeholder and Process Characteristics, (p 265).

It could be argued that the five constructs identified in the study could also form part of either a STEEPLE or PESTLE analysis. However, it is rare that such strategy tools are cited in the literature (Hagen, 2009). It is more likely that researchers utilise SWOT but, purely to direct and inform theory building from an academic perspective as opposed to a practitioner-based view (Liu et al. 2011; Helms and Nixon, 2010). Furthermore, such strategy tools were applied to determine strengths and weaknesses of bioenergy from national perspectives rather than local and regional ones. It is apparent, however, that the political construct has been omitted from the five constructs identified in the study. There was no evidence of political determinants that were key to bioenergy development and thus commercialisation of bioenergy schemes in the region. Investigation in bioenergy production was sought from commercial companies from a supply chain integration point of view. Political factors were omitted because they are seen as involving decision-making from a national and international viewpoint, risk management, and differing ideologies between nations (Ball et al. 2008).

Identification of characteristics in table 8.1.1 was borne out of the results and analysis from the main study from both the survey and case study data. Economic and legal constructs dominate supply chain integration in bioenergy. There are also overlapping characteristics of EU Directives, compliance and planning approval between legal and environmental constructs. Connection to the national grid and transport overlaps economic, legal, social and technological constructs. There were characteristics specific to one type of construct such as informal contract within the social construct and location decision found in the environmental construct for example.

Table 8.1.1: Relationship between Bioenergy Constructs and Stakeholder and Process Characteristics.

<table>
<tr><th rowspan="11">Characteristics</th><th colspan="5">Constructs</th></tr>
<tr><th>Economic</th><th>Legal</th><th>Environmental</th><th>Social</th><th>Technological</th></tr>
<tr><td>Finance</td><td colspan="2">EU Directives</td><td>Relationship Mgt.</td><td>Technology Selection</td></tr>
<tr><td>Company Profits</td><td>Pre-Contract Agreement</td><td>Location</td><td colspan="2">National Grid Connectivity</td></tr>
<tr><td>EU Incentives</td><td colspan="2">Compliance</td><td>Recruitment</td><td rowspan="7">Transport</td></tr>
<tr><td>Nat. Grid Connectivity</td><td colspan="2">Planning Approval</td><td>Informal Contract</td></tr>
<tr><td>ROC/FiT Rates</td><td>Regulators Regulations</td><td>Quality Control</td><td rowspan="5"></td></tr>
<tr><td rowspan="3">Contractual Agreements</td><td>Supplier Agreements (L/T)</td><td>Performance Measurement</td></tr>
<tr><td>Formal Contract</td><td>Biomass Volume</td></tr>
<tr><td>Framework Agreement</td><td>Logistics Storage</td></tr>
<tr><td colspan="3">Transport</td></tr>
</table>

Identification of stakeholder and process characteristics were found in the literature and confirmed in the scoping study and main studies given in chapters two, four, five and previous chapter, (chapter seven). The literature confirms stakeholders are those actors who are influential in determining planning, development and policy in bioenergy production. Process integration, is defined by operations that determine the configuration of the bioenergy supply chain. The main study was based on bioenergy supply chain integration in the West Midlands and an overview of the socio-economic background and potential for biomass-to-bioenergy is provided in chapter five.

Data presented in that chapter was sourced from published reports and policy documents and whilst they were able to scope potential capacity for renewable energy, they did not recommend any guidelines in how to establish a successful bioenergy business together inherent with appropriate linkages. It would appear that the organisation of bioenergy business is disparate and fragmented. Chapter six presented results from the main survey of stakeholders, operators, researchers and case studies from bioenergy companies based in the Region. It would be naïve to assume that stakeholder roles and operator roles could be distinct and separate groups. It was evident from the survey and case study findings that such roles were inter-linked. Crossing of boundaries between stakeholder and process integration factors presented in the analysis, is not unusual in supply chain integration and it is the case in bioenergy supply chain integration that roles and responsibilities in such small and local supply chains cross over between project management and funding manager for example.

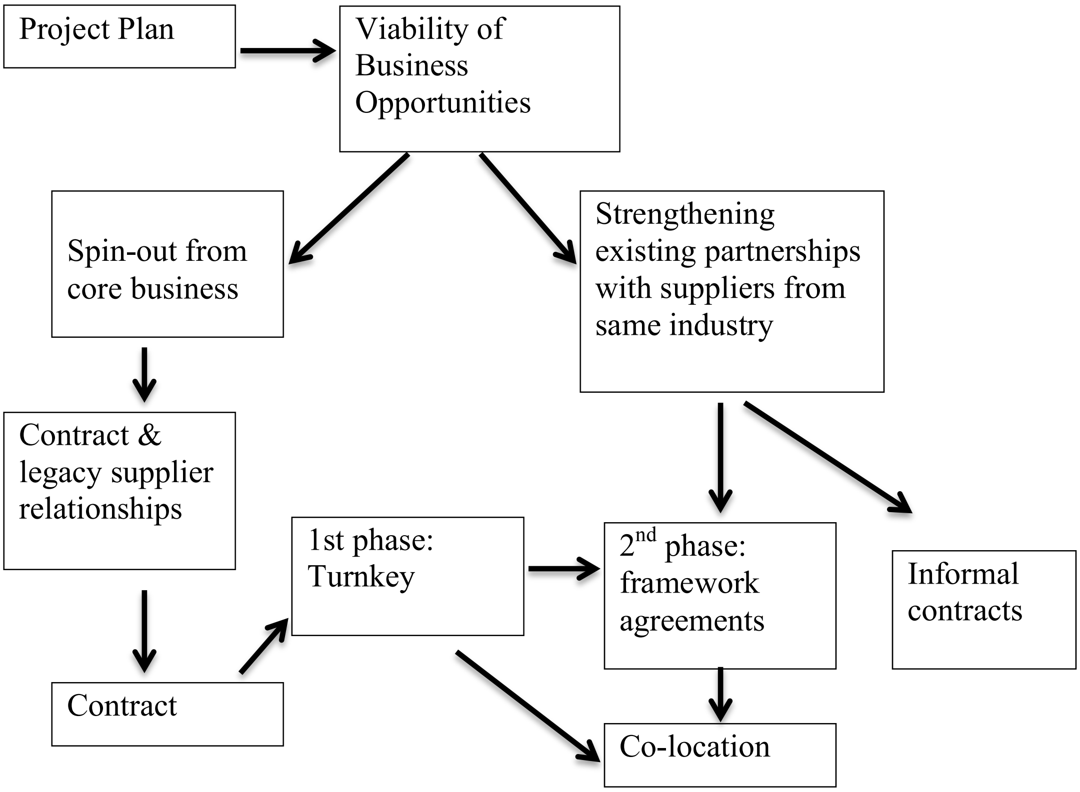
It could also be argued due to the novelty of the industry that supply chains in bioenergy do not exist, a view borne out by a meeting at a case study company. The study, supply chain integration in the UK investigated this topic from a supply chain perspective and by collecting both primary and secondary data on how such supply chains are configured there is strong evidence to support the existence of supply chains in bioenergy, but they lack maturity and as yet are classified as ‘local’ and ‘regional’ supply chains. Organisation of the chapter considers the aim and research questions followed by the contribution that the research has made in extending existing knowledge and theoretical approach and in addition, how the study contributes to adoption of best practice in supply chain integration in bioenergy. The final section in this chapter summarizes the main findings raised in the study and presents scope of further research on this emerging topic.

8.2: Validating the Research Aim: Did the Study Answer the Research Questions?

Methodological approaches deployed in the analysis contribute to trends in operational research methods in gaining an understanding of a novel and emergent industry. Process and stakeholder interventions that comprise a network of bioenergy actors are pivotal to the development of the biomass-to-bioenergy supply chain. To ascertain if the research achieved its aim, identification of characteristics pertinent to supply chain integration stated in the first research question, sought confirmation of integration factors evidenced from the literature and fieldwork. Integration factors cited in the literature were technological, economic, environmental and social. In contrast the study found that supply chain integrity in bioenergy was determined by contractual agreements that were central to creating a robust business environment. This was conditional upon a number of success factors illustrated in figure 8.2.1: Bioenergy Business Viability Factors on page 268.

Central to effective supply chain integration is the rigour of the contract determined by supplier relationships and collaboration. Both strategic partnerships and robust financial approaches create independence from national government incentives and subsidy. Contractual criteria concern performance indicators on cost, quality of delivery and feedstock. Long-term rather than short-term agreements challenge a bioenergy organisation due to lack of flexibility and this, renders them more vulnerable to national government budgetary fluctuations and policy changes. The literature is rather ambiguous on the role of integration by focusing more on supply chain management factors.

Figure 8.2.1: Bioenergy Business Viability Factors



The study finds that levels of intervention of stakeholders throughout the biomass-to-bioenergy supply chain are prominent from inception to commercial production. There were operational factors that did not concern stakeholders but it can be assumed that there are direct linkages between stakeholder involvement during commercial activity in the plant. These concern regulatory, monitoring and evaluation of bioenergy systems that impact on financial viability of the project and across the supply chain. Risk reduction mitigated by robust contractual agreements across the supply chain centralized supply chain configuration. This means that viable bioenergy supply chains conform to existing energy models in the UK. Despite the trend in public sector projects towards decentralized district heating systems from renewable energy, provision conformed to national grid regulatory framework. Centralization is costly but operators are required to purchase a proportion of energy from renewable sources and determination of operator contracts are motivated by costs. There is a keen argument for decentralized energy systems to allow the renewable energy market to develop. District heating prevalent throughout North West Europe could potentially risk the rigour of bioenergy distribution in the UK, particularly in the current climate of full operational costs and reduction of subsidies. Challenges in biomass are concerned with the low value of feedstock and lack of technological innovation to make more efficient use of energy generation. Stakeholder and operator participant views skewed negatively concerning research in this area. Technological selection is linked with long-term capital projects, which is biased towards tried and tested technologies to reduce risk. In addition, quality and volume of feedstock was likewise seen as a risk in relation to seasonal variations, price fluctuation and competition from other sectors. Regulatory measures governing utilization of biomass served to exacerbate risk rather than prevent it. Transport was a characteristic identified by operators and not stakeholders. Such provision was mainly undertaken by third party companies responsible for collection, storage and pre-processing tasks and required space to accommodate vehicles and storage facilities for biomass.

Co-location either between feedstock and conversion sites or, in close proximity to amenities was the preferred option. The second research question included importance of integration in bioenergy supply chains. Integration cannot assume a linear relationship between stakeholder and process actors. There were direct as well as indirect linkages between supply chain attributes identified from main study findings. Some of the attributes were intangible such as relationship management. In the absence of formal IT networks to track and monitor processes across the supply chain, management of supplier relationships were of high importance. The case studies circumvented risk by developing strong, robust supply chain relationships and synergies with partner companies. At the time of writing, bioenergy supply chains were not widely acknowledged but evidence from the literature defines supply chain integration from technological, environmental in relation to carbon emissions; social and economic characteristics in the development of the agro-economy. There is a lack of literature on contract-driven attributes that integrate the bioenergy supply chain.

Performance measurement in the literature mainly refers to life cycle assessment (LCA) methods and not optimization of production. In an attempt to identify key performance indicators (KPIs) that are important in supplier sourcing and selection, contractual agreements were key because they helped standardize and agree contractual criteria between parties. Therefore in the absence of formalized KPIs, the various parties relied on agreed terms within the contract to drive their businesses and work towards improving aspects of performance. The study did not gather quantitative data on KPIs but nevertheless collected data deployed by the industry. These were associated with cost, quality; order accuracy, on time delivery, lead-time and customer relations. Supplier relationships were not considered arms-length and adversarial but promoting strong alliance and partnership arrangements.

8.3: Contribution to Academic Theory Building, Knowledge and Best Practice in an Emergent Industry.

There are two types of theoretical approaches used by scientific enquiry. The first is where theory is deductive to be proven in scientific and rationalist terms from frequency of occurrences, which equate to factors that are statistically significant. The second type of theory building is based on phenomenological approaches formed from pragmatism underpinned by Grounded Theory. Pragmatism is associated with qualitative research methods but differs from interpretism that is linked to intervention and action on the part of the researcher. Goldkuhl (2012) argues that there are alternative paradigms to interpretism, which are biased towards positivism in operations research. Pragmatism has a role in initiating change but is distinct from action research methods because a pragmatist researcher has no direct interventions between the researcher and what is being researched. Bryant (2009) also argues for pragmatism in Grounded Theory as:

'For Pragmatists knowledge exists in the form of statements or theories which are best seen as instruments or tools; coping mechanisms, not once-and-for-all-time truths', (Bryant, 2009, http://www.qualitative-research.net).

On the other hand, a deductive study for practical purposes requires large data sets to evaluate the hypotheses. Another requirement is that it is based on a controlled environment. In this case, the researcher had limited numbers of examples that could be studied and this does not include issues over access to potential data but the fact that the topic being studied is novel and there is a lack of data in this context. Therefore, the study could only be studied by a Grounded Theory approach and opportunities for primary data could only be from pragmatic research methods. It is the novelty of the sector under study and the emphasis of business related issues that help expand current academic knowledge. Thus the aim of Grounded Theory is to develop theory from nascent phenomena. Grounded Theory may be defined as:

'The discovery of data systematically obtained from social research', (Glaser and Strauss, 1967, p. 2).

From a theoretical perspective, chapter three argued in favour of the pragmatist paradigm as opposed to abductionism. Hayden (2015) compared both pragmatist and abductionist paradigms in developing accounting systems that align with climate change and concluded that abductionism did not include key constructs that are central to developing business sectors such as that of bioenergy. Pragmatism relies on social, technological as well as economic constructs that are inter-linked and is thus developed throughout the study.

From a practitioner-based view the reason why this is so important is because bioenergy businesses are not viable through technology alone and need to present a robust business plan through the development of a supply chain where inter-linking firms in the supply chain work towards achieving a common goal. Bioenergy supply chain integration is concerned with stakeholder organisation that support the planning, installation and monitoring mechanisms of bioenergy production and facilitates robust and competitive contractual agreements to ensure effective production of bioenergy.

At present energy production in the UK is centralized. Unlike the conventional supply chain literature, the bioenergy supply chain is locally and regionally organized. Communication flows originating downstream (point of conversion) to biomass producers ensure that demand schedules are met. Whilst the research omitted energy distribution in fieldwork data collection, cost of grid connection restricts growth of renewable energy firms in the UK. The research found evidence of robust financial models that linked firms within a bioenergy supply chain that enabled them to meet grid connection costs.

In terms of industrial contribution, the study finds that bioenergy firms that are successful and operate effectively are independent, although not entirely of National Government subsidies. There were socio-economic benefits of developing agro-businesses in rural areas and there is a trend towards rural location of this industry. However, there is the scope to develop urban district heating systems should the West Midlands Region adopt universal ways of utilizing municipal solid and commercial wastes. There were opposing views in being tied into long-term contractual arrangements in one city authority to being beneficial to another within the Region. The literature supports decentralized district energy schemes but in practical terms, this would open the market up to greater competition from energy providers and an emergent supply chain may lose its stability whilst it is still evolving. Equipment manufacturers tend to be overseas companies and scepticism in bioenergy research has limited development of home grown technologies in this sector. There is a shortage of skills and equipment manufacturers in the UK that needs to be addressed. Findings from the survey and case study data confirm this factor.

Application of a range of contractual terms throughout the operations' process depends on demands from actors across the bioenergy supply chain. Unlike conventional energy supply chains that are vertically integrated, the study confirms that bioenergy supply chains conform to matrix structures that are vertically integrated between operators and horizontally integrated between stakeholders and operators. Generating contractual agreements is time-consuming and expensive, therefore performance indicators are used to help source and select appropriate suppliers. However, where a company displays sufficient confidence to use a 'gentleman's agreement' demonstrates the legacy of trust and collaboration amongst parties well known to the customer. The role of KPIs were not standardized but determined by in-house monitoring systems.

In terms of both contribution to knowledge and implications for practice bioenergy production is an evolving field which in terms of knowledge can be summarised from development of inter-relationships between bioenergy factors pertaining to economic, legal, environmental, technological and social constructs in order to define an evolving system from GT and pragmatist perspectives. In relation to practice, it was clearly evident that such inter-relationships defined by the constructs from either a stakeholder and process factors. Building on table 8.1.1 on page 265 showing relationships between stakeholder and process characteristics and the five constructs confirmed in the study, table 8.3.1: Summary of Contribution towards Theory and Practice in Bioenergy Supply Chain Integration illustrates how the study provides an insight into understanding how such nascent businesses can be investigated and what factors lead to developing more robust business practice.

Table 8.3.1: Summary of Contribution towards Theory and Practice in Bioenergy Supply Chain Integration.

Theory Building	**Knowledge Contribution**	**Practical Contribution**	
		Stakeholder	**Process**
Grounded Theory *(evolving phenomena).*	Development of nascent and evolving systems from: • Economic, • Legal, • Environment, • Technology and, • Social Constructs.	Economic: • Financial investment • Company profits • EU incentives Legal: • Planning approval • Contractual agreement • Regulators • Framework agreement • National grid connection Environmental • Location decision • Compliance Technological • Technology selection Social: • Relationship management	Economic: • Company profits • ROC/FiT rates Legal: • Pre-contract agreement • Formal/ • Informal contract • Regulations Environment: • Regulations • Performance measurement • Compliance Technological • Biomass volume • Biomass storage • Transport Social • Relationship management • Recruitment
Pragmatism Paradigm *(Systematic but not interventionist approach to survey and case study data).*			
Identification of Constructs in Bioenergy			

8.4: Evaluation and Potential for Further Research in Bioenergy Supply Chain Integration.

Bioenergy organizations operate in a way that is not dissimilar to supply chains found in the construction sector. Management of the supply chain is complex due to the number of contractors who operate on different levels and time periods on site. Typically, a construction network deploys a Principal Contractor to co-ordinate sub-contractors (preferred suppliers) during the construction phase but in this context it refers to the bioenergy installation phase. Adoption of partnering consortiums reduces risk and lowers cost (Dainty et al., 2001), thus supply chain integration is considered more strategic than supply chain management. Dainty et al. (2001) recommend a framework for supply chain integration and this framework is compared against supply chain constructs identified from stakeholder and operators participants from survey and case study data summarized in table 8.4.1: Framework for Bioenergy SCI: Responses to Potential Barriers, (p. 276).

Table 8.4.1: Framework for Bioenergy Supply Chain Integration: Responses to Potential Barriers.

Construct	Barrier	Responses
Economic *(Characteristic – Financial)*	Fluctuations in feedstock prices. Transport costs vs. value of feedstock. Grid connection costs. Dependence on subsidy.	Technology selection cope with range of feedstock. Balance between local collection, (short-haul) and long distances (long-haul) to balance costs. National policy on grid connectivity for higher proportion from renewable energy producers and move towards decentralized energy systems. Financial models based on full operational costs.
Technical (*Characteristic -Project Management)*	Control by stakeholders. Lack of communication between stakeholder and Operators	Involvement of all parties at start of project. Clear lines of communication between main contractor and sub-contractors, standard format between parties
Legal (*Characteristic – Contractual)*	Inflexible long-term contracts underpin organization of bioenergy firms.	Better co-ordination of contractual arrangements, operation of a range of contractual terms with suppliers and customers.
Legal, Economic & Environmental *(Characteristic – Partnering)*	Preferred suppliers barrier to market entrants.	Recognition of differences between large-scale and small-scale facilities. Development of information exchange and match-making services that scrutinize potential suppliers up-front.
Legal, Economic, Environmental & Technical *(Characteristic - Performance Measurement)*	Dependence on contractual terms rather than application of KPIs	Develop KPIs in bioenergy that are applicable to supplier sourcing and selection.
Legal, Environmental, Social & Economic (*Characteristics -National and European Policies)*	Changes to EU and National Government Policies in Bioenergy	Effective communications and relationships with stakeholders to respond to changes.
Legal, Economic, Environmental & Social *(Characteristic - Regulators/Regulations*)	Interference with operations at plant level. Plethora of regulations.	Clear lines of communication and bioenergy support mechanisms.
Environmental, Economic & Social *(Characteristic-Location)*	Proximity and co-location ties into single customer/supplier	Evolvement of a supply chain in bioenergy, companies within the same supply chain can compete more effectively.

Source: Format Adapted from Dainty et al. (2001, p. 172).

The table highlights key findings from the research and confirms that for the most part the main challenges and responses to these are not well documented in the literature. It would not be fair to state that such research has not been undertaken and, in addition, there is a lag between research and commercial practice.

In terms of knowledge contribution it should be noted that aligning bioenergy in a supply chain context is novel. On one level this is attributed to the fact that bioenergy supply chains are local and regionalised rather than global. However, on another level and as the study confirms, bioenergy companies are not unique businesses but have grown out of well-established enterprises. In theoretical terms this means new systems have been added to existing ones. Thus, pragmatic approaches enabled a logical and systematic investigation to develop and evolve. From this approach, five constructs have been identified of: economic, legal, environmental, technical and social, which were explored further by identification of their respective characteristics.

Contribution to bioenergy from a practical perspective relates to supply chain integration constructs and characteristics from both stakeholder and process operations. Central to bioenergy supply chain integration is the role and robustness of the contract and this is why the five pillars (constructs) of sustainability cannot be ignored in developing a viable bioenergy supply chain. This is attributed to robust linkages with appropriate enterprises and actors such as government agencies, auditors, financial investment and support, biomass producers and transport providers and including approval from the wider public for example. The study confirms that without such constructs in place these nascent businesses would not be viable.

This study was conducted on a part-time basis and there is a risk that the length of time provided for part-time study becomes out-dated prior to submission, a challenge intrinsic to all research irrespective of candidature. However, the research was refined and able to focus more effectively on the topic over its duration and can confirm that there has not been contemporary research on contract-driven drivers in supply chain integration for bioenergy. In this regard, the topic is robust and makes an original contribution to the existing knowledge on bioenergy supply chain integration.

On reflection of current methodologies and theoretical approaches there is a branch of bioenergy research that supports Multi-Attribute Utility Theory (MAUT) and Multi-Criterion Analysis tools, but such methodologies require large data sets. Analytical Hierarchy Processing and Analytical Network Processing methods using fuzzy logic can analyse both quantitative and qualitative data by utilizing a matrix structure based on the ratio of relationships between main and sub-attributes. This study is entirely qualitative and used action research methods that contribute to recent trends in operations research.

Qualitative approaches as opposed to quantitative methods depended on field study data through survey, semi-structured interviews and site visits to develop the case studies presented in chapter five. Data collected could be described as ‘rich’ and ‘meaningful’, which addresses the gap in contemporary research. One of the main risks in the study relied on a large extent on EU and National Government Renewable Energy Directives. The renewable energy policy environment is subject to changes as determined by modifications in administration, budgets and political parties, that all serve to render such a novel industry vulnerable to new changes that impact on the scope of the research. Recent concerns that the national government exceeded its £7.6 billion budget on renewable energy subsidy, (The Carbon Brief). Table 8.4.2: New Bioenergy Directives demonstrate changes that were introduced in 2015, (p. 279). These concern directions from both EU and national governments.

Table 8.4.2: New Renewable Directives and Policy Changes 2015.

Renewable Energy Directive & Policy Change	**Overview of Change & Impact on SCI Factors**
Ofgem Policy Paper 2010-2015 Government Policy: UK Energy Security Department of Business Innovation and Skills, updated March 2015	Reformation of electricity market Removal of barriers in electricity markets
EU 2030 Energy Strategy	Between 2020-2030 to encourage private investment in pipeline of electricity networks and low carbon technology: EU reform in emissions trading scheme (ETS), New indicators for competitiveness and energy security to tackle price differences amongst competitors, Diversify supply & connection, Standardize energy planning & policy.
Horizon 2020 work programme 2016-2017 information day, Brussels 02.10.15.	Secure clean and efficient energy supply.
Changes to Grandfathering Policy[1]: Future Biomass and Co-firing and Conversion Projects in the RO, DECC 22.09.15	Changes to the support rate under the Renewable Obligation for new biomass conversion and co-firing stations and combination units can no longer be covered by the Government's grandfathering policy
Government response to the consultation on changes to Feed-in Tariff accreditation, DECC, 09.09.15.	Removal of preliminary accreditation from the FiT rates. From 1st October 2015 the UK Government will remove pre-accreditation under the FiT scheme. In addition, the document states that the UK Government will remove the ability to receive a tariff guarantee through pre-registration. This will impact and deter small to medium producers of bioenergy, particular for decentralized and community-based projects.

New EU and National Government Policy changes confirm the main findings from the study in relation to subsidy and deterrence of new market entrants into the bioenergy industry. In contrast to the EU 2020-2030 Energy Strategy seeking to

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[1] Grandfathering is a policy a generating station in receipt of ROCs that it will receive support over the lifetime of the project. In April 2013, grandfathering policy was extended to biomass conversion and mid-range co-firing firms. From 1st April 2014 grandfathering policy included high-range co-firing firms.

encourage more effective inter-connectivity and fair competition in energy pricing policies. Issues with grid connectivity in the UK will limit deployment and expansion of the renewable energy sector. Potential for further research could take two directions in relation to this topic. First, the study presented provided limited data on the remaining supply chain factors that is bioenergy conversion-to-bioenergy distribution and consumption. Limited information provided would suggest that this was at a 'superficial' level. More research needs to be undertaken on what are the success factors associated with competitive renewable energy distribution and what forms of renewable energy are more connective than others to the National Grid?
The UK Government reports renewable electricity generation was 19.9 TWh in the second quarter of 2015 (March-June) which represents an increase of 51 per cent on the 13.2 TWh in the same quarter of 2014, (Gov.uk Energy Trends 28.09.15).

The second area for potential research is to investigate stakeholder determinants in renewable energy policy. Throughout the study, it was apparent that stakeholders had considerable influence on directions within the renewable energy sector only some officers had more influence than others. It would make an interesting topic for further research to ascertain the factors that determine renewable energy policy and impact that their directives have on the industry. This study forms the basis upon which to develop and expand knowledge in an emergent sector and it is likely that key findings in relation to technology, finance, site location and supplier relationships can also apply to other emergent industries.

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Scoping Study Questionnaire

Supply Chain Integration in Bioenergy Pilot Study

The questionnaire is divided into eight sections and is part of a pilot study for research in supply chain integration in the bioenergy industry within the UK. The responses and suggestions you provide will be extremely valuable for designing the full scale study. In order to complete the questionnaire, which should not take more than 20 minutes of your time please indicate in order of importance your responses to each question using the scale of 1-5 by placing a tick in the box of your main choice: ☑

Please return the questionnaire to: christine.lloyd@bcu.ac.uk/lloydce@aston.ac.uk

Thank you for taking time to complete the questionnaire

Scale

5	**Highly important to the bioenergy industry**
4	**Important to the bioenergy industry**
3	**Not applicable to the bioenergy industry**
2	**Partially important to the bioenergy industry**
1	**Not at all important to the bioenergy industry**

Appendix 1 Scoping Study Questionnaire

	5	4	3	2	1
Supply Chain and Logistics Planning (SCLP)					
Supplier selection, including energy companies is important to ensure security of supply of resources					
Inventory replenishment is important to ensure effective operations of bioenergy production.					
Carrier selection is important to bioenergy supply chain planning and logistics.					
Direct transport services is important to bioenergy supply chain planning and logistics.					
Logistics Functions (RLF)					
The collection of bio-fuel/mass resources is an important feature in the logistics operations of the bioenergy organisation.					
Storage of bio-fuels/mass is a feature of the logistics operations.					
Sorting is part of the logistics operations in the organisation.					
Transitional processing is part of the logistics operations in the logistics operations.					
Our company outsources all of the above.					
Organisational Role (OR)					
Co-ordination and organisation of delivery is undertaken by the organisation.					
Decontaminating and cleaning is part of the operational role in the organisation.					
Waste management is critical to the operations of our organisation.					
Waste management is outsourced and passed on to 2nd customers in terms of the management of waste and/or bi-product from biomass.					
Location is taken into consideration in the decision-making process of choice of site.					
Partnerships and responsibility to Project Mgt Team, Funding Bodies are an important feature in the overall organisational strategic aims and objectives.					
User Satisfaction (US)					
Effective communications is important to user satisfaction in the organisation.					

Overall working relations is necessary to effective operations in the organisation.					
Cost saving enables the organisation to be more competitive.					
Marketing and brand image is important to competitive strategy of the organisation.					
Service improvement is necessary to gain better user satisfaction ratings.					
Impact of Use (IU)					
Customer satisfaction is measured by the organisation.					
Profitability is a key indicator of usage of bioenergy in our organisation.					
Employee morale is a measure of effective operations in our organisation.					
Organisation Performance Costs (OPC)					
Quality is measured as it is key to effective performance.					
Cost is an important indication of performance in the organisation					
Time is an important indication of organisational performance in bioenergy production.					
Flexibility in bioenergy production is important to the business.					
Customer satisfaction is a performance measure.					
IT Applications (IT)					
IT is used in storage management.					
IT is used for order management.					
IT is used for planning the supply chain.					
IT is used for shipment and tracking.					
IT is used for freight payment					
IT is used for environmental auditingin the organisation.					
Waste Management Operations (WMO)					
The company organises cleaning/decontamination of the waste products/bi-products .					
The company sorts its own bi-products from bioenergy production.					
Storage is on-site of the waste products.					

Transportation is required for waste products.					
Waste management is outsourced.					
Please add further information should you wish to do so:					

Appendix Two: Main Study Questionnaire (Stakeholders and Operators)

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Supply Chain Integration Survey

This questionnaire has been developed to collect data that will help identify factors and characteristics that integrate supply chains in bioenergy organisations. The purpose of the survey will serve three main purposes:

- To help define the scope of the bioenergy industry for newcomers into the market,
- To identify supply chain factors that will encourage models of best practice in bioenergy supply chain planning and organization,
- To help build an effective methodology that will serve planners and key stakeholders in their development of bioenergy businesses.

It is intended that there will be supplementary benefits in the context of this study, which relates to the development of performance measures pertinent to this industry.

The information you provide will be treated **in the strictest confidence and in accordance with the University's ethical codes of practice**. If you would like to read details of this code please visit: http://moodle.bcu.ac.uk/tee/course/view.php?id=1189&topic=13

Questionnaire Completion Instructions

There are eight sections that relate to bioenergy organizations. Please place a tick in the box ☑ most relevant to your organization. In some cases you will be required to choose all that apply and some of the questions in this questionnaire may neither be relevant to your role, nor your organization. Please indicate by stating 'N/A', (Not Applicable) against that particular question.

Contact Details

Aston University

Information on this page has been removed for data protection purposes

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE

Organisational Information

Name of Company:

Company Address

Your role in the Company:

Type of Bioenergy Company, tick all that apply: ☑

☐ **Timber CHP Plant**
☐ **Anaerobic Digestion Plant**
☐ **Wind Farm**
☐ **Biofuel Producer**
☐ **Photo Voltaic**
☐ **Algae**
☐ **Solar Energy**

Number of years, company has been in operation:

☐ **1 year**
☐ **2-5 years**
☐ **5-10 years**
☐ **10-15 years**
☐ **15 or more years**

1. Supply chain integration and planning

This section includes the total end-to-end supply chain in order to ascertain integration between up and downstream functionality.

1.1 How important is supplier selection to a bioenergy business?

☐ **1. Unimportant**
☐ **2. Important**
☐ **3. Neither important, nor unimportant**
☐ **4. Fairly Important**
☐ **5. Very Important**

1.2 What is the length of the supplier agreements in the company?

☐ **1. 5 years**
☐ **2. 6-10 years**
☐ **3. 11-15 years**

☐ **4. 16-20 years**
☐ **5. 25+ years**

1.3 How many suppliers do you order stock from?

☐ **1. 1-5 suppliers**
☐ **2. 6-10 suppliers**
☐ **3. 11-15 suppliers**
☐ **4. 16-20 suppliers**
☐ **5. 25+ suppliers**

1.4 How often do you need to replenish biomass from suppliers?

☐ **1. Every day**
☐ **2. Once a week**
☐ **3. Once a month**
☐ **4. Every 4 months**
5. State how frequently you need to replenish biomass material: …….

1.5 How far are your suppliers located from your plant? Tick all that apply

☐ **1. They are adjacent to the company.**
☐ **2. 5-10 miles from the company**
☐ **3. 11-50 miles from the company**
☐ **4. 51-200 miles from the company**
☐ **5. The materials we need are imported from another country.**

Please could you specify how far your main materials for bioenergy production, including biomass come from:

1.6 What volumes of biomass do you require for your plant?

Please could you specify the volume of materials and resources required for bioenergy production:

1.7 What are the main risks associated with your supplier agreements? Please tick all that apply:

☐ **1. Quality of biomass from supplier.**
☐ **2. Security of supply of biomass materials.**
☐ **3. Transportation of biomass materials.**
☐ **4. Safety of biomass materials**
☐ **5. Competition from other bioenergy companies**
☐ **6. Other, please describe:**

2. Logistics Functions

This includes transport operations to the site, on-site and distribution channels, (eg pipelines for gas/fluids) containers and transport adapted for biomass.

2.1 How are the main components of biomass transported to the organization? Tick all that apply:

☐ **1. Road Freight**
☐ **2. Rail Freight**
☐ **3. Marine Freight**
☐ **4. Inland Waterway**
☐ **5. Pipeline**

2.2 What are the main functions that your logistics provider is responsible for? Tick all that apply:

☐ **1. Harvesting biomass**
☐ **2. Baling biomass**
☐ **3. Processing biomass**
☐ **4. Storage of biomass**
☐ **5. Transitional processing of biomass**
☐ **6. Other, please describe:**

2.3 Do you outsource your logistics operations to 3PL companies?

☐ **1. Yes**
☐ **2. No**
☐ **3. Not Applicable**
☐ **4. Yes, for some of the operations only**

2.4 What type of operations are outsourced to 3PL companies? Tick all that apply:

☐ **1. Transitional processing biomass (eg. sorting, baling, cleaning etc)**
☐ **2. Storage of biomass and materials**
☐ **3. Supply chain solutions**
☐ **4. Transportation of materials including biomass**
☐ **5. Other, please describe:**

2.5 What part of your operations do you need transportation? Tick all that apply:

☐ **1. Delivery of materials into the plant.**
☐ **2. Movement of materials around the plant.**
☐ **3. Transportation of waste to second customers.**
☐ **4. Transportation of biofuels to distributors.**
☐ **5. Other, please describe:**

3. Supply Chain Operations at a Strategic Level in Bioenergy

Supply management and logistics at a strategic level.

3.1 How many public sector organizations are involved in the planning stages of establishing your company?

☐ **1. 5-10 organizations**
☐ **2. 11-15 organizations**
☐ **3. 16-20 organizations**
☐ **4. 21-25 organizations**
☐ **5. Not applicable**

3.2 How many private sector organizations are involved in planning stages of establishing the company?

☐ **1. 5-10 organizations**
☐ **2. 11-15 organizations**
☐ **3. 16-20 organizations**
☐ **4. 21-25 organizations**
☐ **5. Not applicable**

3.3 How many organizations are currently involved in the company?

☐ **1. 5-10 organizations**
☐ **2. 11-15 organizations**
☐ **3. 16-20 organizations**
☐ **4. 21-25 organizations**

Please identify the main organisations that are currently involved at strategic level in the company:

3.4 What operating standards must your company comply with in order to perform its operations? Tick all that apply:

☐ **1. ISO 14001**
☐ **2. Other ISO Standards. Please identify all that apply**
☐ **3. National Government Directives.**
☐ **4. EU Directives**
☐ **5. Other International Standards. Please identify all that apply:**

Please describe the benefits and barriers to the current operating and compliance standards that apply to bioenergy organizations:

3.5 Who are your key decision makers that drive your bioenergy organization? Tick all that apply:

☐ **1. Energy Company**
☐ **2. The Company Director/Owner**
☐ **3. Regional Development Agency**
☐ **4. Local Authority**
☐ **5. EU Consortium**
☐ **6. None of the above, Please describe:**

3.6 Which party was key in deciding your company location? Tick all that apply:

☐ **1. Energy Company**
☐ **2. The Company Director/Owner**
☐ **3. Regional Development Agency**
☐ **4. Local Authority**
☐ **5. EU Consortium**
☐ **6. None of the above, Please describe:**

3.7 How was your organization funded? Please tick all that apply:

☐ **1. Energy Company**
☐ **2. The Company Director/Owner**
☐ **3. Regional Development Agency**
☐ **4. Local Authority**
☐ **5. EU Consortium**
☐ **6. None of the above, Please describe:**

3.8 What approaches do you think add value to bioenergy?

☐ **1. EU policies**
☐ **2. National Government policies**
☐ **3. Carbon Auditing methodologies, (eg LCA tools etc)**
☐ **4. Number linkages in the supply chain**
☐ **5. Supply chain resilience**
☐ **6. None of the above, Please describe:**

4. Communications and Marketing

This is concerned with supply chain visibility and relationships between the respective suppliers/customers.

4.1 Which suppliers do you talk to most frequently? Tick all that apply:

☐ **1. We operate through a consortia of partners.**
☐ **2. Our biomass suppliers**
☐ **3. Our materials suppliers**
☐ **4. The logistics company**
☐ **5. None of the above, Please describe:**

4.2 Which customers do you talk to most frequently? Tick all that apply:

☐ **1. Energy Company**
☐ **2. Our biomass suppliers**
☐ **3. Our materials suppliers**
☐ **4. The logistics company**
☐ **5. None of the above, Please describe:**

4.3 What public relations activities does your company perform to promote bioenergy production? Tick all that apply:

☐ **1. Open days/open door policy**
☐ **2. Exhibit at bioenergy expos and conferences**
☐ **3. Links with research institution**
☐ **4. Links with policy makers**
☐ **5. None of the above/Not applicable**

4.4 What forces would encourage your company to integrate more effectively? Tick all that apply:

☐ **1. Less involvement from parties who are not directly involved**
☐ **2. Policies that are directly aligned to bioenergy**
☐ **3. More examples of good practice in supply chain management**
☐ **4. Better visibility in the supply chain**
☐ **5. Better clarity of standard operating procedures, (SOPs)**

4.5 What is the main market do you distribute the bioenergy you produce into?

☐ **1. National energy grid**
☐ **2. Regional consortia**
☐ **3. Other bioenergy companies**
☐ **4. Our own institution (college/university/company)**
☐ **5. Local renewable energy initiative**

5. OrganizationPerformance Costs

This section relates to quality measures and supply chain performance Costs.

5.1 What KPIs does your company use? Tick all that apply:

☐ **1. Costs of materials and labour**
☐ **2. On time delivery**
☐ **3. Customer relations**
☐ **4. Supplier relations**
☐ **5. Quality of product**

5.2 What KPIs do you use to select suppliers? Tick all that apply:

☐ **1. Costs of materials**
☐ **2. On time delivery**
☐ **3. Customer relations**
☐ **4. Order accuracy**
☐ **5. Quality of product**

5.3 How quickly could your company respond to an extra 25% in demand for example? Tick all that apply:

☐ **1. Yes**
☐ **2. No**
☐ **3. Not applicable, we are a pilot plant**
☐ **4. The company would outsource in order to attain capacity**
☐ **5. The company would place demand on its 3PL providers**

5.4 If your suppliers do not meet your standards what does this mean for your company?

☐ **1. Our company would source other suppliers**
☐ **2. Our company would seek ways of improving their standards**
☐ **3. None of these, as we are tied into preferred suppliers**
☐ **4. Our company has to use a range of suppliers for materials.**

5.5 Our organisation is targeted to reduce production costs from its initial investment.

☐ **1. >5-10% over the next 5 years**
☐ **2. >11-20% over the next 5 years**
☐ **3. >21-25% over the next 5 years**
☐ **4. >26-50% over the next 5 years**
☐ **5. Not applicable**

6. IT Applications

The use and application of IT in day-to-day operations of bioenergy production.

6.1 What function does your company use IT? Tick all that apply:

☐ **1. IT is used for order management.**
☐ **2. IT is used for storage management (eg warehouse systems).**
☐ **3. IT is used for shipment tracking (eg vehicle routing and scheduling).**
☐ **4. IT is used for managing payments to suppliers.**
☐ **5. IT is used for environmental auditing in the company**
☐ **6. IT is used for location decisions (eg GIS)**
☐ **7. IT is used for quality management and monitoring (eg yield quality)**

Please state what software your company uses in its operations:

7. Waste Management

Post-production and management of biomass bi-products

7.1 Does your company perform its own cleaning/decontamination of waste products from bioenergy production?

☐ **1. Yes, the company recycles all waste into other products.**
☐ **2. No, the company sends its waste to secondary customers.**
☐ **3.The company recycles some waste but sends the rest to specialist waste disposal companies.**
☐ **4. Waste is recycled to produce bioenergy.**
☐ **5. The company has to separate its waste prior to disposal.**
☐ **6. Other, please describe:**

8. Would you be willing to participate in a case study?

☐ **1. Yes**
☐ **2. No**

Thank you for taking the time to complete this questionnaire

Appendix Three: Main Study Questionnaire, (Researcher)

Bioenergy Research Survey

This questionnaire has been developed to collect data that will help identify factors and characteristics of the range and scope of bioenergy research currently performed in Research Centres and Institutions across North West Europe. The survey will serve three main purposes:

- To help define the scope of bioenergy research across North West European Countries,
- To identify in those Research Centres and Institutions models of best practice, in particular to inform bioenergy supply chain planning and organization,
- To help build an effective methodology that will serve planners and key stakeholders in their development of bioenergy businesses.

It is intended that there will be supplementary benefits in the context of this study that will aid development this nascent industry.

The information you provide will be treated **in the strictest confidence and in accordance with the University's ethical codes of practice**. If you would like to read details of this code please visit: http://moodle.bcu.ac.uk/tee/course/view.php?id=1189&topic=13

Questionnaire Completion Instructions

There are eight sections that relate to bioenergy organizations. Please place a tick in the box ☑ most relevant to your organization. In some cases you will be required to choose all that apply and some of the questions in this questionnaire may neither be relevant to your role, nor your organization. Please indicate by stating 'N/A', (Not Applicable) against that particular question.

Contact Details

Aston University

Information on this page has been removed for data protection purposes

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE

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A. Organisational Information

Name of Research Centre/Institution:

Address:

Your role in the Company:

Number of employees:

Type of Bioenergy Company, tick all that apply: ☑

- ☐ **Timber CHP Plant**
- ☐ **Anaerobic Digestion Plant**
- ☐ **Wind Farm**
- ☐ **Biofuel Producer**
- ☐ **Photo Voltaic**
- ☐ **Algae**
- ☐ **Solar Energy**

1. Number of years, Centre has been in operation:

- ☐ **1 year**
- ☐ **2-5 years**
- ☐ **5-10 years**
- ☐ **10-15 years**
- ☐ **15 or more years**

2. Number of employees in your Research Centre?

- ☐ **1-5 employees**
- ☐ **6-10 employees**
- ☐ **11-15 employees**
- ☐ **16-20 employees**
- ☐ **21+ employees**

3. Does your Research Centre have a bioenergy plant in operation?

- ☐ **Yes**
- ☐ **No**

If you answered 'Yes' continue to the next section, Section B. If answering 'No', go to Section C

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Section B

This section is about your knowledge of operating a bioenergy research plant.

4. Was your bioenergy plant specifically built for research into bioenergy production?

☐ **Yes**
☐ **No**

Other, please describe briefly:

5. How long did it take for you to gain approval for your Bioenergy Research Production Plant?

☐ **1 year**
☐ **2-5 years**
☐ **6-10 years**
☐ **11-15 years**
☐ **16+ years**

6. What was involved in planning and development? Please tick all that apply, ☑

☐ **University Authorities (e.g. Senate, Vice Chancellor etc.)**
☐ **Faculty/School Decision**
☐ **Research Council**
☐ **Regional Development Agency**
☐ **Municipal Authority**
☐ **National Government**
☐ **Environmental Agency**
☐ **European Government**

Others, Please describe:

7. How did you obtain your sources of funding to establish your Bioenergy Research Plant? Please tick all that apply ☑

☐	**Research Council Grant**
☐	**National Government Funding**
☐	**European Union Funding**
☐	**Public-Private Partnership Funding**

8. Please identify the initiatives from which you obtained funding.

Please describe:

9. Please indicate the amount of grant received to establish your Bioenergy Research Plant:

- ☐ **250,000-500,000 €**
- ☐ **500,000-1 million €**
- ☐ **1 million €**
- ☐ **> 1 million €**

10. What were the key drivers that helped realize your Bioenergy Research Plant?

Please describe briefly:

11. Did co-location to a large industrial facility influence you obtaining approval for the Bioenergy Research Plant?

- ☐ **Yes**
- ☐ **No**

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12. How many suppliers do you order stock from?

☐ **1-5 suppliers**
☐ **6-10 suppliers**
☐ **11-15 suppliers**
☐ **16-20 suppliers**
☐ **25+ suppliers**

13. Are these 'preferred' suppliers, governed by 'Public Sector' rules?

☐ **Yes**
☐ **No**

Please could you specify how far your main materials for bioenergy production, including biomass come from? Please indicate:

14. How often do you need to replenish biomass from suppliers?

☐ **Every day**
☐ **Once a week**
☐ **Once a month**
☐ **Every 4 months**

Please state how frequently you need to replenish biomass material?

16. How far are your suppliers located from your plant? Tick all that apply

☐ **1. They are adjacent to the Research Centre**
☐ **2. 5-10 miles from the Research Centre**
☐ **3. 11-50 miles from the Research Centre**

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☐ **4. 51-200 miles from the Research Centre**
☐ **5. The materials we need are imported from another country.**

17. What volumes of biomass do you require for your plant?

Please could you specify the volume of materials and resources required for bioenergy production:

18. What are the main risks associated with your supplier agreements? Please tick all that apply:

☐ **1. Quality of biomass from supplier.**
☐ **2. Security of supply of biomass materials.**
☐ **3. Transportation of biomass materials.**
☐ **4. Safety of biomass materials**
☐ **5. Competition from other bioenergy companies**
☐ **6. Other, please describe:**

19. In your specialist field of research how important do you think supply chain management is in bioenergy?

☐ **Not important**
☐ **Slightly important**
☐ **Neither important nor unimportant**
☐ **Important**
☐ **Very important**

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20. What do you understand to be upstream operations in bioenergy? Tick all that apply ☑

☐ **Bio-crop production (including growing and harvesting)**
☐ **Processing biomass**
☐ **Storage of biomass**
☐ **Transportation of biomass**
☐ **Conversion of biomass into bioenergy**
☐ **Distribution of bioenergy to consumers**
☐ **Marketing bioenergy**

21. What do you understand to be downstream operations in bioenergy. Tick all that apply ☑

☐ **Storage of biomass**
☐ **Transportation of biomass**
☐ **Conversion of biomass into bioenergy**
☐ **Distribution of Bioenergy to consumers**
☐ **Treating waste from bioenergy production**
☐ **Transportation of bioenergy to energy provider**
☐ **Marketing bioenergy**

22. Any further information that will help research into bioenergy?

Please provide any further information here:

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Thank you for your time

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Section C

This section investigates reasons why your Research Centre was not successful in gaining approval for your bioenergy research plant.

23. Did your Research Centre conduct a feasibility study as part of the planning application?

☐ **Yes**
☐ **No**
☐ **Not Applicable**

24. Assuming that your planning application was successful, what were the major factors influenced the decision in gaining approval of your Bioenergy Research Plant? Please tick all that apply, ☑

☐	**Appropriate allocation of funding**
☐	**Allocation of site**
☐	**Stakeholder agreements**
☐	**Approval of Scheme**
☐	**Private-Public Partnership Arrangements in place**

Other, please describe:

25. Assuming that your planning application was successful, what were the major factors that mitigated against you building your Bioenergy Research Plant? Please tick all that apply, ☑

☐	**Length of time it took to get approval**
☐	**Risk in the funding arrangements**
☐	**Gaining approval from all the stakeholders**
☐	**Location issues**
☐	**Legislative issues**
☐	**Risk in obtaining funding from some of the funding bodies**
☐	**Change in Government policy in bioenergy**

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Other, please describe:

26. Will you continue to look for ways to realize your bioenergy research plant despite set-backs at this present time?

☐ **Yes**
☐ **No**

27. 22. Any further information that will help research into bioenergy?

Please provide any further information here:

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Severn Trent Services Assurance Map

04/12/2013

		SALES AND CUSTOMER					PRODUCTS AND SERVICES							ENTITIES & GLOBAL LOCATIONS	
		Pipeline / New Business Management (KPI 7)	Contract Retention (KPI 9)	Contract tender and bid (including legal aspects)	Meeting customers' expectations - VOC (KPI 11)	Managing Reps and Distributors	Water and Waste Water treatment quality (KPI 10)	Performance against contractual commitments	On time delivery (KPI 8)	Design, Quality & Compliance with standards / certifications	Intellectual property	Procurement / Supply Chain Management	Management of Product Development	New entity set up / acquisition / disposal (incl. JVs)	Management of remote offices (control environment)
	Policy				✓	✓	✓	✓	✓	✓		✓			
		D/P	D	P	D	P	D	P	D	P	P	P	P	P	P
	Performance Provider														
Operations 1st Line	Operating Services - US	🟧	🟨	🟨	🟧		🟧	🟧				🟧		🟧	
	Operating Services - UK & Ireland	🟧	🟨	🟨	🟧	🟨	🟨	🟧		🟩		🟨		🟨	🟧
	Operating Services - Italy	🟧	🟨	🟨	🟧		🟨	🟧	🟨	🟩		🟧		🟧	
	Water Purification	🟧		🟧	🟧	🟧		🟨	🟨	🟧	🟧	🟧	🟨	🟧	🟧
	Marketing				🟧										
	Finance	🟧		🟨		🟨						🟨		🟨	🟨
	IT														🟨
	Human Resources													🟨	🟧
	Assurance Provider														
	Severn Trent Services														
Oversight 2nd Line	STS Health, Safety & Environment						🟨								🟧
	2nd line providers embedded within the 1st line (e.g. Technical Services)						🟨	🟨		🟫	🟧		🟨		
	Legal			🟫							🟫			🟫	
	STS Contracts & Risk Management	🟦	🟦	🟫	🟦	🟦	🟦	🟫	🟦			🟫			
	STS Corporate Finance														
	Severn Trent Plc														
	ST Plc - General Counsel			🟨										🟨	
	ST Plc - Assurance Services (RRS, Insurance)														
	ST Plc - Strategy & Regulation													🟨	
	ST Plc - Finance, Treasury, Tax													🟨	
	ST Plc - Human Resources														
	STS Executive Commitee, STEC (or Steering Group)	✓	✓	✓	✓	✓	✓		✓			✓	✓	✓	
	Independent Assurance Provider														
Independent 3rd Line	Internal Audit			✓		✓	✓	✓		✓	✓	✓		✓	✓
	External Audit (Deloitte, etc.)														✓

		FINANCIAL								INFORMATION TECHNOLOGY	
		Annual accounts - statutory (including interim)	Financial Transaction Processing	Deliver current year budget (KPI 3, 4, 5, 6, 12 & 13)	Business Planning & Analysis	Credit control and receivables management	Tax compliance	Treasury & Cash Management	Insurance programme	Service & Project Delivery	IT Security
	Policy										
		D/P	P	D	P	P	P	P	P	D/P	P
	Performance Provider										
Operations 1st Line	Operating Services - US			🟨	🟨	🟨					
	Operating Services - UK & Ireland			🟨	🟨	🟨					
	Operating Services - Italy			🟨	🟧	🟨			🟧		
	Water Purification			🟨	🟨	🟨			🟧		
	Marketing										
	Finance	🟨	🟧	🟨	🟨	🟨	🟧	🟧			
	IT				🟨					🟧	🟧
	Human Resources				🟨						
	Assurance Provider										
	Severn Trent Services										
Oversight 2nd Line	STS Health, Safety & Environment										
	2nd line providers embedded within the 1st line (e.g. Technical Services)		🟧							🟫	🟫
	Legal										
	STS Contracts & Risk Management		🟫			🟫			🟫		
	STS Corporate Finance	🟨		🟨	🟨	🟨	🟧	🟧			
	Severn Trent Plc										
	ST Plc - General Counsel										
	ST Plc - Assurance Services (RRS, Insurance)								🟧		
	ST Plc - Strategy & Regulation										
	ST Plc - Finance, Treasury, Tax	🟨			🟨		🟧	🟧			
	ST Plc - Human Resources										
	STS Executive Commitee, STEC (or Steering Group)	✓		✓	✓	✓	✓	✓	✓	✓	✓
	Independent Assurance Provider										
Independent 3rd Line	Internal Audit					✓					✓
	External Audit (Deloitte, etc.)	✓	✓			✓	✓	✓			

		EMPLOYEE						HEALTH & SAFETY		
		Recruit and train staff	Employee engagement (KPI 2)	Compliance with Employment Law	Code of Conduct and Whistleblowing	Diversity (% of female and ethnic minorities)	Talent management / management capability	Operational Health, Safety & Wellbeing (& Compliance)	Recording and reporting H&S incidents (KPI 1)	Travel safety & assistance
	Policy	✓	✓	✓	✓	✓	✓	✓	✓	✓
		P	D	P	P	D	P	P	D	P
	Performance Provider									
Operations 1st Line	Operating Services - US	🟧		🟨	🟧			🟧	🟩	🟧
	Operating Services - UK & Ireland	🟨		🟨	🟨			🟨	🟩	🟧
	Operating Services - Italy	🟧		🟨	🟨			🟧	🟩	
	Water Purification	🟧		🟨	🟨			🟧	🟩	🟧
	Marketing				🟨			🟨	🟩	
	Finance				🟨			🟨	🟩	
	IT				🟨			🟨	🟩	
	Human Resources	🟧	🟨	🟧	🟧	🟨	🟧	🟨	🟩	🟧
	Assurance Provider									
	Severn Trent Services									
Oversight 2nd Line	STS Health, Safety & Environment				🟨			🟧	🟩	🟧
	2nd line providers embedded within the 1st line (e.g. Technical Services)									
	Legal									
	STS Contracts & Risk Management		🟦			🟦		🟦	🟦	🟫
	STS Corporate Finance									
	Severn Trent Plc									
	ST Plc - General Counsel									
	ST Plc - Assurance Services (RRS, Insurance)									
	ST Plc - Strategy & Regulation									
	ST Plc - Finance, Treasury, Tax									
	ST Plc - Human Resources				🟨		🟧			
	STS Executive Commitee, STEC (or Steering Group)		✓	✓	✓	✓	✓	✓	✓	
	Independent Assurance Provider									
Independent 3rd Line	Internal Audit	✓			✓			✓	✓	
	External Audit (Deloitte, etc.)									

		REGULATION & LEGAL							ENVIRONMENT & COMMUNITY		RISK, RESILIENCE & CONTINUITY		
		Information Management (including data protection)	Anti-fraud & bribery (incl. FCPA)	Local statutory requirements / FSA Compliance	Governance over statutory companies (incl. JVs)	International Trade - Export Laws & Licensing Conditions	Competition Law Compliance	Benefit Program obligations (Pensions)	Corporate Responsibility Framework (incl. Community)	Compliance with environmental laws, regulations & permits	Enterprise Risk Management Framework	Security of facilities	Business Continuity, Disaster Recovery & Crisis Mgmt
	Policy	✓	✓				✓		✓	✓	✓	✓	✓
		P	P	P	P	P	P	P	D	P	P	P	P
	Performance Provider												
Operations 1st Line	Operating Services - US		🟧	🟨	🟧		🟧			🟧	🟧	🟨	🟧
	Operating Services - UK & Ireland		🟧	🟨	🟨		🟧	🟧		🟨	🟨	🟨	🟨
	Operating Services - Italy		🟧	🟩	🟧	🟨	🟧	🟨		🟨	🟧	🟨	🟧
	Water Purification		🟧	🟨	🟧	🟧	🟧				🟧	🟨	🟧
	Marketing		🟧				🟧		🟧		🟧		
	Finance	🟧	🟧	🟨							🟧		🟧
	IT	🟧	🟧								🟨		🟧
	Human Resources	🟧	🟧					🟨			🟧		🟧
	Assurance Provider												
	Severn Trent Services												
Oversight 2nd Line	STS Health, Safety & Environment									🟨	🟧	🟫	🟫
	2nd line providers embedded within the 1st line (e.g. Technical Services)									🟨			
	Legal		🟫	🟫	🟦	🟦	🟧						
	STS Contracts & Risk Management					🟦				🟦	🟧		🟫
	STS Corporate Finance	🟫											
	Severn Trent Plc												
	ST Plc - General Counsel		🟧	🟨	🟧								
	ST Plc - Assurance Services (RRS, Insurance)										🟧		
	ST Plc - Strategy & Regulation								🟨				
	ST Plc - Finance, Treasury, Tax												
	ST Plc - Human Resources							🟨					
	STS Executive Commitee, STEC (or Steering Group)		✓						✓	✓	✓		
	Independent Assurance Provider												
Independent 3rd Line	Internal Audit		✓			✓			✓	✓	✓		✓
	External Audit (Deloitte, etc.)			✓			✓						

Key

🟥	There is no defined process or the designed process is not operating effectively.
🟧	Procedures have been defined but are not being fully applied or assurance is only operational over some parts of the area.
🟨	Procedures have been defined and are understood; and the assurance activity is in operation as designed.
🟩	Procedures have been defined and are understood; and the assurance activity has been confirmed as operating effectively.
✓	Assurance activity takes place but is not assessed.
🟦	STS 2nd Line Assurance - in development, planned for FY14
🟫	STS 2nd line assurance deferred to FY15

Sheet Owner: CW