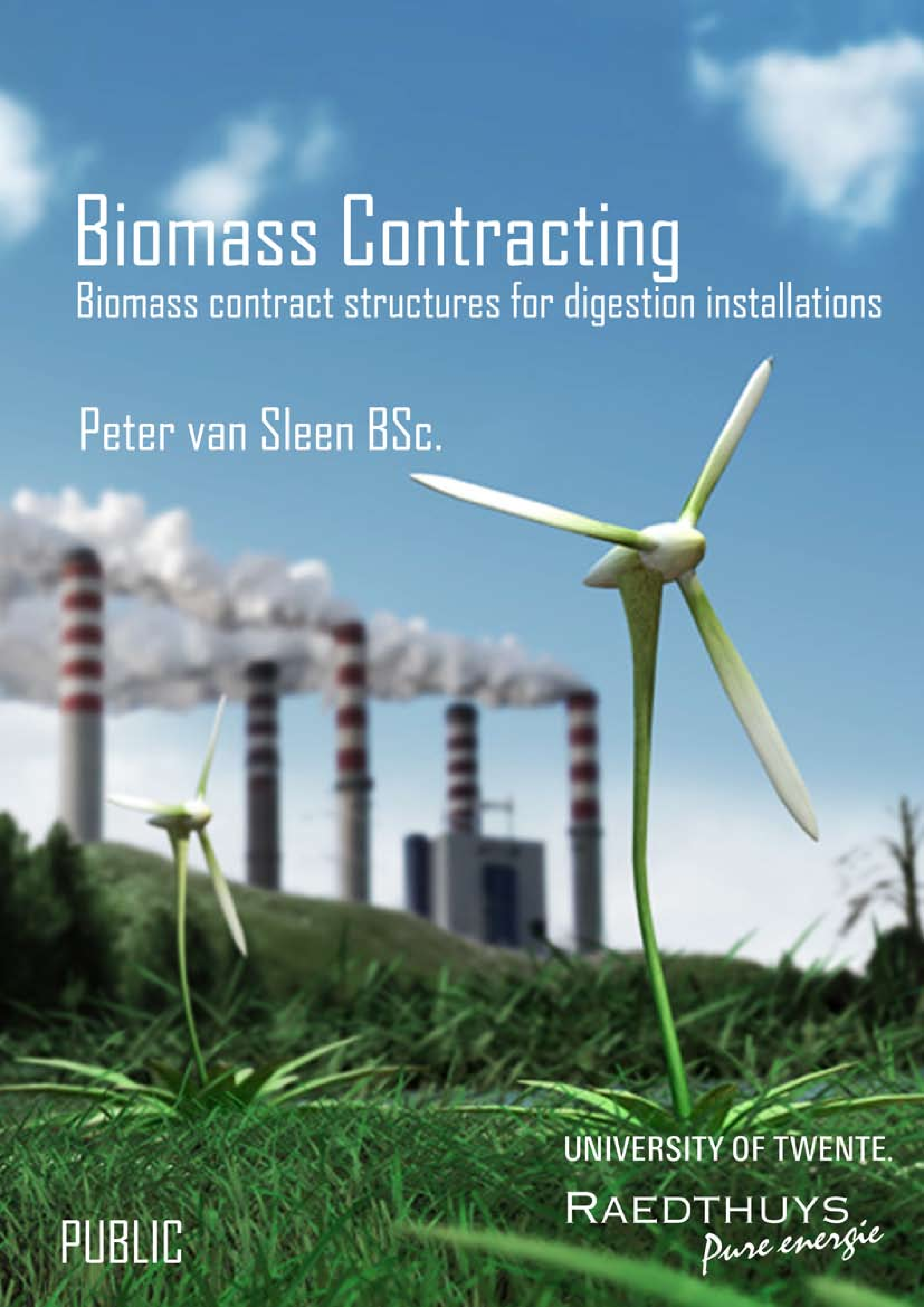

Biomass Contracting

Biomass contract structures for digestion installations

Peter van Sleen BSc.

UNIVERSITY OF TWENTE.

RAEDTHUYS
Pure energie

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This research is concerned with contracting in the biomass market and is looking for possible contract structures for positive list digestion installations. Using theory about markets and contracts, the research pioneers on possible market structures for the quite stable manure market and for the non-transparent and price volatile co-substrate market. A contract structure for the co-substrate market, the basket contract, is developed, and is tested empirically using data from the animal feed industry.

Management Summary

In the biomass market all kinds of different biomass products - products from biological origin (vegetable or animal) - are traded. The current problem in the market is that demand-side organizations want to sign longer-term contracts in this non-transparent market on the delivery of biomass. This is necessary to achieve investment security and is demanded by investors and banks before finance is supplied. One of the organizations struck by this problem is the sustainable energy organization Raedthuys - the principal of this research. The market, however, only developed the institutional environment (laws, regulations etc.) and the resource allocation level, leaving contract structures undeveloped. Therefore, the goal of this research is to give an advice on what contract structures to use in the non-transparent biomass market. The problem definition of this research is:

> *How can Raedthuys use contract structures in the biomass sector to obtain more investment security on the purchase of biomass?*

This research is mainly focused at exploring the biomass field on its problem and possible contract structures. The research method used is existing data research. Besides, information from the market is gathered using survey research. The focus of this research lays on market actors taking part in the positive list digestion installation market. These installations produce biogas from (liquid) biomass in a heated, mixed and gas-proof tank using bacteria and/or enzymes to ultimately produce electricity and heat. These positive list digestion installations only use biomass which is listed on the positive list developed by the government and digest at least 50 percent manure. Besides manure, co-substrates are used in the installation to heighten the gas production. The manure and co-substrate submarkets are analyzed using agricultural organizations, the animal feed industry and the food industry as main analysis units.

Theory is used to analyze market structures and contracts. Theory about markets shows trade emerges in markets when some kind of benefit (private or public) can be gained. These benefits meet on a market, using specific trading rules or systems, where an equilibrium quantity and price is produced. However, not all markets, including the biomass market, are operating efficiently due to non-transparency, illiquidity and volatile prices. The market is illiquid, because it is hard to assess the costs for a trade at a given size. Theory on contracts, on the other hand, analyses the alignment of transactions with governance structures. This research uses two theories in this field. First, agency theory, which is used to describe the conflicting goals between contract partners and to analyze risk-sharing and information asymmetry. Second, transactions cost economics, which is used to analyze governance structures using risk-neutral actors. Besides, four contract durations or commitments are identified, namely: spot-, full-, long-term and short-term commitment. Also the value of renegotiation in contracts is outlined, because long-term contracts are by nature incomplete.

The manure market is a quite stable market and has a growing manure surplus in the Netherlands in the near future, which means an increasing manure price. However, some influences like governmental policy and phosphate shortages can have an effect on further prices. Due to these developments contract competition in the manure market will focus on duration and risk avoidance. Due to the fact there are no relationship-specific investments in the market and the transaction costs are low, theory advices to use short-term contracts in this market. The market, although, demands long-term contracts. When closing longer-term contracts the central goal should be to find a credible supplier, who can fix short-term problems on the longer term. Three contract structures which can be used in this market are:

- Continuous renewal of short-term contracts of 1 year
- A long-term contract for the full length of the SDE subsidy with profit-sharing
- A 3-5 year contract with a fixed price

The co-substrate market is a still developing market with higher value products when compared to the manure market. The market is still growing with more availability and demand in the future. Due to non-transparency, heterogeneous products, and the positive list of the government, the co-substrate market is very price volatile. Due to the fact a lot of co-substrates are not available structurally, the main basis for contract competition in this market are prices. From theory there are both signs for using short-term and long-term contracts in this market. Long-term contracts can be used best because of recurrent transactions, high transaction costs and high price volatility. Short-term contracts, on the other hand, can be used best because there are no relationship-specific investments and products can be codified. In general, a digestion installation operator should not get locked into one supplier and should include the option of renegotiation in contracts. Two contract structures can be used in this market:

- A combination of a long-term volume contract and a short-term price contract
- A basket contract for an energy-mix of co-substrates

One of the contract structures, the basket contract, was tested empirically using data gathered from the animal feed industry. In this contract structure a fixed price is paid for a basket of co-substrates and the supplier is given the option to vary with the co-substrates in this basket. The structure works in theory, but practice shows some drawbacks. Two examples of these drawbacks are determining the fixed price using normal distributions and the reliability of computations. Therefore, it can be concluded a contract structure like the basket contract is too early for this market and should be reconsidered in the future again. The idea can, however, be used as internal system already, by introducing the profit/risk question into menu calculations.

In the end, it can be stated that some investment security can be obtained on the purchase of biomass. Especially, in the efficient functioning manure market, biomass can be obtained with some certainty. The co-substrate market, on the other hand, can provide less investment security. In this market not structurally available co-substrates can only be purchased on a spot market. On the more structurally available co-substrates, only longer term volume security can be obtained nowadays and the actual co-substrates delivered with their price should be determined on the shorter term. For Raedthuys, who is a newcomer on the market, a manure contract for a period of 3 years with profit sharing is advised at first. The company is then not locked-in to a contract and has the possibility to close better contracts when market changes occur due to regulation changes or new techniques in the future. With such a contract investment security can be gained, market movements are followed, risk is reduced and incentives are in place to remain the contract till the end. In the co-substrate market, on the other hand, a supplier has more private information on the market, which can be used by the supplier to close better contracts. Besides, when closing contracts where the co-substrates are not specified in front, Raedthuys cannot control the search process of the supplier. Therefore, it is advised to search for one supplier, who gathers all sorts of biomass, and to build a trust relationship with this partner for the first three years. This partner can be used to get to know the co-substrate market better, and with the feedback from Raedthuys' digestion installation, standardized rules can be developed for contracts as well as innovative co-substrate mixes. Raedthuys should, however, be aware not to get locked-in to this supplier for the whole subsidy period. Therefore, after three years, Raedthuys should assess the market again, and use the knowledge gained, to close more profitable contracts.

Managementsamenvatting

In de biomassamarkt worden allerlei verschillende biomassaproducten - producten van biologische herkomst (plantaardig of dierlijk) - verhandeld. Het huidige probleem in deze niet transparante markt is dat organisaties die biomassa willen kopen langere termijncontract willen sluiten met betrekking tot de levering van deze biomassa. Dit is noodzakelijk om investeringszekerheid te verkrijgen en te voldoen aan de eisen die investeerders en banken stellen voordat financiering wordt toegezegd. Een van de organisaties die met dit probleem te maken heeft, is de duurzame energieontwikkelaar Raedthuys - de voornaamste actor in dit onderzoek. De biomassamarkt ontwikkelde gedurende de jaren alleen de institutionele omgeving (wetten, regels etc.) en het niveau van aanwenden van middelen, waarbij private contracten niet tot nauwelijks ontwikkeld werden. Het doel van dit onderzoek is daarom een advies te geven over welke contractstructuren er in de niet-transparante biomassamarkt gebruikt kunnen worden. De probleemdefinitie van dit onderzoek is:

> *Hoe kan Raedthuys contractstructuren gebruiken in de biomassasector om investeringszekerheid te verkrijgen aangaande de aankoop van biomassa?*

Het onderzoek is voornamelijk gericht op het exploreren van het probleem en mogelijke biomassa contractstructuren in het biomassaveld. De onderzoeksmethode die gebruikt wordt is de analyse van bestaande databronnen. Daarnaast is gebruik gemaakt van interviews en/of vragenlijsten om informatie te verkrijgen. De focus van dit onderzoek ligt op actoren uit de markt voor vergistinginstallaties die alleen biomassa van de positieve lijst gebruiken. Deze installaties produceren biogas uit (vloeibare) biomassa in een verwarmde, geroerde, gasdichte silo, waarbij bacteriën en enzymen gebruikt worden om biogas op te wekken dat kan worden omgezet in elektriciteit en warmte. Deze installaties gebruiken alleen biomassa van de positieve lijst die is opgesteld door de overheid, en gebruiken tenminste 50 procent mest. Naast mest gebruikt de installatie cosubstraten om de gasproductie te verhogen. De mest- en cosubstraat submarkten worden geanalyseerd, waarbij agrarische ondernemingen, de diervoederindustrie en de voedings- en genotsmiddelenindustrie fungeren als belangrijkste analyse-eenheden.

Theorie is gebruikt om marktstructuren en contracten te analyseren. Theorie met betrekking tot marktstructuren laat zien dat handel ontstaat in markten waar voordelen (private of publieke) voor actoren bereikt kunnen worden. Deze voordelen ontmoeten elkaar op een markt met specifieke handelssystemen en regels, waarop een evenwichtsprijs en -hoeveelheid wordt geproduceerd. Niet alle markten opereren echter efficiënt. In de biomassamarkt komt dit doordat de markt niet transparant en liquide is, en doordat de prijzen erg volatiel zijn. De markt is niet liquide, doordat het voor vergistinginstallaties moeilijk is om de kosten te bepalen voor een transactie met een vooraf bepaalde hoeveelheid. Theorie met betrekking tot contracten analyseert, aan de andere kant, het afstemmen van transacties met 'governance' structuren. Dit onderzoek gebruikt twee theorieën vanuit dit onderzoeksveld. Ten eerste de 'agency' theorie, die wordt gebruikt om de conflicterende doelen tussen contractpartijen, risicodeling en informatieasymmetrie te analyseren. Ten tweede de transactiekosteneconomie, voor de analyse van 'governance' structuren met risiconeutrale actoren. Vier verbintenislengtes kunnen vervolgens worden onderscheiden, namelijk: spot-, volledige, lange termijn en korte termijn verbintenissen. Daarnaast wordt de waarde van heronderhandeling aangegeven, omdat lange termijncontracten van nature incompleet zijn.

De mestmarkt is een vrij stabiele markt waarop het mestoverschot in Nederland in de toekomst licht zal groeien, wat een stijgende mestprijs zal betekenen. Het beleid rondom mest en mogelijke fosfaattekorten zullen echter invloed uitoefenen op toekomstige prijzen. Door dit soort ontwikkelingen zal de competitie om contracten zich in de mestmarkt focussen op de lengte van het contract en het vermijden van risico's. Doordat de markt geen relatiespecifieke investeringen kent en de transactiekosten laag zijn, adviseert de theorie om korte termijncontracten te gebruiken. De

markt vraagt echter lange termijncontracten. Wanneer toch lange termijncontracten worden gesloten is het zaak om een betrouwbare leverancier te vinden, die korte termijnproblemen op de langere termijn oplost. Drie contractstructuren kunnen in deze markt gebruikt worden:

- Continue heronderhandelen van korte contracten van 1 jaar
- Lange termijncontracten voor de volledige lengte van de SDE subsidie met winstdeling
- Een contract voor een periode van 3 tot 5 jaar met een vaste prijs

De markt voor cosubstraten is een zich nog steeds ontwikkelende markt met producten die een hogere waarde vertegenwoordigen (hogere gasopbrengst per ton) dan in de mestmarkt. In de toekomst zal het aanbod van cosubstraten alsmede de vraag toenemen. Doordat de markt niet transparant is, de producten heterogeen zijn en de overheid werkt met een positieve lijst is de cosubstraten markt erg prijsvolatiel. Daarnaast zijn de meeste cosubstraten niet structureel beschikbaar zijn, waardoor contractcompetitie zich zal focussen op prijzen. De theorie geeft zowel signalen voor het gebruik van lange als korte termijncontracten. Lange termijncontracten kunnen het beste worden gebruikt door de aanwezigheid van terugkerende transacties, hoge transactiekosten en een prijsvolatiele markt. Korte termijncontracten, aan de andere kant, kunnen het beste gebruikt worden door de afwezigheid van relatiespecifieke investeringen en een hoge mate van codificeerbaarheid. In het algemeen dient een vergistinginstallatie eigenaar ervoor te zorgen dat deze zich niet committeert aan één contractpartij en de optie tot heronderhandeling open houdt. Twee contractstructuren kunnen worden gebruikt in deze markt:

- Een combinatie van een lange termijn volumecontract met een korte termijn prijscontract
- Een mandjescontract voor een energiemix aan cosubstraten

Een van de contractstructuren, het mandjescontract, is empirisch getest met gebruik van data uit de diervoederindustrie. In deze contractstructuur wordt een vaste prijs betaald voor een mandje van cosubstraten en de leverancier wordt de mogelijkheid geboden om te variëren met de cosubstraten in het mandje. De structuur werkt in theorie, maar de praktijk brengt echter enkele problemen aan het licht. Twee voorbeelden van deze problemen zijn het bepalen van de vaste prijs door middel van normaalverdelingen en de betrouwbaarheid van de berekeningen. Daarom kan er geconcludeerd worden dat deze contractstructuur te vroeg komt voor deze markt en misschien in de toekomst heroverwogen dient te worden. Het idee kan echter al wel gebruikt worden als intern systeem, waarbij het winst/risico denken wordt geïntroduceerd in menuberekeningen.

Uiteindelijk kan er gesteld worden dat er enige mate van investeringszekerheid kan worden verkregen op de aankoop van biomassa. Dit kan voornamelijk door de efficiënt functionerende mestmarkt. De cosubstraten markt, aan de andere kant, kan minder investeringszekerheid bieden. In deze markt kunnen de niet structureel beschikbare cosubstraten alleen gekocht worden op een spot markt. Voor cosubstraten die wel structureel beschikbaar zijn kunnen alleen lange termijn volumecontracten worden gesloten en dienen de uiteindelijk geleverde cosubstraten met hun prijzen op een kortere termijn bepaald te worden. Voor Raedthuys, die een nieuwkomer is in deze markt, wordt een contract voor een periode van 3 jaar met winstdeling in eerste instantie geadviseerd. Het bedrijf heeft dan geen lock-in op de markt en kan betere contracten sluiten wanneer beleidsveranderingen of technieken zich aandienen. Met dit soort contracten kan investeringszekerheid worden verkregen, worden marktontwikkelingen gevolgd, wordt risico gereduceerd en zijn er beloningen om het contract tot het eind te behouden. In de cosubstraten markt heeft een leverancier meer (private) informatie over de markt, die door deze leverancier gebruikt kan worden om betere contracten te bedingen. Daarnaast is het voor Raedthuys moeilijk om het zoekproces te controleren indien er een contract wordt gesloten waarin de cosubstraten niet van te voren worden gespecificeerd. Er wordt daarom geadviseerd om te zoeken naar één leverancier die verschillende soorten biomassa verzameld, en om met deze leverancier een vertrouwensrelatie op te bouwen voor de eerste 3 jaar. Door middel van deze partner kan dan de markt beter doorgrond worden, en met de feedback vanuit de vergistinginstallaties van Raedthuys kunnen gestandaardiseerde regels voor contracten alsmede voor innovatieve cosubstraat mixen worden opgesteld. Raedthuys moet echter alert zijn om niet gecommitteerd (locked-in) te raken aan deze leverancier voor de gehele SDE subsidieperiode. Daarom zal na drie jaar de markt opnieuw bekeken moeten worden, en zal de kennis die verkregen is, gebruikt moeten worden om meer winstgevende contracten te sluiten.

Table of Contents

List of figures and tables

Figures

Tables

Foreword

This master thesis is written to graduate from the master Business Administration at the faculty of Management and Governance of the University of Twente. After writing my bachelor thesis in the renewable energy sector, the enormous amount of possibilities in this field gained my attention. During my master the renewable energy sector always kept my attention, by following its developments in several media. It was therefore not odd I wrote Raedthuys - a renewable energy organization - with the question if I could perform my master thesis within this organization. After some meetings a research topic was found in the bio-energy field - biomass contracting. A field still in development with large potentials, but without a lot of scientific research. I am glad I could be one of the first contributing to this research field. This master thesis could, however, not be written in its present form without the contribution of several persons.

First, I would like to thank my supervisors of the University of Twente; dr. Piet de Vries and dr. Maarten Arentsen. Sir De Vries and sir Arentsen complemented each other perfectly, with sir De Vries taking care of the (financial) theory part and sir Arentsen of the application to the biomass market. Especially thanks for reading and commenting my work and for giving good literature suggestions.

Second, I would like to thank Raedthuys as a company for giving me the opportunity to write my master thesis within the organization. I would especially like to thank Marianne Kok, Marcel Bovenmars and Michel Arninkhof for supervising my work. Marianne always kept our meetings energetic and full of new ideas. Marcel guarded my planning and reminded me when I overtook the time for a certain section. Michel asked the right questions at the right time, which added to the quality of my work. Besides, I also have to thank Robert Meijers for the hours we spent together on developing the basket contract. With its structured way of working and Excel skills he helped a great deal in developing this contract structure. In general, I would like to thank all my fellow co-workers at Raedthuys who made me feel at home from day one. Especially thanks for the fun and energetic moments during lunch breaks playing darts and table soccer.

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It is impossible to thank all people who contributed in person. Therefore I would like to thank all other persons who contributed in one or another way to this master thesis.

Oldenzaal, May 2010

Peter van Sleen

1. Introduction

> *"In order to secure further investments and sustain the growth of bioenergy markets, the supply and demand side of the market need to be balanced and distortions have to be avoided. Bioenergy markets are however poorly mapped and the available analyses, statistics and modelling exercises are limited. Consequently, the knowledge and insights on the relevant market mechanisms and trade flows are relatively poor, making it difficult to manage and organize a stable and sustainable bioenergy market."* (Junginger & Hoefnagels, 2009, p. 9).

In the country report for the Netherlands, part of the European wide research on bio-energy trade (IEA Task 40), the above citation is mentioned. This citation perfectly covers the problems currently going on in the bio-energy market. The supply and demand on the market grew rapidly in the last years; the market mechanisms and instruments, on the other hand, did not. Therefore, the market became unbalanced and distorted with biomass prices fluctuating between extremes. The bio-energy market should have been evolved to a 'mature' market to match supply and demand effectively, but now is immature and not suited to the large quantities traded on the market.

Although every market matches demand and supply, in the bio-energy market just little research has been performed on the mechanisms and trade flows leading to this equilibrium. Therefore, it is currently hard for market actors to intervene in the bio-energy market and make it more stable and mature. This research contributes to this gap in knowledge by mapping the risks involved in the biomass market for positive list digestion installations - using biomass from a list determined by government - and by searching for possible contract structures which can solve these problems.

The introduction will continue with a more in depth problem description. Then the principal company of this research; Raedthuys from Enschede, the Netherlands; is introduced. The next subsection contains the societal and scientific relevance of this research. Last, an outline is provided of the most important sections of this report.

1.1 Problem description

When investing in a bio-energy installation the initial investment costs are high, due to the fact the installation needs to be build. In the following 12 operating years - the exact length of the subsidy period in the Netherlands - most of the costs incurred are from biomass purchase. It could be stated the success or failure of the installation depends highly on the profitable sourcing of biomass. To gain finance from potential investors/banks - who demand contracts before finance - and to have a solid investment plan, some certainty is needed on the long-term pricing of this biomass. An example of how certainty can be gained is by negotiating longer-term contracts. However, the problem is, long-term biomass contracting is not the standard in the biomass market. Instead, biomass is currently often sourced from bilateral trade on a spot market.

Market actors - bio-energy companies - indicate a few reasons why there are currently no longer-term contracts in the market. The first reason indicated is that buyers can often not find the right biomass products in the market. In other words, the market is quite opaque or non-transparent. A buyer has difficulties in finding the right quantity and quality products, because it has little information on which supplier can deliver the demanded biomass. There is no one location or index where all biomass is traded and information about prices and quantities is brought together. Instead, the market is widely dispersed and a lot of actors are offering biomass on the market. Main reason for this is because the market is supply-driven by companies offering their waste products. So, it is difficult for companies to gather information on the availability and price of biomass.

Another problem often indicated are the large price fluctuations (volatility) on the market. This volatility is due to the fact waste streams are only available when there is a certain amount of production in the supply chain. Suppliers of biomass are therefore not willing to close contracts, because they do not know what the price will be in the future. On the other hand, the current trend is biomass prices are increasing. One of the factors causing this trend are subsidy regulations. Suppliers are therefore a bit anxious to negotiate contracts, because by waiting they could close even better contracts with a higher price. In addition, this volatility is one of the main reasons for investors in being anxious to supply finance. The volatility makes future biomass purchase and profit figures uncertain when buying on a spot market and therefore long-term contracts with a fixed price are demanded.

Due to the inefficient operation of this biomass market, it is difficult for bio-energy organizations to source biomass for their installations in advance and to negotiate longer-term contracts with fixed prices on the delivery of biomass. To make it easier to source biomass, the organizations have two options. The first option is to find instruments which make the biomass market more transparent and stable, so it is easier to determine what quantity and quality is available against what price. The second option is to find instruments which make it easier for organizations to negotiate contracts in a non-transparent and volatile market. In this research, the second option is chosen. Firstly, because it is difficult for a single organization to change macro influences and secondly because contract instruments in a non-transparent market are valuable in the current competition for biomass.

To conclude, the problem is that demand-side organizations want to sign longer-term contracts in a non-transparent market on the delivery of biomass to achieve investment security. However, organizations do not know what contracts to sign, because contracts are a quite new phenomenon in the biomass market. In addition, all risk-averse organizations strive to close long-term contracts, with risk premiums paid becoming more important. The goal of this research is therefore to analyze contracting in the biomass market and ultimately give an advice on what contract structures to use in the non-transparent biomass market.

1.2 Raedthuys

Every organization which wants to realize anaerobic digestion installations is conflicted with the problem outlined in the previous subsection. Raedthuys, the principal of this research, is one of them. Raedthuys is a sustainable energy organization which delivers 100% renewable energy. The organization was founded in 1995 and during the years it developed several activities. These activities are: the development, financing, insurance, construction, operation and management of renewable energy projects and the sale of renewable ‘green’ energy. The energy is sold on the APX/ENDEX electricity market and to large companies directly. In 2010 Raedthuys started selling energy to individual households from its wind turbines in Waddinxveen (Raedthuys, n.d.).

Raedthuys has outlined its activities in a vision and mission for the organization, which are:

> *“Renewable energy is the energy of the future. Raedthuys’ opinion is that global warming, the finite amount of fossil fuels available and the reliance on less stable regions for the delivery of those fuels, makes it necessary to invest in renewable energy projects."*
>
> *“Delivering a leading contribution on the development of a stable renewable energy supply in the future."*

In 1995 Raedthuys started with the realization of wind-energy projects and in 2009 has already installed 63 turbines with a capacity of 78 megawatts (MW) (Windenergie, n.d.). Until 2006 these projects were investment opportunities for private investors. After 2006 the projects were realized for own risk. Besides the realization of wind turbine projects, Raedthuys is also one of the largest wind turbine insurers with the company Paulowski, Müller & Partners. This company is the market leader in the Benelux and insures around 35% of installed capacity. In 2006, Raedthuys started with the development of bio-energy projects. These bio-energy projects, in the form of positive list digestion installations, are the main focus of this research (Raedthuys, n.d.).

1.3 Relevance

Renewable energy and sustainable development are topics discussed a lot worldwide. Take, for example, one of the largest polluters in the world: the United States of America. President Obama announced a plan which should reduce vehicle fuel use by 30 percent and increase recycling by 50 percent in 2015. In addition, high-efficiency building codes should be introduced, so that houses become more energy efficient (Tankersley, 2009). The independent states are following this example and California announced a plan to draw 33 percent of energy from renewable sources in 2020. However, setting targets does not mean they are achieved. California's plan to produce 20 percent renewable energy in 2010 will most likely not be achieved. The current prognoses indicate this will, on average, be 10 percent in 2010 (Galbraith, 2009).

In the Netherlands, the same development as in the United States of America can be identified. The Dutch government presented its goals in the working program clean and economical (free translation from: Schoon en Zuinig), and states that in 2020, 20 percent of the energy supply should come from renewable sources. The policy instruments developed aim at maximizing the CO_2 reduction per euro invested (VROM, 2007). The goals and instruments are currently used in combination with the 'Stimuleringsregeling Duurzame Energieproductie' (SDE) subsidy regulation, which is the successor of the former subsidy regulation 'Milieukwaliteit ElektriciteitsProductie' (MEP). Due to the fact the MEP subsidy projects end before 2020, these will not contribute to the 2020 goal. Therefore, new projects should be developed with the SDE subsidy now, because renewable energy project development takes 3 to 5 years (VROM, 2007). However, as identified by an article in the Twentsche Courant Tubantia from September 26, 2009, the investment climate is not optimal. This is due to the fact the allotment of the SDE subsidy regulation is an unqualified lottery - there are more investment projects than available subsidy (Roesink & Hellegers, 2009).

An important renewable energy option the government is aiming for is biomass. The government aims to install 50 PJ of combined electricity/heat biomass installations and wants to transfer the agricultural sector to a bio-based economy, where the whole sector delivers sustainable raw materials for non-food usage (VROM, 2007). An example of a current project on micro-level is an initiative by the Dutch dairy producer FrieslandCampina. This company launched a project where cattle breeders - who deliver to FrieslandCampina - can undertake biogas projects with support from FrieslandCampina. The company will take care of a connection to the natural gas grid, the direct use of biogas in its factories and the appeal of guarantees of origin (Boerderij, 2009).

However, realizing biogas projects is difficult, as is outlined by AgriHolland and the magazine 'Nieuwe Oogst'. A research performed by the Rabobank turned out that two third of the digestion installations is losing money with an average of 2.1 eurocents per kilowatt-hour. According to Hans van den Boom - sector manager renewable energy Rabobank Nederland - 75 percent of the digestion installations run break-even or make a loss. First reason of this problem is most digestion installations are not running at full capacity used in calculations. A second reason is that most installations cannot use the generated heat as was projected and therefore miss the financial heat bonus (AgriHolland, 2009). Often there are no industries or residential neighbourhoods in the area to sell the heat to (Koerts, 2009). In addition, as identified by

> De inkomstenkant is met de subsidie en de stroomprijs vrij goed ingedekt. Of je verdient aan biovergisting hangt vooral af van de kostenkant. Vorig jaar waren de grondstoffen duur en moest er geld bij. Nu zijn de prijzen lager en kunnen we ermee verdienen (Hylkema, 2009).
>
> *Citation 2.1. Nieuwe Oogst*

Nieuwe Oogst, it is hard for a digestion installation's operator to determine the rate of return. The income of the installation is quite sure, due to subsidies and a stable electricity price. The input costs (biomass), on the other hand, are quite unsure and these costs influence the installation's rate of return most. It is also difficult to determine what co-substrates (e.g. grain, maize or glycerine) to use to foster optimum biogas production (Hylkema, 2009).

These articles are just a small selection of the many developments in the renewable energy sector. As can be noted, a lot of work still needs to be done to achieve the goals, but with the renewed trust from investors and biomass as a vanguard in the Netherlands, biomass projects are likely to be developed in the following years. However, the current problems with the subsidy regulation and uncertainty on the cost side of biomass make investors anxious in developing new projects. This research contributes to the uncertainty discussion by mapping the risks from biomass procurement and the search for solutions in the form of contract structures. The solutions can help in achieving more investment security for biomass installations and in the end can help in achieving goals set by government. On the other hand, this research also contributes to scientific theory, by applying theories to a new market. The theories are tested against the distinct market characteristics of the biomass market. The outcome of this research can, in the future, say something about the predictable value of these theories.

1.4 Outline

The report is divided in 11 sections, of which the first section is this introduction. In the second section a research strategy is outlined, containing the problem definition, research questions and research methodology. Section 3 outlines an introduction to the (renewable) energy and biomass market. Next, two sections are presented containing scientific literature. The fourth section contains literature on markets and the fifth section theory on contracts. These two sections are applied to the biomass market in sections 6 and 7. The former contains information on the manure and co-substrate market now and in the future. The latter applies the theory on contracts to the biomass market and identifies conditions under which contracts are developed. Next, section 8 outlines contract structures which can be used in the biomass market. One of these contract structures - the basket contract - is elaborated on, in more detail, in section 9. The report ends with a conclusion, recommendations and a discussion in sections 10 and 11.

2. Research strategy

As was already stated in subsection 1.1 the central topic of this research is biomass contracting. The goal is to analyze contracting in the biomass market and to give an advice on what contract instruments to use in the market. In this second section the research strategy is outlined starting with the problem definition and research questions and ending with the research methodology.

2.1 Problem definition and research questions

Using the problem and goal of this research the following problem definition can be formulated:

- How can Raedthuys use contract structures in the biomass sector to obtain more investment security on the purchase of biomass?

Besides this problem definition, research questions are formulated. The goal of these research questions are to gather all necessary information to, in the end, answer the problem definition. The research questions for this research are:

- How are positive list digestion installations linked to the bio-energy and renewable energy market at large?
- When does trade emerge in markets and how are efficient markets organized according to theory?
- What does contract theory tell about contract structures and duration?
- What risks emerge from the current organization of the biomass market?
- What are the conditions under which contract structures should be developed in the biomass market?
- What contract structures can be used in the biomass market taking the current organization and conditions of the biomass market in mind?

2.2 Research methodology

As was stated in the introduction of this report, little research has been performed in the bio-energy market on biomass contracting. Therefore, this research mainly focuses on exploring this field. First and foremost, this research aims at exploring what biomass contracts are possible now and in the future. Is it even feasible to close contracts in the specific biomass market? However, before these contracts can be explored, the real problem drivers in the market have to be identified. With this exploration new insights are gained on the problem and contracts. Besides, fields for further research can be identified.

The research method used during the research on the biomass market is existing data research. This means the research mainly uses data gathered by others. This research method is used, because the biomass market is non-transparent and it is hard to gather information about the market in a short timeframe. However, this information should be handled with care, because the validity and reliability of the information cannot be guaranteed (Babbie, 2004, p108). When data are not available, survey research is used. Surveys or interviews were presented to employees of Raedthuys with knowledge of the information necessary. If these employees do not have knowledge about the information needed, experts outside Raedthuys were contacted. These are for example animal feed organizations on what biomass streams they actually deliver.

This research focuses on all actors taking part in the biomass market. However, because this research is conducted for the Raedthuys company, not all actors participating in the biomass market are important. Therefore, a sample of this market is taken, and only those actors relevant for projects at Raedthuys are included. This means only the actors able to deliver positive list biomass to Raedthuys are part of the sample. Besides the observation of individual actors in the market, also the relations between actors are important. It is during the communication between two or more actors where relations and therefore contracts evolve (Babbie, 2004, p108). Although this research can be marked as a case study of the Raedthuys situation, the research opts to make clear conclusions which can be generalized to other positive list digestion installation operators.

The research is divided in four research activities each containing one or more sections. The first research activity gives an introduction to the electricity market, biomass market and biomass techniques. This is done, because the biomass market is quite new and some knowledge of the basics is required to understand the remainder of this research.

The second research activity contains a literature review of two sections. The first section identifies how trade emerges in markets, what market structures can be identified and when a market can be marked as efficient. This section is mainly based on research by Mankiw (2004) and Harris (2003). The second section of this activity contains literature on contract theory and is mainly based on the agency theory by Eisenhardt (1989) and Rees (1985); and on the transaction cost economics by Williamson (1979). It also contains literature from several authors on contract duration and renegotiation.

The third activity can be marked as the application of the theory outlined in the second part. The first section of this activity contains a description of the biomass market by identifying the biomass streams offered on the market. This is done, instead of identifying individual actors, because the biomass market is widespread and non-transparent. From this description the positive list biomass streams are selected for the remainder of the research. This is done to give more focus to the research and suit the biomass to the projects Raedthuys is developing. The second section of this activity applies the contract theory to the biomass market and the projects of Raedthuys. For this activity, market reports are used which are published by research agencies such as the Copernicus Institute and ECN.

The fourth and last section concludes on the previous parts and identifies which kind of contract structures can be used in the biomass market and for the Raedthuys projects. When possible, the contract structures are empirically tested using market data. An example is the development of the basket contract using price and quality data from the animal feed industry. Main bases of this contract is the portfolio theory of Markowitz (1952). When empirically testing, the time dimension is of importance. Data can be taken from one point in time (cross section study) or from multiple periods (longitudinal study). For this research a longitudinal study is taken to control for exogenous price effects - effects determined by developments outside the biomass market. An example for the biomass market is the credit crunch which can effect raw material pricing. A summary of the research steps is provided in appendix 1.

3. An introduction to the biomass market

Biomass is a quite new phenomenon in the energy market and is therefore not widely known by the public yet. Therefore, in this chapter, a general introduction will be provided on biomass and the energy market. If you have knowledge of biomass and the energy market this section can be skipped and you can continue reading with section 4. First, this section outlines how the (renewable) energy market works. Second, a definition and general introduction is provided on biomass. Third, the biomass techniques will be outlined. Fourth and last, in a conclusion the following research question will be answered:

> *How are positive list digestion installations linked to the bio-energy and renewable energy market at large?*

3.1 The renewable energy market

In the last ten to fifteen years the Dutch energy market has changed significantly – where it first was a very vague and non-transparent market, nowadays the market is more developed and professionalized. This development was due to the introduction of the 1998 electricity act - mainly based on the first electricity directive issued by the European Union. The goal of this electricity act was to reform the market, so that more competition and customer choice was introduced. In the mean while also the generation efficiency, security of supply and affordability of energy should be maintained. Main instruments in achieving these goals were liberalization, privatization and the unbundling of vertical integrated energy companies in production and supply companies. Together with other regulations the energy act changed the market to what it is nowadays (Van Damme, 2005).

The energy market in the Netherlands consists of two submarkets, namely the electricity market and the gas market. The gas market in the Netherlands is quite simple and is heavily influenced by one actor, namely Gasterra. The electricity market is more complex – different actors are necessary before the electricity and heat is delivered to the final customer. A graphic overview of the electricity market is provided in appendix 2.

In this second appendix three different flows are presented, namely the electricity, contract and green energy flow. In the electricity flow the path is presented from initial production to final delivery. The whole process starts with the production companies. These companies can use a lot of different techniques, that can range from nuclear energy to energy from renewable sources. Raedthuys is besides producer of wind-energy also a producer of bio-energy when it realizes its digestion installations. After the production, the electricity is transferred to the high tension power grid managed by the state owned transmission system operator TenneT. Thereafter, the electricity is transferred to a regional supply company - with its low tension power grid - delivers the electricity to the final customer. It has to be noted the supply companies, since the introduction of the energy act, need to be independent from the vertically integrated production companies. This is also called 'unbundling' (Brunekreeft & Van Damme, 2005; Van Damme, 2005).

The second flow is the contract flow where the suppliers are the most important actors. This flow is a separate flow, because suppliers are not directly involved in the delivery process. This is due to the fact electricity is added to the network and is delivered to customers demanding electricity at that moment. The supply companies can be seen as 'virtual' actors in the electricity flow. Within this contract flow most of the electricity is traded in an informal, bilateral market for non-standardized contracts. This can be typified as an Over The Counter (OTC) market. However, there are two institutions which trade in more standardized contracts. First, the APX market is established as a day-ahead spot market, where electricity can be bought which is 'delivered' the next day. On the other hand, the Endex market, were futures are traded. These are contracts with a fixed instalment and are mostly for longer term (Van Damme, 2005).

The third flow is the so called green energy flow where guarantees of origin are issued by CertiQ. A renewable energy producer and delivery company need these guarantees to sell the electricity and heat as ‘renewable’ or ‘green’. The government developed this procedure to make sure renewable energy is only sold to a customer once instead of multiple times. This is necessary, because the consumer cannot see if the energy is really produced green (it just receives the available energy on the power grid) (CertiQ, n.d.).

Besides these actors, an independent market regulator is established, namely DTe. The responsibility of this actor is to guarantee non-discriminatory access to the grid and to regulate prices for the end users (Van Damme, 2005).

In 2008, renewable energy accounted for 3.4% of the total energy supply. As can be noted from appendix 3, of the renewable energy production 62.8% was generated using biomass. Other biogas - where the positive digestion installations are also situated - accounted for 2.3% of biomass energy generation. With this 2.3% 105kton of CO_2 was avoided (Centraal Bureau voor de Statistiek, 2009).

3.2 Biomass

In research, the term biomass is often used. However, most authors do not give a definition of what they actually mean with biomass. This is, although, necessary because biomass is a so-called container definition, it's not one product but a diverse set of products. The European Parliament (2009) gives a widely accepted definition of biomass in their Renewable Energy Directive 2009/28, which states:

> *"Biomass means the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as biodegradable fraction of industrial and municipal waste"* (European Parliament, 2009: p12).

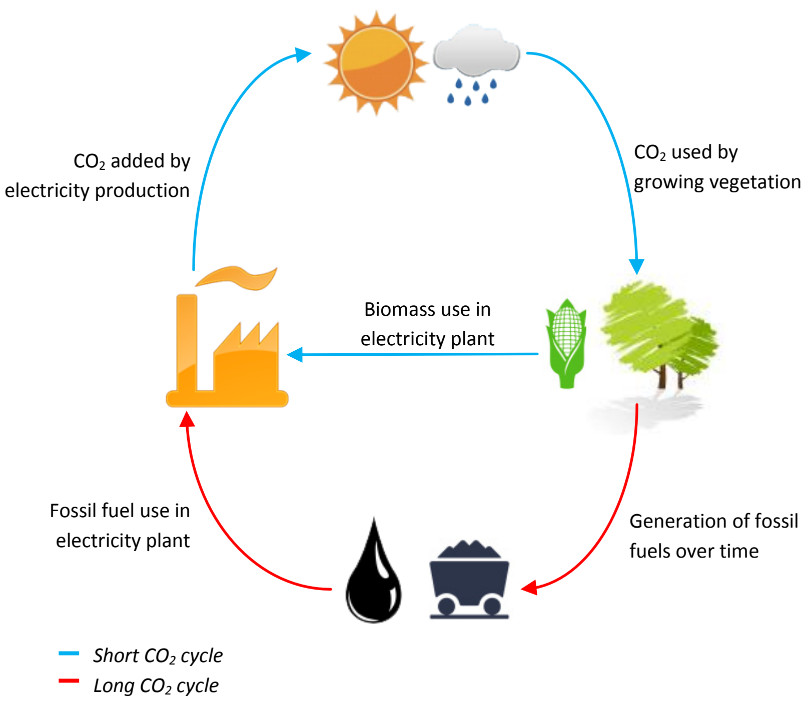

Figure 3.1. CO_2 cycle

Biomass can be used for two purposes, namely the combined electricity/heat production and the production of biofuels (bio ethanol and biodiesel). By using bio energy (with biomass) instead of fossil fuel-based electricity generation the net carbon emission is reduced with a factor 10 to 20 (Sims, Hastings, Schlamadinger, Taylor & Smith, 2006). How this reduction can be so high is explained in the next paragraph.

In figure 3.1 the CO_2 cycle is presented. CO_2 is one of the most important gasses that causes the global warming process. However, what most people do not know is there are two different CO_2 cycles, namely a short and a long cycle. Both cycles start in the middle right of the figure, where vegetation is using CO_2 in its photosynthetic process to grow and to produce oxygen. Thereafter, both cycles continue in a different direction. Within the short cycle, the biomass is directly used into an electricity plant, which is adding the CO_2 from the biomass to the atmosphere again. The long cycle, on the other hand, first needs to undergo another step, namely transforming the biomass (plants and organisms) into fossil fuels like oil, coal and natural gas (indicated by the red arrows in figure 3.1). This transfer process can take ages and depends on the pressure, heat and composition of earth layers. For example, an earth layer, which cannot be penetrated, will collect an amount of natural gas underneath it. These fossil fuels are then extracted and used in electricity plants. This is also were the long cycle intersects again with the short CO_2 cycle. The idea behind these cycles is they are both not adding extra carbon dioxide to the atmosphere, but the short cycle time is a lot shorter than the long cycle. In the short term, the long cycle is adding extra CO_2 to the atmosphere when more fossil fuels are used then are transformed. When using fossil fuels (long cycle) the climate problem is worsening. The short cycle is not worsening the climate problem, because biomass is recycled (and CO_2) again and again. So when only using short CO_2 cycle biomass instead of fossil fuels, the carbon emission is 10 to 20 times lower (Sims et al., 2006).

Biomass is composed of liquid matter and dry matter. To produce a large amount of biogas, and therefore a lot of electricity and heat, biomass with a high percentage of dry matter is needed. However, dry matter only is not enough, the biomass also needs a high percentage of organic matter. On the other hand, ash and heavy metals are not good for the amount of biogas produced. So, biomass with high percentages of dry and organic matter and low percentages of ash and heavy metals are most efficient (Cogen Projects, 2008).

The use of biomass differs widely between countries and is connected with the wealth of a country and the availability of fossil fuels. In western countries - without large amounts of fossil fuels - the biomass use is never higher than 5 percent. In developing countries biomass use approaches 20 percent in most countries. In these countries biomass, mostly in the form of dry manure and wood, is used for heating small homes and to cook on (Senternovem, 2008).

The biomass availability in countries differs depending on the climate in that country. Generally speaking, all biomass can be grouped in a certain way. However, there is still no generally accepted standard for grouping biomass. Two of these standards are indicated in citations 3.1 and 3.2 below.

Liquid biomass: e.g. palm oil, soya oil and fat from food production.
Woody biomass : e.g. wood pellets, wood chips, saw-dust and knotting wood.
Agricultural residues: e.g. olive pulp, palm oil seeds and cacao hulls.
Waste streams: e.g. municipal and industrial waste.

Citation 3.1. Biomass grouped (Sims et al., 2006)

Oil crops: e.g. oilseed rape, linseed, field mustard, hemp, sunflower, safflower, castor oil, olive, palm, coconut and groundnut.
Cereals: e.g. barley, wheat, oats, maize and rye.
Starch and sugar crops: e.g. potato, sugar beet, Jerusalem artichoke and sugarcane.
Fibre crops: e.g. straw, wood, short rotation coppice.
Solid energy crops: e.g. cardoon, sorghum, kenaf, prickly pear, whole crop maize, reed canary grass, miscanthus and SRC willow, poplar and eucalyptus.

Citation 3.2. Biomass grouped (IUCN, 2008)

In the end, it can be stated biomass is all material from biological origin (vegetable or animal). There are a lot of different types of biomass which can be obtained from even more sources. However, the question remains what types and what quantity of biomass is available now and in the future. This problem is addressed in section 6.

3.3 Biomass installations

As stated in subsection 3.2 biomass can be used to produce combined electricity/heat and to produce bio fuels. However, there are several techniques available to produce the same 'product'. According to Faaij (2006) there are roughly two kinds of conversion routes or techniques, namely thermo chemical conversion and biochemical conversion (see figure 3.2). Within thermo chemical conversion heat and/or pressure is used to produce electricity, heat and fuels. On the other hand, within biochemical conversion bacteria and enzymes are used to produce gas or bio fuels. These two main conversion routes house several more distinct techniques summarized below:

1. *Combustion*: Within this process dry biomass is burnt under availability of oxygen. From this burning process steam is collected which can be used in a steam turbine to produce electricity. The excess heat can be used for domestic or district heating. This process is widely applied worldwide in the form of co-combustion of biomass – biomass is burnt together with fossil fuels in a coal-fired power plant.
2. *Gasification*: Within this process biomass is transferred into fumes or fuel gas under the absence of oxygen. These gasses can be further converted and/or cleaned before they are combusted in a gas engine. The advantage of this process, in comparison to combustion, is that no additional solid fuel feeding lines have to be built and less fume gases are produced.
3. *Pyrolysis*: Pyrolysis converts biomass in the absence of oxygen into liquid (bio-oil) gasses and solid fractions. This process takes place at temperatures of around 500 degrees Celsius. The oil created with this process can be burnt and used for heat/electricity, can be used as bio fuels and can also be treated in refineries. This process is in its child shoes but is developing rapidly.
4. *Anaerobic Digestion*: Within this process, biogas is produced from liquid biomass mostly by using bacteria and enzymes. The biogas is then used to produce electricity and heat.
5. *Fermentation*: This process uses fermentation to produce bio fuels. Examples of biomass used are sugar and starch.
6. *Extraction*: This process extracts oil from seeds directly and mixes it with fossil fuels (Faaij, 2006; Cogen Projects, 2008).

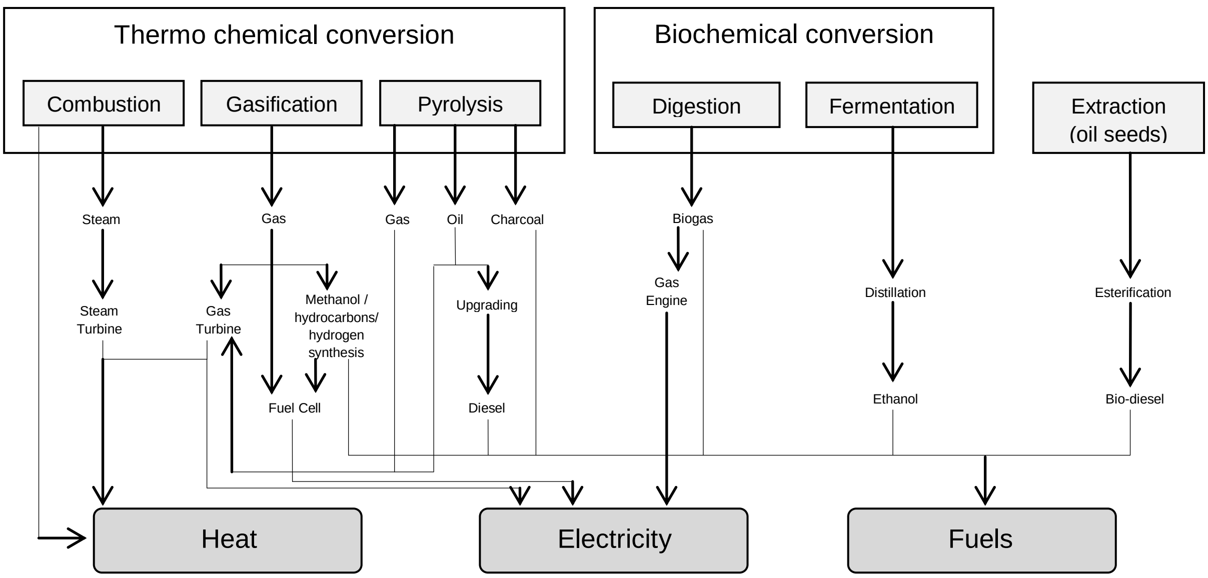

Figure 3.2. Main conversion routes for biomass to secondary energy carriers (Faaij, 2006).

From the above mentioned conversion options Raedthuys, in general, is focusing on the combustion and digestion techniques. However, this research focuses on the digestion technique. This digestion technique can be split up in the co-digestion of manure and co-substrates (farm digestion installation) and an industrial digestion installation. This research is concerned mainly with the farm digestion installation using positive list biomass. Positive list biomass is biomass which is stated on a list developed by government. When solely using biomass on this list, the digestate produced by the installation can be used on farmer's land as fertilizer (more in section 6). A graphical overview of a digestion installation is presented in figure 3.3.

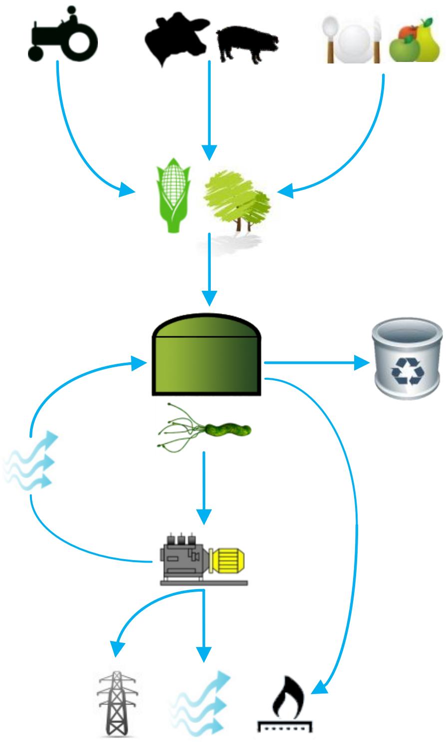

Figure 3.3. The digestion process.

The digestion installation receives its biomass mainly from three sources – the food industry, the animal feed industry and agricultural organizations. Depending on the sort of biomass, the organization can receive (e.g. livestock manure) or has to pay money for the biomass. This biomass can be stored before the digestion process or can be put in the digestion installation directly. When storing biomass, a problem which can arise is that biomass starts digesting on its own. In this case a lot of gas can be lost.
The digestion installation itself is a gas proof, isolated, heated and mixed tank in which bacteria and/or enzymes are breaking down the biomass in methane and other substances. The output from this process is usable gas and some trash in the form of non-usable gasses and digestate (can be used on farmer's land). This digestate can be processed further by separating different kinds of digestate and drying it, so that the value is heightened. In the digestion installation it is of importance to feed the same amount of biomass as the amount of digestate that leaves the installation.
After the combustion process, the company can decide to sell the normal cubic meters (Nm^3) of green gas on the energy market or to burn the gas in the combined electricity/heat facility. After this burning process the kilowatt hours (kWh) of electricity and the heat are sellable on the energy market or can be used internally to, for example, heat the biomass (Ministerie van Volkshuisvesting, Ruimtelijk Ordening en Beheer, n.d.). In the Netherlands 85 of these digestion installations are already installed with a capacity of around 95 MWe. Another 40 projects are still on hold due to problems with granting subsidy or permit procedures (Senternovem, 2009a).

3.4 Conclusion

The positive list digestion installations can be marked as production organizations in the wider renewable energy market. This means the installations are producing electricity/heat and deliver these 'products' to the national and local power grid. Besides, positive list digestion installations are part of the larger bio-energy production. Within the process, biogas is produced from (liquid) biomass in a heated, mixed and gas-proof tank by using bacteria and enzymes. When ultimately burning the biogas, electricity and heat is produced.

The most important input for the digestion installation is biomass, which for this research is defined as all material from biological origin (vegetable or animal). This biomass is mainly sourced from the food industry, the animal feed industry and agricultural organizations. In the end, it can be stated the positive list digestion installation is a production plant part of the short CO_2 cycle.

4. Markets

When analyzing the biomass market it is important to first have knowledge on how markets function. According to Mankiw (2004) a market is a group of buyers and sellers of a particular good or service. Every market is different; there are virtual markets and actual markets, markets with a lot of buyers and sellers or just a few, markets where all the products sold are the same or all different. This list can be extended further, but it is clear that all markets have their own distinct characteristics. Therefore all markets also have their own distinct actors, structures and contracts that work efficiently for that specific market. In this section the theory behind trading, market structures and efficient markets will be outlined. In the end, the following research question is answered:

> *When does trade emerge in markets and how are efficient markets organized according to theory?*

4.1 Trading

Trading takes place in a lot of different forms and markets. However, most trades can be marked as bilateral trades - traders arrange trades among themselves. There are, although, also markets were brokers arrange trades among two customers. Think of for example the stock market. Trading emerges in markets when actors think they are able to gain some benefit from trading. These can be private benefits - which accrue to traders directly when they trade - or public benefits which accrue to everyone no matter if they use the market or not. These public benefits are also referred to as positive externalities - benefits that are not compensated for. The highest benefits occur when an actor can trade effectively and the assets are suited to the particular trade. In the end, trading is a zero-sum game, where one actor makes a profit the other loses the same amount (Harris, 2003).

The trade benefits are, although, different for other types of traders. Harris (2003) identifies three general types of traders and their respective benefits. Although, a trading partner cannot be fitted in one of the categories exclusively, the categories clearly identify reasons why people trade. The three types of traders are:

1. *Profit motivated traders*: these actors trade because they rationally expect to make a profit from their trade. The benefit for these traders is profit only.
2. *Utilitarian traders*: expect to make a benefit other than profit. The benefit is often an externality which is triggered by a small profit loss.
3. *Futile traders*: think they are rational traders, but are in fact not, because their expectations are not rational. The benefit for these traders is profit (Harris, 2003).

To make the benefits of these traders more clear, a few examples are outlined below. First, an example of a profit motivated trader is a speculator. These traders use the market to predict prices or at least they try to. When they think assets are overvalued they will sell the assets and when these are undervalued they are bought. Another example of a profit motivated trader is a dealer, who makes itself available to other traders to match supply and demand. When a deal is found, the benefit, in the form of a commission, is paid. On the other hand, an example of an utilitarian trader is someone who wants to move money in time, also called intertemporal cash flow timing problems. For example, an organization wants to move money from the future to the present to finance the construction of a new plant. Another example of utilitarian traders are hedgers, who use markets to reduce their exposure to financial risks. They often use vertical integration, forward contracts (agreements to trade in the future for a price that is determined now) and futures contracts (standardized forward contracts). A last example of a utilitarian trader is a fledgling, who uses the market to learn if in the future trade can be profitable (Harris, 2003).

4.2 Market structures

A market structure is defined as the trading rules or trading system of a certain market. By using specific rules (e.g. only trade between several hours) and trading system (e.g. how orders are fulfilled) supply and demand can be matched (Harris, 2003). Every market structure has its own problem and therefore also its own solution in the form of a trade structure. However, when transferring these specific market structures to more general ones, four market structures can be identified using three characteristics. These characteristics will be addressed in the following paragraphs.

The first characteristic is the amount of sellers. This is a quite vague characteristic, because it cannot be measured in absolute numbers. However, it is quite clear that the market for consumer electronics has many sellers compared to the market for drinking water (Mankiw, 2004).

A second characteristic is the kind of product, namely a homogenous or heterogeneous product. The difference between the two is that in a homogenous market all the products sold are the same and in a heterogeneous market the products are differentiated (Mankiw, 2004). According to Wohlgenant (1999) two different kinds of heterogeneity can be identified for agricultural products. First there is heterogeneity in the product group (e.g. fruit), because of heterogeneous products of different competitive industries. Second there can arise product heterogeneity due to product differentiation of similar products (different kind of apples) in a monopolistic competition. The research identified price competition in product groups is harder to analyze, due to input substitution and imperfect competition (Wohlgenant, 1999).

The third and last characteristic are the entry and exit barriers. Barriers for entry are, for example, large investments in machines or permits. An example of an exit barrier is the large investment made on the project start, when you exit the market you cannot recover these costs any longer. In the end, four market structures can be identified using these characteristics, namely: full competition, oligopoly, monopolistic competition and monopoly (Mankiw, 2004). These structures are further described below.

Market Structure	Amount of sellers	Kind of product	Entry / exit barriers
Full competition	Many	Homogenous	None
Monopolistic Competition	Many	Heterogeneous	None
Oligopoly	Few	Homogenous / Heterogeneous	Few
Monopoly	One	Homogenous / Heterogeneous	Many

Table 4.1. Market structures and their characteristics (Mankiw, 2004).

Full competition

A full competitive market is characterized by a large amount of sellers, a homogenous product and no entry or exit barriers. Due to the fact there are a lot of buyers and sellers in the market one single seller cannot influence the price of the product sold. Therefore, the suppliers in this market are also called price takers. Besides, due to the absence of entry and exit barriers the market always functions efficient. This means demand - amount of products buyers are willing and able to buy - is always matched (equilibrium) by supply - amount sellers are willing and able to sell. When profits arise in the market, more suppliers will join due to the absence of entry barriers and the price is driven down to marginal cost. The opposite is true when losses are incurred, suppliers will leave the market due to the absence of exit barriers and the price is driven up to marginal cost. In the end, it can be stated a fully competitive market is always functioning efficient and the right price is paid in theory (Mankiw, 2004).

To determine how much the equilibrium in the market moves when changes occur, the theory about demand elasticity is crucial. Elasticity tells something about how demand changes when the market price fluctuates and can be computed by dividing the percentage change in quantity demanded with the percentage change in price. Demand can be elastic - the change in demand is higher than the change in price or inelastic - the change in demand is lower than the change in price. When price changes occur in the market the slope (elasticity) of the demand and supply lines determine the increase or decrease in demand. The change in demand and supply also depends on the type of products. Is the product a substitute or a complement of another product? Substitutes are two products that are used in place of each other, like coffee and tea. When the price of one product increases the demand of the other increases. Complements are two goods which are often used together, such as a computer and a keyboard. When the price of one good increases the demand of the other decreases (Mankiw, 2004).

Monopolistic competition
A market with monopolistic competition differs from a full competitive market on the fact it offers heterogeneous instead of homogeneous products. An example of a market with heterogeneous products is the magazine market. A lot of magazines are offered in store, but each magazine differs just a little from the other magazines offered. In the short run, a supplier can make profit in this market, but on the longer term the costs of entry and exit force prices down to marginal cost (Mankiw, 2004).

Oligopoly
Within an oligopolistic market there are just a few sellers, the products can be homogeneous or heterogeneous and there are just a few entry and exit barriers. The few sellers in these markets do often not compete aggressively and therefore the market does not work efficient. The equilibrium found in this market is also called a Nash equilibrium. The supplier sets its strategy according to the strategies chosen by the other suppliers. Therefore, in these markets, there is always a tension between self-interest and cooperation. When self-interest takes over and the supplier increases its production to make more profit, the other suppliers in the market correspond accordingly and increase their production too. In the end, the supplier is left with less profit than before its action. An oligopoly is not that efficient as a full competitive market but also not that inefficient as a monopoly (Mankiw, 2004).

Monopoly
A monopoly is characterized by just one seller, a homogenous or heterogeneous product and many entry and exit barriers. Because there is only one seller and there are no close substitutes for the product, this seller is also called a price maker. There is no competition in this market because there are barriers of entry. An example is when a seller owns a key resource or the cost of production is lower with only one supplier. A monopoly can be marked as inefficient, because the monopolist demands a higher price than the efficient price. In this case the surplus (profit) of the monopolist is higher than in full competitive markets, but the total surplus (society and supplier) is lower. This loss is called the deadweight loss (Mankiw, 2004).

4.3 Efficient markets
Markets are, however, not always functioning well and therefore the optimum equilibrium price is not achieved. The optimum equilibrium price, and therefore an efficient market, is achieved when the price equals marginal cost/marginal revenue of the supplier, so that optimal wealth for society is achieved. As was noted in subsection 4.2, barriers to exit/entry, the kind of product and transport costs are influencing the efficient functioning of the market. Two other important variables which are

essential in determining if a market is functioning efficient are transparency and liquidity (Harris, 2003).

Transparency tells something about how quickly the market is reporting complete information to the public. The faster full information is reported the more informed the trader is and therefore able to assess the value of a product/service/security. However, in opaque markets without information, the trader cannot assess what is going on in the market and has to put expensive information collection systems in place to get informed. An informative price is necessary to solve production and allocation problems - what products to produce, against what price, with which funds and managers (Harris, 2003).

Liquidity, on the other hand, is the ability to trade when you want to trade, at low cost and in large size quickly. This liquidity needs to be found in the market, by searching for a partner who wants to be, and is, able to trade at mutually acceptable terms. For every trader this search process is different, because they all have their own acceptable trade terms. When a trader has found a trade partner, liquidity has been found in the market. However, who this trade partner will be, is dependent on the amount of time put into the search process and the prices and adequate sizes the trade partner offers. So, the first best alternative is not always found, because a lot of costs are already incurred during the search process. A trader can look for four different types of liquidity:

1. *Immediacy*: how fast trades of a given size at given cost can be arranged.
2. *Width*: refers to the cost of doing a trade of a given size.
3. *Depth*: refers to the size of a trade which can be arranged at a given cost.
4. *Resiliency*: how fast prices revert to efficient values after a flow imbalance by an uninformed trader (Harris, 2003).

When the market is, however, not transparent and liquid, and thus inefficient, the volatility is often high. Volatility is the tendency for prices to change unexpectedly and in large amounts. For example, the prices of stocks are not always the same, but vary with general market movements and the performance of the organization. One type of stocks reacts more on these events and other stocks will react less. In general, the markets for these stocks are therefore more or less volatile. There are two types of volatility:

1. *Fundamental volatility*: the price fluctuates because fundamental factors or fundamental value changes. Examples of events which can trigger this volatility are demand conditions, interest costs and storage costs.
2. *Transitory volatility*: prices diverge from fundamental values, because of demand from uninformed traders. When this volatility is large, the markets are often illiquid (Harris, 2003).

4.4 Conclusion

Trade emerges in markets when actors think they are able to gain some benefit from trading. These can be private benefits which accrue to traders directly when they trade, or public benefits, which accrue to everyone no matter if they use the market or not. However, every trader is looking for a different benefit in the market. In general, three kind of traders can be distinguished: profit motivated traders, utilitarian traders and futile traders.

These trade benefits need to be found in a market structure - the trading rules or trading system of a certain market. There are three characteristics which determine the market structure of a particular market. These are: the amount of sellers, the kind of product (homogenous or heterogeneous) and entry and exit barriers. In the end, four general market structures can be indentified: full competition, monopolistic competition, oligopoly and monopoly.

The trade benefits accrue to traders fully when the market operates efficiently. For the market to operate efficient, the market needs to be transparent - information is reported quickly to the public - and liquid - a trade can be arranged quick and at the desired trade terms. When the market is, on the other hand, inefficient, large price volatility can emerge. These theories are applied to the biomass market in section 6.

5. Contracts

As was outlined in section 4, an efficient price is reached in a market of full competition, because supply and demand are matched at an efficient equilibrium price. In these markets, the price equals the marginal cost/marginal revenue of a supplier and no profit can be obtained on the longer term. The biomass market, however, does not function efficient and the price does not equal marginal cost. First of all, the market is non-transparent, one does not know exactly which biomass is available where and on what moment. This non-transparency means market uncertainty for both the supplier and demander. Second, the market is not liquid for an actor who wants to purchase biomass, because prices for a given trade size are unsure. Third, prices are extremely volatile in the market, with prices for glycerin fluctuating between 80 and 180 Euros. These extreme fluctuations, with its uncertainty, make it extremely complex to establish a futures market. Fourth, the demand on the market is quite stable, due to large investments in digestion installations on the side of the demander, but supply is not. Some biomass products are available structurally throughout the year, but most products are only available when a certain event happens (e.g. production process failures). When basing the investment decision solely on the biomass market, no investment security can be obtained.

A solution can possibly be found in using contracts, which are established in the biomass market using bilateral trade. By closing contracts with a contract partner, agreements can be reached on the delivery of an amount of biomass against a certain price. However, these contracts can, in some cases, not be based on a market on which a price is determined. For some biomass products, markets emerge when a product is available, for other more structurally available products markets are still in development (e.g. grass). Question in these contracts is, however, if a contract can be based on prices which are determined out of the blue and not by supply and demand in a market.

This section outlines theory which can be used to analyze contracting in the biomass market. The application of the theory to the biomass market is performed in section 7. In this section the agency theory is outlined first, with the goal to analyze the amount of information asymmetry between contract partners and their conflicting interests. Second, the transaction cost economics is outlined to analyze if there are transaction-specific investments and to determine which structure is necessary to govern the relationship. Third, several theories are outlined to determine the best duration of the contract and if the possibility of renegotiation should be included in the contract. In the end, the following research question will be answered:

What does contract theory tell about contract structures and duration?

5.1 Background and definitions

The theory, as was outlined in the previous section, took the price mechanism as a coordinating factor of resource allocation. In this case, supply and demand determine the price and resource allocation. However, Coase (1937) introduced another viewpoint by stating that in some industries transactions were taken from the market and were coordinated by another mechanism - the firm. According to Coase (1937), the firm could be typified as: "*A system of relationships which comes into existence when the direction of resources is dependent on an entrepreneur*." A firm emerges in those industries where short-term, spot market transactions are unsatisfactory. This is the case when the costs of determining the 'right' market price and negotiating several contracts with the factors of production, are high. So besides short-term, spot market transactions, Coase (1937) identified the emergence of firms (hierarchy) where transactions were taken from the market and resource allocation is determined by more sophisticated longer-term contracts which avoided the negotiation of small transactions. Nowadays, it can be stated that this article is the starting point of the new institutional economics. One would no longer think in small, short-term driven transactions only, but about reducing (transaction) cost by using other, more sophisticated, contract structures.

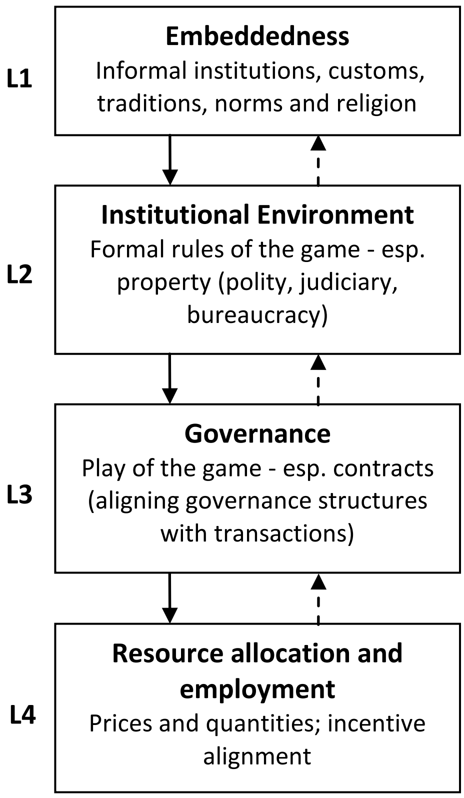

Figure 5.1. Economics of institutions (Williamson, 1998).

The question, however, is where contract structures are situated in the social environment. Williamson (1998) answers this question and states that four social analysis levels can be identified. The levels are a hierarchic system based on how fast the contents of the social level change. All levels influence each other through feedback lines. First, there is the level of embeddedness. This level changes rather slowly (100 to 1000 years) and contains the informal social rules. One can think of for example trade customs - in some cultures bribes are quite normal. The second level is the institutional environment and can be marked as the formal rules (e.g. judiciary, bureaucracy) of the game. In this social level of analysis people believe the legal system perfectly and costly solves all problems. The third level is the governance level and is also called the play of the game. The central question in this level is how to move from a costless legal system to costless private contracting, taking the legal system in mind. This is also the level where contracts emerge. The fourth and last level is resource allocation and employment. These are the continuous day-to-day activities of an organization and contains, for example, price and quantity setting (Williamson, 1998). In section 7 the theory is applied to the biomass market. It states the institutional environment is still in development, but the 'resource allocation and employment level' is already developed. The third level of 'governance', was never developed thoroughly, and should be explored further.

In literature a lot of different definitions of a contract are stated. The problem, however, is that most definitions do not cover the behavioural sides as well as the legal sides of a contract. Therefore, in this research, two definitions of a contract are combined. These are the more behavioural like definition of Krishna, Karlapalem & Dani (2005) and the more legal like definition of Wohlgenant (1999). The definition used in this research states:

> *"A contract is an agreement between two or more parties creating obligations between them. It defines a set of activities, to be performed by different parties, to satisfy a set of terms and conditions (clauses); and provides the allowance to a transactor to go to a third party to sanction an opportunistic trading partner"* (Krishna, Karlapalem & Dani, 2005; Wohlgenant, 1999).

Krishna et al. (2005) define three stages in the development of a contract. The first stage is contract preparation and defines the specifications for the fulfilment of the contract. The second stage is contract negotiation and is concerned with payments, deliverables and milestones. The third and last stage is contract fulfilment and actually executes the contract with the specific tasks of the contract. This fifth section is mainly concerned with the first stage of contract preparation and describes several theories on how to analyze contract partners and contract specifications.

5.2 Agency Theory

The agency theory is used to analyze the interaction of a principal and agent or a small group of actors. Central topic in this research is the information asymmetry between principal and agent, whereby one actor is informed and has more information on the environment in which the contract partners are operating. The actors operate in an environment constrained by the prevailing institutional setting and play a non-cooperative game with asymmetric information (Salanié, 2005). In general, the agency theory can be divided into two influential research fields, namely the principal agent-theory and the positive agent theory. The principal-agent research is broad in nature and has the following research question: *"what is the most efficient contract in a situation?"*. The positivist agent theory focuses more on the conflicting goals of contract parties and on the normative development of contract alternatives (Eisenhardt, 1989). In this research both research fields are used. The principal-agent theory is used to describe the relationship between two contract partners and the positivist agent theory as normative theory on what contract structures to use.

The principal-agent theory is often referred to as one individual who has the responsibility of taking an action in the interest of one or more others and receives some payment for this action. The actions are often performed within a contract signed by both contract partners. Central goal of the principal-agent theory is to identify if there is information asymmetry between the principal or leader (P) and the follower or agent (A). When one of the contract partners has private information on the state of the world (z), which cannot be observed by the other contract partner(s), one can speak of information asymmetry. When there is information asymmetry it is hard for the principal to penalize or reward the agent. Therefore, the contract is not efficient on trading of the benefits of risk sharing with the costs of providing an incentive to the agent. This information asymmetry is also called an incentive constraint, which can emerge in two different ways:

1. *Adverse selection*: In this case the agent withholds information from the principal. The uninformed actor has imperfect information on the actions of the informed party. In this case the uninformed actor moves first. An example is when an agent occurs as having high productivity, but actually has low productivity.
2. *Moral hazard*: The agent takes the wrong actions in the eyes of the principal. For example, if an agent is fully insured against fire damage, there is no incentive to take fire precautions. This can also be stated as when the uninformed actor has imperfect information of the characteristics of the actor which is informed well. In this case the uninformed party takes the first step (Rees, 1985b; Salanié, 2005).

In this theory the agent is contracted/hired/asked to perform a certain task for the principal. This can range from delivering a certain amount of high quality products to house insurance. The agent chooses an action (a) from a given set of actions {a}. The outcome of this action is, however, unsure, because the action is taken before the state of the world is known. The action (a) taken has a utility (x) for the principal and is dependent on the value of the action (influenced by the state of the world) and the payment (y) from the principal to the agent (Rees, 1985a). It is the principal who proposes a contract and the agent who can accept the contract or not. It is also referred to as a take or leave contract (Salanié, 2006). The optimal payment is one which maximizes the principal's utility and minimizes the level of the agent's utility (Rees, 1985a; Salanié, 2005).

For example, take a risk-neutral principal, who wants to buy a product, from a risk-averse agent. What the principal can do is to pay a fixed price (incentive) to the agent, no matter what the future state of the world will be. The problem of the action taken before the future state of the world is known, is also called the incentive problem. The principal just does not know what incentive to offer. Besides, the agent can cheat on the principal, because the agent can have more information to predict the future state of the world and its actions are difficult to observe by the principal. The agent can take an action other than the optimal action (a*), but is supplied the optimal incentive (y*) for this action. To force the agent to take the optimal action, different incentives can be supplied depending on the risk preferences of principal and agent (Rees, 1985a; Rees 1985b).

The border between principal-agent theory and the positivist agent theory becomes rather vague when the clauses of the contract need to be determined at the outset of the contract. Theoretically these activities are part of the contract preparation phase which is part of the more normative positivist agent theory. In this phase, adverse selection can be identified, which is part of the principal-agent theory. The information asymmetry between contract partners can also influence the negotiation of contract clauses. When the agent has more information about the state of the world it also knows what variables are efficient to include in the contract. The agent can, due to its superior knowledge, propose variables which are not efficient for the principal (less informed), but supplies superior profit to the agent. So, information asymmetry also influences contract closure in the more normative positivist agent theory.

In addition, a lot of research has been conducted using the positive agent theory on contract alternatives. The research, which shows actual contracts used in practice, outlines two kinds of contract alternatives, namely behaviour-based contracts and outcome-based contracts. The difference between the two is that agent's behaviour or the outcome of the agent's action is measured. In table 5.1 several variables are outlined, which have an influence on the use of the contract alternatives. For example, when the outcome uncertainty of an action is high, the principal can better use behaviour-based contracts instead of outcome-based contracts (Eisenhardt, 1989).

Variable	Behaviour based contracts	Outcome based contracts
Information systems	Positive	Negative
Outcome uncertainty	Positive	Negative
Programmability	Positive	Negative
Outcome measurability	Negative	Positive
Length of contract	Positive	Negative
Risk averse agent	Positive	Negative

Table 5.1. Influence of different variables on the choice between behaviour-based contracts and outcome-based contracts (Eisenhardt, 1989).

> "The principal-agent model, with risk aversion as main variable, fails to predict contract choice in North American farming. They found evidence risk-neutral actors and other margins influence moral hazard and enforcement costs."
>
> *Citation 5.1. Remark on agency theory (Allen & Lueck, 1995a; 1995b).*

In the end, it can be stated the agency theory can be divided into two research fields, namely the principal-agent theory and the positive agent theory. The former is mainly concerned with information asymmetry, which has an influence on contracts and the willingness to accept risks. The former is more concerned with conflicting goals and is normative in nature (Rees, 1985b; Eisenhardt, 1989). However, the agency theory is questioned by several authors including Allen & Lueck (1995a) who state that other factors influence moral hazard and enforcement costs (citation 5.1). Therefore the risk-neutral model of transaction cost economics is examined in subsection 5.3.

5.3 Transaction Cost Economics

As was already stated in subsection 5.1 transaction cost economics (TCE) is concerned with aligning governance structures with transactions. The goal of this risk-neutral model is the optimization of costs incurred in the private contract. In transactions (the main unit of analysis) two kinds of costs are incurred, namely the production expense and the transaction costs. The production expense can be marked as all those costs involved with the physical product or service. The transaction costs are those costs incurred to close a deal and to monitor it. These are for example the contract preparation costs. However, both costs are negatively correlated, when an organization wants to reduce production expenses the transaction costs rise (Williamson, 1979).

Dyer (1997) specified these transaction costs further in his research of Japanese and American car production plants. According to this research it is important to assess transaction costs over longer periods, because every contract has its own set-up costs and therefore different transaction costs over the contract horizon. For example, the first contract of a series of short-term contracts with the same supplier has high initial transaction costs. Further transactions have lower (incremental) transaction costs, because the right supplier has already been found (Dyer, 1997). The four categories of transaction costs are:

1. *Search costs*: costs incurred due to information gathering necessary to identify and evaluate trading partners.
2. *Contracting costs*: costs incurred with negotiating and actually writing the contract.
3. *Monitoring costs*: costs incurred with monitoring the agreement to determine if each partner is fulfilling its part of the agreement.
4. *Enforcement costs*: costs incurred in enforcing a trading partner to perform its part of the deal or punishing the partner when it did not (Dyer, 1997).

To optimize these costs, the transaction cost economics states the right governance structure should be chosen for a particular transaction. A governance structure can be described as: *"The means by which order is accomplished in a relation in which potential conflict threatens to undo or upset opportunities to reduce mutual gains"* (Williamson, 1998). A governance structure can also be defined as: *"The institutional framework within which the integrity of a transaction is described"* (Williamson, 1979). However, the governance structure in itself is unavoidably incomplete, because the rationality of a human is bounded as was formulated by Herbert Simon. In the end, there are three important variables which determine the right governance structure for a transaction, namely: frequency of transactions, uncertainty (disturbances) and investment characteristics (Williamson, 1979; Williamson, 1998).

		Investment Characteristics		
		Nonspecific	*Mixed*	*Idiosyncratic*
Frequency	*Occasional*	Market Governance *Purchasing standard equipment*	Trilateral Governance *Purchasing customized equipment*	Trilateral Governance *Constructing a plant*
	Recurrent	Market Governance *Purchasing standard material*	Transaction-Specific Governance *Purchasing customized material*	Transaction-Specific Governance *Site-specific transfer of intermediate product across successive stages*

Figure 5.2. Governance structures according to frequency and investment characteristics (Williamson, 1979).

The two most important variables are frequency (buyer activity) and investment characteristics. Williamson (1979) defined two frequency subcategories, namely occasional and recurrent transactions. However, no absolute amount of transactions is mentioned. The variable investment characteristics can also be defined as the degree to which durable transaction-specific investments are incurred. In this case transaction-specific investments are those investments which cannot be used for another transaction. Williamson (1979) defines two categories of transaction-specific investments:

1. *Physical Capital*: investments in certain capital, for example a gas-pipe-line. Without the transaction of natural gas, the pipeline is worthless.
2. *Human Capital*: for example personal trust which makes the renegotiation of transactions possible.

In the end, there are three kinds of transactions, namely nonspecific-, mixed- and idiosyncratic transactions. An idiosyncratic transaction is a transaction which contains costs due to the specific identity of the partners involved. However, these investments pose mutual gains after the transaction is realized (Williamson, 1979).

When combining these two most important variables, figure 5.2 can be formed, where the market transaction meets the contract structures (governance). As can be noted there are three governance structures for different types of transactions. These three governance structures are:

1. *Market governance (classical contracting)*: This governance system can be best used for nonspecific occasional and recurrent contracting. Within this governance system the market, with its rules and norms, is used as the main regulator. There is no direct experience with the product, but the market (other buyers and sellers) are trusted. The contract closed in this governance structure is simple and the contract does not change during the contract length.
2. *Trilateral governance (neoclassical contracting)*: This governance system can be best used for occasional transactions of the mixed and highly idiosyncratic type. The costs made during the occasional transactions cannot be recovered. Therefore there are large incentives to remain the contract until the end of the period. This is also the governance system were long-term contracts are situated. Contracts in this governance structure often contain clauses which adjust the contract to market conditions. To enforce these kind of contracts, arbitration (third party assistance) can be used.
3. *Transaction-specific governance (relational contracting)*: This governance system can be best used for transactions of the mixed and highly idiosyncratic kind. In these contracts the relation between the two actors is of utter importance and decisions are taken in mutual agreement. An organization can first choose for a bilateral structure with autonomy of the parties and lots of physical and human assets in place. A second choice can be unified governance or vertical integration, which makes it easier for both parties to adapt the transaction to new events (Williamson, 1979; Dyer, 1997).

The third variable, 'uncertainty' is also useful, although it is less important in the model developed by Williamson (1979). It is stated that when the amount of uncertainty raises also the amount of unknown contingencies increase. In general, when the transaction costs increase (e.g. more uncertainty) this can be seen as a hazard or can be safeguarded using one of the three options below:

1. *Competition safeguard*: within a competitive market no or little transaction costs are incurred.
2. *Contractual safeguards*: using extra regulations into contracts, for example penalties.
3. *Unified ownership*: take the transaction out of the market and manage them internally.

Joskow (1987) and Crocker & Masten (1996) elaborate further on the relationship-specific investments and use four categories. The categories identified are:

1. *Site specifity*: an investment due to the fact the factors or assets are located near your supplier or customer.
2. *Physical asset specifity*: a piece of equipment with specific characteristics especially designed for a certain type of transaction and with lower value in other transaction types.
3. *Human capital specifity*: skills and knowledge of employees obtained for one type of transaction.
4. *Dedicated assets*: general investments which are otherwise not done (Joskow, 1987; Crocker & Masten, 1996).

Joskow (1987) used these categories in his research on 277 coal contracts in the United States. Goal was to map the influence of relationship-specific investments on the duration of coal contracts between coal suppliers and electric utilities. The two variables most important in the research were site specific and physical asset investments. The site specific investments were categorized in mine-mouth and non-mine-mouth plants. Mine-mouth plants are electricity plants located near one specific mine. The physical asset investments were investigated, because electricity plants are 'locked-in' to a certain type of coal. The reason for this is because plants are designed to burn a certain type of coal. The conclusion from this research is that buyers and sellers make longer term commitments on future trade, and therefore rely less on repeated bargaining, when relationship-specific investments are more important (Joskow, 1987). It could therefore be safely stated the transaction cost economics of Williamson is a good predictor of contract duration in the coal market.

Crocker & Masten (1996) applied the transaction cost economics to public utilities in their research. Two general conclusions were found. First, competitive bidding works less well when the buyer cares about quality, reliability and other attributes of its complex good or service. Second, the more complexity and uncertainty involved, the more long-term contracts are used. For public utility this means it is not wise to struggle about prices, because large investments are made at the outset. Think of hospitals with large investments in buildings and equipment. Due to these large investments, organizations are often locked-in to each other in the public utility sector. Organizations therefore do not look at market possibilities any longer, because it is impossible to recover the relationship-specific investments (Crocker & Masten, 1996). In the end, a learning point from this research is to think twice before closing contracts with relationship-specific investments. Once the market can offer better alternatives, an organization cannot switch, because it is locked in to the current supplier.

In the article by Ghosal & Moran (1996) the transaction cost economics is however questioned. Main argument used by the authors is that the normative impact of the theory could be too high. Besides, the assumptions of opportunistic behaviour and that efficiency is the rule of the game, can become a self-fulfilling prophecy. An example given by the authors is that the transaction cost theory is only concerned with rational controls and not with social controls. They state that when one type of opportunistic behaviour is controlled by new contractual (rational) controls, other more difficult to detect opportunistic behaviour will arise which can only be controlled by social controls. In the end, the mutual gains can disappear, because the 'feeling for the entity' - the assessment of the transaction partner - is reduced more than the rational controls can better (Ghosal & Moran, 1996). In the end, taking the article of Ghosal & Moran into mind, it can be stated the transaction cost theory is only suited to markets where opportunistic behaviour is in place. In other markets one should be very aware when using this theory.

5.4 Contract Duration

A part of contract theory which receives a lot of attention is contract duration. Especially in the field of econometrics, complex models are developed to predict what kind of contract can be used best. Most of this research is, however, directed at production organizations producing and delivering actual products. Because these organizations are out of the scope of this research, more general theory on contract duration is outlined below.

In general, four kinds of contract durations, or commitments can be identified. These are:

1. *Spot commitment*: a onetime contract for the current period.
2. *Full commitment*: a contract for the full length of the relationship.
3. *Long-term commitment*: a contract for a long period, but not the full length of the commitment. Renegotiation of this contract is possible.
4. *Short-term commitment*: everything in between a spot and long-term contract (Salanié, 2005).

Benefits Long-term	Source	Benefits Short-term	Source
Easier and more frequent communication	Li et al. (2009) Cohen & Agrawal (1999)	Flexibility of switching to other supplier	Cohen & Agrawal (1999)
Exchange of information	Li et al. (2009)	Near zero fixed investment costs	Cohen & Agrawal (1999)
Effective monitoring of quality	Li et al. (2009) Cohen & Agrawal (1999) Kleindorfer & Wu (2003)	Service can be better	Li et al. (2009)
Learning effect (economics of scale)	Li et al. (2009) Cohen & Agrawal (1999)	Absence of structural constraints	Williamson (1972)
Faster product development	Cohen & Agrawal (1999)	Broader competitive market	Kleindorfer & Wu (2003)
Mutual cooperation in order fulfilment	Cohen & Agrawal (1999)		
No cost in renegotiation of the contract	Cohen & Agrawal (1999)		
No spot volatility in prices	Kleindorfer & Wu (2003)		

Table 5.2. Advantages of long- and short term contracts.

In other literature the categorization is narrower in nature and only divides contracts in long- and short-term. The long-term contracts are equal to long-term or full commitment and the short-term contracts to short-term or spot commitment. Besides, literature identifies a lot of advantages and disadvantages of both types of contracts. The benefits are listed in table 5.2. Disadvantages are mapped less thoroughly, although it can be stated long-term contracts have the disadvantage of being incomplete by nature, due to information asymmetry and the cost of information gathering. The high negotiation costs are the main disadvantage of short-term contracts (Williamson, 1972).

The question is, which contract duration to use in what situation? Li, Murat & Huang (2009) state that when there is more price volatility in the market, long-term contracts are the better choice. This is due to the fact a learning effect, of decreasing costs and better quality, can emerge. This learning effect should, although, be larger than the one-time investment (incentive) the buyer makes to keep the supplier delivering higher quality products. However, an important clause which needs to be added to the contract is a minimum purchase quantity. This is necessary, because when the prices in the spot market are decreasing, an organization only has to buy the minimum quantity and can purchase the rest from the cheaper spot market. On the other side, when the prices are increasing, the organization has the lower fixed price of the long-term contract (Li et al, 2009). Salanié (2005) states that in this situation a full commitment contract can be used best, because of the immediate revelation of information. However, he concludes these kind of contracts are often not realistic in complex and uncertain markets. Therefore, long-term contracts with the possibility of renegotiation are a good alternative, although there is an efficiency loss in the revelation of information. Short-term contracts can also be used when the conditions are right - e.g. stable market (Salanie, 2005). Williamson (1972) outlines the same conclusion and gives the advice to vertically integrate a company when there are separable production stages and specific assets in place. Due to the fact this is often not possible, two alternatives are advised. The first option is to use incomplete long-term contracts with profit sharing. In these cases the contract has a general clause of profit sharing between the supplier and buyer. It therefore also serves as profit maximizing function - the supplier has an incentive to supply the right products. The second option is the continuous renewal of spot contracts. These, however, have the disadvantage of high renegotiation costs (Williamson, 1972).

Kleindorfer & Wu (2003) do not give a general advice, but base the contract duration on the 'codifiability' of the product/service and investments. Codifiability is the ability of an organization to specify product, delivery and settlement requirements which can be verified by a third party. Investments by suppliers are also called adaptation costs - modifying products so they are according to requirements. However, on the long term these investments can be earned back due to decreasing incremental costs of planning possibilities. The general conclusion by Kleindorfer & Wu (2003) is the lower the codifiability of the products/services, the more long-term contracts will be used due to large investments. So longer-term contracts are used for products with a lot of idiosyncratic investments and spot-market purchases for low value products with easily addressable quality. Due to the fact most contracts lay somewhere in between, long-term contracts can be used for some part of the purchase and spot market purchases to fine tune (Kleindorfer & Wu, 2003).

Ganesan (1994) states long-term orientation of actors can be predicted by mutual dependence and the extent to which partners trust each other. Trust is defined as: *"the willingness to rely on an exchange partner in whom one has confidence"* and can be measured by credibility (confidence in supplier) and benevolence (actions taken in benefit of both partners). Trust can be built by actual interactions or taken from the market when reputation is given to the partner by someone other than the focal partner. The benefits of creating trust between contract partners are; trust reduces perception of risk associated with opportunistic behaviours, gives confidence short-term problems are fixed on the longer term and transaction cost reduction. In the end, it can be stated long-term orientation and therefore long-term contracts are determined by trust in the contract partner. Mutual dependence has an influence, but the best predictor is credibility (Ganesan, 1994).

5.6 Incomplete contracts

Long-term contracts are, however, inevitably incomplete (Crocker & Masten, 1996; Hart & Moore, 1988; Salanié, 2005; Williamson, 1972). A complete contract takes into account all variables relevant now and in the future, over the time the contract is executed. Most long-term contracts, are incomplete, because they are not able to describe in detail all these contingencies (Salanié, 2005), so that the courts could later verify what states occurred (Hart & Moore, 1998). Hart & Moore (1988) give two reasons why these contracts are incomplete:

1. *Information asymmetry*: both actors cannot observe the state of the world evenly well.
2. *Cost of processing*: writing a contract which incorporates all the contingencies is very costly.

Incomplete contracts are often noticed in long-term contracts with a fixed price. At the outset, the contract functions as a risk diminishing or risk sharing device favouring both actors. However, when market developments emerge, the fixed price cannot track the market developments (states of the world) and the contract is unsatisfactory for one of the contract partners. If this contract partner is the supplier, delivery delays and the supply of lower quality products is often the case. Crocker & Masten (1996) identify two solutions for this problem. First, an alternative contract structure is proposed, of which a base price is paid and a change based on several variables in the market. A second solution, which is also supported by Salanié (2005) and Hart & Moore (1988), is contract renegotiation. When both contract partners know their respective benefits and costs after a certain period or some state of the world emerges, they can arrange a contract negotiation.

According to Salanié (2005) the possibility to include renegotiation into a contract depends on the commitment of the contract partners to the relationship. Commitment can be defined as: "*the extent to which agents pledge in advance to keep their activities in accord with the contract until some predetermined date*" (Salanié, 2005). The amount of commitment of the contract partners depends on contract law (more contract law, more commitment), credibility of agents (higher credibility, more commitment) and existence of investments which lose some value after contract penalties are indulged (more investments, more commitment) (Salanié, 2005).

Hart & Moore (1988), however, identify communication possibilities as the most important means in renegotiation. Two communication cases can occur: one where it is impossible to publicly record a message and one where this is possible. When it is possible to publicly record a message this can also be called a verifiable means of communication. General conclusion from their research, in which an econometric model is developed, is when messages can be verified and no relationship-specific investments are made, the first-best message can be implemented to renegotiate the contract. When, however, the contract has relationship-specific investments this is not the case, and both contract partners often under invest in the relationship (Hart & Moore, 1988).

5.7 Conclusion

In general, it can be stated contract theory evolved from the failures of the general equilibrium or perfect competition model and has to do with aligning transactions with governance structures. Before something can be concluded about which contract structures or duration is best, the transactions and governance structures first need to be analyzed.

This analysis can be best performed using two theories, namely the agency theory and transaction cost economics. The agency theory focuses on information asymmetry and can be used to structure contracts and share risk in the light of incentive problems and tries to find an optimal payment whereby the principal's utility is maximized and the agent's utility minimized. In addition, the theory is able to analyze conflicting goals and is normative in nature on contract structures. The transaction cost economics, on the other hand, is a risk-neutral model mapping governance models on transactions. Using the variables frequency of transaction, uncertainty and investment characteristics three types of governance structures can be identified. These are market governance, trilateral governance and transaction-specific governance.

In contracts, four types of contract durations (commitment) can be used: spot-, full-, long-term and short-term commitment. Theory identified that the higher the relationship-specific investments, the lower the 'codifiability', and the higher the trust; the more long-term contracts should be used. Besides, several other general contract structures are advised, such as: long-term contracts with minimum purchase quantity, contracts with risk sharing and continuous renewal of spot contracts. Besides, due to the fact of information asymmetry and the cost of processing new contracts, theory advises to use contracts with the option of renegotiation. These theories are applied to the biomass market in section 7.

6. The biomass market

On the biomass market bio-energy installation operators can obtain biomass necessary to produce electricity and heat. However, this market is still developing and not mapped thoroughly. What are reasons for actors to trade on these markets and what benefits do they obtain? How is the market organized and what is the availability of biomass now and in the future? These and more questions will be answered in this section containing several subsections. The first subsection will elaborate on the trade benefits of the market actors. The second subsection will analyze the manure market with its distinct risks. The same is performed in subsection three for the co-substrate market. In the fourth and last subsection, an answer will be given on the central research question of this section, namely:

What risks emerge from the current organization of the biomass market?

6.1 Trade benefits

Trade emerges in markets where actors think they are able to gain some benefit from trading. This is not different in the biomass market. A farmer has to trade its manure on the market, because this solves its problem of manure surplus which cannot be used on the own farm. The private benefit for the farmer also highly depends on the price paid on the market to dispose the manure. The buyer - a positive list digestion installation operator - on the other hand, also receives a private benefit of trading manure. This private benefit contains a money inflow - the farmer has to pay to solve its problem - and the fact the buyer now can operate his installation according to law. Law prohibits the use of more than 50% manure in positive list digestion installations. Due to the low initial value of the manure, large quantities need to be traded to gain private benefits (Luesink, Blokland, Bosma & Hoogeveen, 2009; Luesink, Blokland & Mokveld, 2008).

The same story can be more or less told for suppliers who need to dispose their waste streams, largely originating from the food industry. The private benefit is that their problem of waste is solved and is even heightened in these sectors, because money has to be paid by buyers for these products due to high initial values and a lot of alternative applications. In these markets, however, the different products are often gathered by one intermediary (animal feed industry). The private benefit for these organizations is profit (Novem, 2002).

The positive list digestion installation operator - Raedthuys - has two private benefits from biomass trade. First, with its technique, the biomass can be transformed into electricity and heat, from which profit can be obtained. Second, by sourcing positive list biomass, the organization is eligible for a subsidy regulation. Besides, Raedthuys triggers some public benefits (externalities) with its biomass installation. First, a positive externality, it contributes to the fight against global warming and cleaner air, due to the avoidance of fossil fuel use. Second, a negative externality, because by using biomass, according to some researchers, Raedthuys is competing with the animal feed industry - with changing feed habits in developing countries more land is needed for food production. Although, most biomass streams used in digestion installations cannot be used for consumption. Besides, biomass use can possibly have a negative effect on biodiversity, water quality, water use and soil erosion (IUCN, 2008; Senternovem, 2009a).

In the end, it can be stated there are profit motivated traders and utilitarian traders in the biomass market. First, farmers can be marked as utilitarian traders, because they trade for another benefit than profit. In this case the reason for trade is the manure problem. Second, the food industry can be marked as an utilitarian trader as well as a profit motivated trader. They want to dispose their waste, but on the other hand know a large profit can be obtained. Third, the animal feed industry is a pure profit motivated trader. Fourth and last, Raedthuys is both a profit motivated trader and a utilitarian trader. Besides profit, Raedthuys trades to obtain biomass streams necessary for their subsidy eligibility and to better the environment.

These trade benefits gather on the biomass market, which can be divided in a manure and co-substrate market. The manure market is a quite stable and organized market. The co-substrate market, on the other hand, is still developing and widely dispersed. On these markets, Raedthuys is concerned with the wide (liquidity) of the trade - the cost of doing a trade at a given size. It is in search of 18.000 tonnes of manure and 18.000 tonnes of co-substrate per digestion installation. With multiple projects at hand, these amounts can be even higher.

6.2 The manure market

On the manure market, the supply and demand of animal manure is matched. The supply comes from organizations, mostly farmers, who cannot use the manure within the allowed user standards set by government. Demand comes from all organizations who can, and are able, to use manure which is not produced by livestock within the own organization. The price development on the manure market is the total opposite of retailer markets, because the manure turnover price is used. In retailer markets when supply drops and demand rises the price will increase. In the manure market, on the other hand, the price increases. This is due to the fact the manure price is a cost instead of a revenue for the farmer. A farmer is willing to pay money to dispose its manure waste stream. For a company like Raedthuys, who needs manure in its digestion installations, a large supply and low demand is perfect (Luesink, et al., 2009).

6.2.1 Availability now and in the future

To determine the supply and demand of the manure market the 'mestprijzenmonitor' was used until recently. This initiative, unfortunately, stopped its operation and it became more difficult to determine the supply and demand on the manure market. The best approach nowadays is to use information gathered by the Landbouw Economisch Instituut (LEI); a research institute of Wageningen University. From research conducted by this institute, it can be concluded the manure production in 2008 is 384 million kilograms of nitrogen and 170 million kilograms of phosphate. However, not all of this manure is available on the manure market, because most of the manure is used within the own organization to, for example, fertilize land. Therefore, the manure market in 2008 consisted of 136 million kilograms of nitrogen and 78 million kilograms of phosphate. This is also the market where Raedthuys has to get its manure from. However, the manure market is a very regional market, because the relatively low value of manure makes it hard to transport efficiently. An overview of manure for different regions is presented in table 6.1.

Region	Nitrogen	Phosphate
1. Groningen en Noord-Friesland	5	3
2. Noordelijke weidegebied	13	7
3. Veenkoloniën	1	1
4. Oostelijk veehouderijgebied	25	13
5. Centraal veehouderijgebied	16	9
6. Rivierengebied	5	2
7. Zuid-Limburg	0	0
8. IJsselmeerpolders	2	1
9. Zuidelijk veehouderijgebied	68	38
10. West-Nederland	5	3
11. Zuidwestelijk akkerbouwgebied	6	3

Table 6.1. Manure market per region in million kilograms (Luesink et al., 2009).

The average manure price during the year 2009 was €17,45 per tonne. These prices differ per region and time of the year (DCA, 2009). During winter the prices are higher than in the summer, because in winter time manure cannot be used on farmer's land. Raedthuys is, however, currently not taking part in the manure market. Therefore, it is also valuable to look at the amount of manure which could not be placed. According to table 6.2 this amount decreases from 3 million kilograms of both kinds of manure to 0 million kilograms. This prediction is, however, downplayed because the article gives different scenarios. The amount of manure which cannot be placed can lay somewhere in between the 0 to 7 million kilograms of phosphate and 0 to 10 million kilograms of nitrogen depending on several scenarios (Luesink et al., 2009).

Description	Verification 2006		Verification 2007		Basis 2008	
	Nitrogen	*Phosphate*	*Nitrogen*	*Phosphate*	*Nitrogen*	*Phosphate*
Production	377	167	384	170	384	170
Stock	-	-	8	5	-	-
Placed	373	164	385	169	384	170
Own organization	*253*	*93*	*246*	*91*	*248*	*92*
Supply manure market	*120*	*71*	*139*	*78*	*136*	*78*
Extra export	-	-	6	4	-	-
Not placed	3	3	1	1	0	0

Table 6.2. Not placed manure in million kilograms according to model (Luesink et al., 2009, p70-71).

As can be noted, the manure market is currently a surplus market, but how will this be in the future? According to Luesink, Blokland & Mokveld (2008) the surplus on the manure market will grow in the period 2006 to 2015. The surplus grows from 4 million kilograms of nitrogen and 4 million kilograms of phosphate in 2006 to 24 million kilograms of nitrogen and 12 million kilograms of phosphate in 2015 (see table 6.3). When these amounts are cumulated, the surplus of phosphate is 61 million kilograms of phosphate in 2015. This change is mainly due to increased regulations by the European Union and the Dutch government.

Description	2006		2009		2012		2015	
Scenario 1	Nitrogen	Phosphate	Nitrogen	Phosphate	Nitrogen	Phosphate	Nitrogen	Phosphate
Production	367	161	371	164	368	163	365	162
Placed	359	156	359	159	350	153	338	148
Difference	7	5	12	5	19	9	28	14
Change computation	*3*	*1*	*5*	*1*	*3*	*1*	*2*	*1*
Not placed	*4*	*4*	*6*	*4*	*15*	*8*	*25*	*13*
Scenario 2	Nitrogen	Phosphate	Nitrogen	Phosphate	Nitrogen	Phosphate	Nitrogen	Phosphate
Production	366	161	371	164	368	163	365	162
Placed	359	156	359	159	347	152	335	146
Difference	7	5	12	5	22	11	31	16
Change computation	*3*	*1*	*5*	*1*	*3*	*1*	*2*	*2*
Not placed	*4*	*4*	*6*	*4*	*19*	*10*	*28*	*14*

Table 6.3. Not placed manure for the years 2006 to 2015 (Luesink et al., 2008, p38).

Table 6.3 outlines a quite positive prediction of the manure market in the future. However, an article published on November 26, 2009 in NRC.Next gives a slightly different view. The article states that in the foreseeable future - estimates ranging from 25 to 75 years - the phosphate mines will be exhausted and will have an effect on the phosphate price. Main reason for this exhaustion is the growing worldwide population who demands a higher food production and artificial manure use of which phosphate is the main ingredient. Besides, two thirds of all phosphate is located in Chinese and Moroccan mines. An export ban of phosphate issued by China in 2007, increased price with a factor 10. Animal manure, on the other hand, also contains large amounts of phosphate, but it is difficult to harvest from manure. However, in the future this may be necessary, which has a negative effect on the manure price (De Haes & Van der Weijden, 2009).

In the end, it can be stated the manure market is currently a surplus market. In the future, on the other hand, some developments can influence the manure availability and price. Due to the fact these developments are out of the project duration at Raedthuys (12 years), they would not influence projects that much. The developments in the near future have a positive effect on the manure market, when supply (surplus) increases it becomes harder to dispose manure, and the price will increase. This development is positive for Raedthuys, because in the future it can receive more for a tonne of manure.

6.2.2 Market efficiency

It can be stated the manure market is a market of full competition now and in the near future. The market has many sellers - farmers which have more manure than can be used on its own farm - and no exit and entry barriers - every farmer can sell manure on the market. The manure market also contains homogenous products - manure does not differ from farmer to farmer and from time to time that much. Besides, in the manure market the different kinds of manure (chicken, pig and cattle) are complements of each other. When one type of manure has a price increase due to, for example, animal disease, an organization can always switch to a different kind of manure. However, chicken manure is not seen as a true substitute in case of digestion installations, because it is very dry and mainly used to combust.

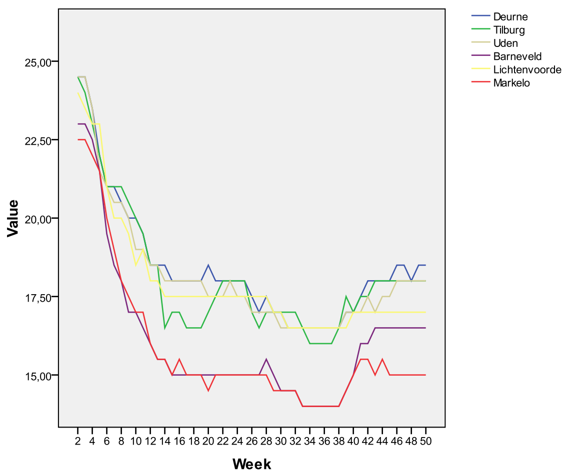

Figure 6.2. Price development manure 2009 (DCA, 2009).

The market can also be marked as transparent. Due to the disappearance of the 'mestprijzenmonitor' less market information is available, but information is still gathered on a regular basis. Therefore, market information is reported quite quickly, and due to the fact the market is one of full competition, prices reflect information quickly. Besides, the market can be marked as liquid. There are a lot of suppliers willing and able to trade their manure surplus. In the end, it can be stated the market price reflects fundamental value in the manure market, due to full competition and substitutes.

That the market is working efficiently can also be noticed from the price development in 2009. In the first 13 weeks of 2009 the price was decreasing (farmer had to pay less money to dispose) due to the fact the price of artificial manure increased rapidly (AGD, 2009). In this case the substitute animal manure becomes cheaper, demand increases and price drops. When we leave out this sudden price drop and analyze the prices from week 13 to 50 - which continue in the same trend in 2010 - it can be stated the price volatility measured in standard deviation lays between 2 and 6 percent in different regions (see also table 6.4). This low volatility is also a sign the market is working efficiently.

Regions	Mean	SD	%
Deurne	€17.58	€0.72	4.10%
Tilburg	€17.18	€0.70	4.07%
Uden	€17.31	€0.59	3.41%
Barneveld	€15.19	€0.85	5.60%
Lichtenvoorde	€17.08	€0.40	2.34%
Markelo	€14.82	€0.46	3.10%

Table 6.4. Average manure price and standard deviation week 13 to 50 2009 (DCA, 2009).

To conclude, it can be stated the manure market is an efficient functioning full competition market offering commodity products of low value. In the near future, the market is functioning efficient with quite stable prices. However, between 10 and 25 years a change can occur with diminishing manure prices due to exhaustion of phosphate. In general, the 'risks' which influence the manure price are:

- Animal population which is dependent on the use of animal products.
- Price of artificial manure which is dependent on phosphate prices.
- Animal diseases.
- Weather conditions.
- Law, especially the amount of manure allowed on the own farm (Senternovem, 2009b; Luesink et al., 2008).

6.3 The co-substrate market

The co-substrate market is the market where biomass is traded other than manure. These biomass streams are called co-substrates, because in digestion installations these can be added to the manure to heighten the gas production. The market has no index or virtual market place - although there are some initiatives to construct these - but can be typified as an Over The Counter (OTC) market where trade is bilateral. Besides, the market is very widespread, due to the fact a lot of industries are offering waste streams which can be used in a digestion installation. If a digestion installation operator needs biomass, it needs to source these co-substrates from different industries or should search for an intermediary who gathers the co-substrates for them. Examples of industries where co-substrates are produced are: wood processing industry, meat and fish processing industries, production of alcohol, and production of bread. This subsection first identifies the difference between positive list biomass and 'normal' biomass. Second, outlines the availability of biomass now and in the future. Third and last, it concludes on the efficiency of the market.

6.3.1 Positive list biomass

In the Dutch biomass market two kinds of biomass can be identified, namely positive list and 'normal' biomass. Positive list biomass is all the biomass present on a list published by the Dutch ministry of Agriculture, Nature and Food Quality (LNV). If an aerobic digestion installation wants to obtain subsidy, only biomass from this list can be used. When digestion has taken place solely with products from this positive list and with at least 50 percent animal manure, the digestate can be used on farmer's land as digested manure. The installations using positive list biomass are called positive list digestion installations or farm installations. Normal biomass is all the biomass not present on the positive list and is often used in industrial digestion installations which do receive a lower subsidy tariff.

The main categories of this list, with a few examples per category, are outlined in citation 6.1. In these categories all kinds of subcategories are listed. It needs to be noted there is a lot of discussion between digestion operators and the government on these subcategories. Therefore, a 'grey' category is emerging nowadays with co-substrates not explicitly on the positive list but 'tolerated' by the government.

In the future it can be doubted if this positive list can still continue in its original form, or that several co-substrates are removed or added. It has to be noted the available co-substrates can fluctuate fast, due to this positive list. If a stream is on the positive list, every organization asks for this stream and the price will be high. However, if the stream is removed from the list, the supply is still high, but the demand decreases and the price will drop. If the organization has a contract for a positive list digestion installation for the removed streams, the contract is not valuable any longer, because the streams cannot be used any longer. The positive list is therefore a large risk - the list can cause large volatility and contracts can lose their value.

A. **Substances of vegetable origin from an agricultural organization**
   A1. Crops (products) for human consumption or animal feed
   Silage maize, potatoes, unions, fodder beet, grains, corn cob mix etc.
   A2. Crops (products) for biogas production
   Energy maize
B. **Substances of vegetable origin from undisturbed ground**
   B1. Grass from grass land
C. **Substances from the food industry**
   C1. Substances of vegetable origin
   Waste from starch production, steamed potato shells, beet roots etc.
   C2. Substances of animal origin whether or not combined with substances from vegetable origin.
   Waste from ice production, unpacked food for human consumption etc.
D. **Substances from the animal feed industry**
E. **Substances from other industries**
   Glycerine
F. **Adjuvant or additives**
   Mud from the production of drinking water etc.

Citation 6.1. Positive list co-substrates from implementation manure regulation (BW: TRCJZ/2005/3295).

That the list can change is dependent on the fact if the government shall follow advices given by several commissions and organizations. These more strict advices, can in the future possibly lead to the removal of some co-substrates from the positive list. One of the advices is formulated by the Cramer-commission which comes up with sustainability guidelines for the future use of biomass in the Netherlands. These guidelines are:

1. *Greenhouse gas balance*: an emission reduction of 30 percent in comparison with fossil fuels.
2. *Competition:* no competition with food production, local energy supply, medicine production or the availability of building materials.
3. *Biodiversity*: no harmful activities in protected areas and valuable ecosystems.
4. *Prosperity:* no negative side effects on the regional and national economies.
5. *Welfare*: no negative effect on labour conditions, human rights, property rights and social conditions of local inhabitants.
6. *Environment*: there should be right waste management in place (Cogen Projects, 2008).

Categorization	Product
Positive	Waste wood from FSC industry Wood scrap (from trees) Paper sludge
Positive, but	Waste streams from sugar production Kitchen and garden waste Algae, seaware, water plants Waste wood (A and B)
No, but	Jatropha-oil Cane sugar Algae from land Straw
Negative	Eatable vegetable oils Wheat Maize

Table 6.5. Categorization of biomass (De provinciale milieufederaties en stichting natuur en milieu, 2008).

Besides, in 2008 'De provinciale milieufederaties en de stichting natuur en milieu' also formulated an advice on the sustainability of biomass. This actor divided biomass into four categories (see also table 6.5 containing some examples), namely:

1. *Positive*: This biomass is sustainable. Sustainability check after use.
2. *Positive, but*: This biomass is sustainable, if the biomass is proven sustainable.
3. *No, but*: The sustainability of this biomass is doubted. Biomass is only sustainable when this can be proved.
4. *Negative*: This biomass is not sustainable. There is also no subsidy regulation for these kinds of biomass (De Provinciale Milieufederaties en Stichting Natuur en Milieu, 2008).

6.3.2 Availability now and in the future

The best way to determine the availability of co-substrates is to gather information from all biomass suppliers in the market. However, due to the non-transparency of this market it is impossible to track down all the suppliers and the co-substrates they deliver. Therefore, this paragraph identifies the availability of co-substrates now and in the future by determining what co-substrates are currently and in the future offered on the market. However, it is difficult to determine the availability of positive list co-substrates, due to the fact no research has been conducted. Therefore, this paragraph focuses on all possible co-substrates now and in the future.

Just like there is no one best definition of biomass, there are also a lot of categorizations possible for co-substrates. For this research the categorization presented by Senternovem (2005) is chosen, because this organization is grouping biomass into three kinds of groups (see appendix 4). The groups are: a main group, a 'normal' group and a subgroup. Due to this categorization it is easier to see where the streams are actually coming from. The main groups where co-substrates originate from are woody biomass, not-woody biomass, fruit, other biomass and recovered fuels. For this research it goes too far to describe all the co-substrates from appendix 4. However, two examples are given in the form of fresh waste wood and grains.

First, fresh waste wood is all the wood which comes from living trees and is gathered during the season trees are felled. This can range from small branches to large chunks of tree and is gathered by forestry commissions, municipalities, fruit production, farmers and individuals. This wood can be used for different purposes; it can be chipped and used on the land or in livestock stables as floor cover. However, there are also a lot of other possible uses, which leaves just little of this fresh waste wood to burn in biomass installations. Secondly, the same story can be outlined for grains. The grains which are harvested are mainly used for food production. Besides, there is some competition from the bio-ethanol sector, who uses fermentation to turn the grains into bio fuels. In the end, there is not much left which can be used as a co-substrate in digestion installations (Senternovem, 2005).

One of the largest potentials of biomass comes from the food industry (group 4.1 in appendix 4). In 2002 a research has been conducted in this sector by Novem, and they concluded around 10 million tonnes of waste streams were available with an energetic potential of around 122 PJ in this year. A research conducted by SenterNovem (2009b) outlines the same conclusion of 10 million tonnes, from which 4.9 million tonnes is dry (dm > 80%), 5 million tonnes wet (10-80% dm) and 750,000 tonnes of liquid co-substrates. However, the availability of waste streams from the food industry is very dependent on the production. Due to the fact food is one of the primary needs to survive, this production will always stay around the same level. Examples of sectors within the food industry are: butchers and meat processing, production of animal and vegetable oils, production of sugar; and production of tobacco. In appendix 5 an overview is given of the waste streams from the food industry (Novem, 2002).

From these waste streams around 80 to 90 percent are used as raw material for the animal feed industry. An example of a waste stream from the food industry is distillers' wash. This biomass waste stream originates from the production of beer. As can be noted in figure 6.2 the supply chain of distillers' wash, until it reaches the digestion installation, is quite long. First, the grain should be cultivated and transported to the farm and the beer brewery. From the grain, beer is produced, but also the waste stream distillers' wash. This waste stream is then transported to the animal feed industry, which uses the best quality distillers' wash for animal feed. In the end, only a small portion of the distillers' wash is left which can be used in the digestion installation. The problem with this long supply chain is when something went wrong in the earlier chains, the last chain can experience most problems. An example is a fall in beer breweries' production. In those cases, also the lower quality distillers' wash is used for animal feed and nothing is left for the digestion installation.

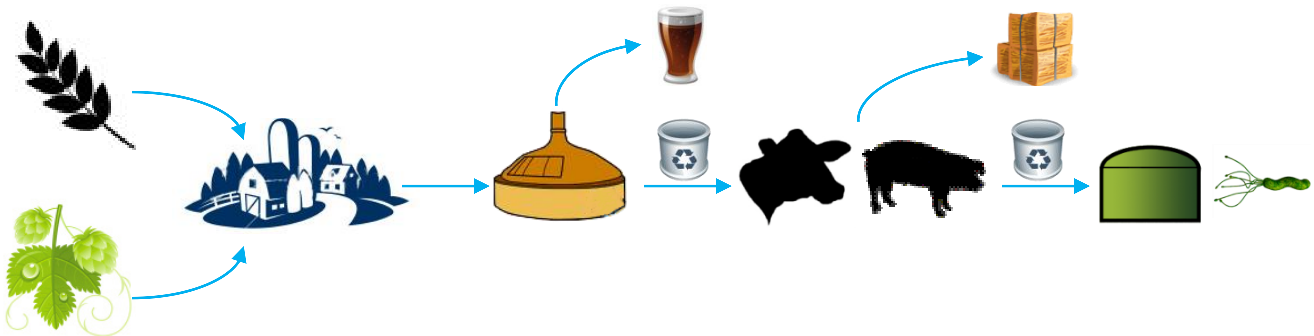

Figure 6.2: The supply chain of distillers' wash.

To get a feeling about how large the supply of biomass streams are in the Netherlands, examples are given below with their amount of biomass available:

1. *Dry industrial waste wood*: 351.5 ktonnes with an import of 78.5 ktonnes (mainly wood pellets).
2. *Discarded frying oil*: 60 ktonnes production and also 60 ktonnes of import.
3. *Animal fat*: 206 ktonnes of domestic production and substantial imports and exports.
4. *Total used wood (Category A, B and C):* 1485 ktonnes.
5. *Municipal solid waste*: 10.551 ktonnes (Jungigner & Hoefnagels, 2009).

Biomass stream	Energy potential (TJ/year)[1]		
Year	*2000*	*2010*	*2020*
Agricultural crop residues	11.22	12.35	13.65
Wet and dry manure	44.48	49.10	54.26
FBP and RW[2]	16.25	17.89	19.78
Industrial biomass	3.40	3.78	4.16
Gas from sewage	3.15	3.49	3.86
BMW[3]	131.88	199.5	243.22

Table 6.6. Availability of different categories of biomass in the Netherlands (Panoutsou et al, 2009).

[1] Recomputed from ktoe to TJ. ktoe = kilo metric tons of oil equivalent (1000 tons of oil equivalent). The amount of energy released by burning one ton of crude oil. This is approximately the same as 0,042 TJ (American Physical Society, n.d.).
[2] Forestry by-products and refined wood fuels.
[3] Biodegradable municipal waste.

The availability of the above mentioned co-substrates is guaranteed nowadays, but in the future the availability can fluctuate. The scenarios developed in the article of Heinimö, Pakarinen, Ojanen & Kässi (2007) state the bio-energy market will develop further by diversifying and growing rapidly. The trend is that in the future the biomass and bio-energy markets will become more complex and multi-layered. However, as stated in table 6.6 the biomass availability in TJ grows for all kinds of biomass streams for the Netherlands towards 2020. For example, biodegradable municipal waste (BMW) grows from an energy potential of 131.88 TJ a year in 2000 to 243.22 TJ in 2020. In table 6.7 this availability is divided in more subcategories. As can be noted the availability of biomass streams in the future grows between 0.5 and 3 percent a year, except for the land filled biodegradable municipal waste (BMW). This biomass stream shrinks with 3 percent a year, mainly due to the fact land filled BMW is used, and therefore the amount of waste on landfills drops (Panoutsou et al, 2009).

Sector	Resource	Category	Trend
Agriculture	Crop residues	Dry	**+ 1% a year**
	Livestock Waste	Wet or Dry	**+ 0.5% a year**
Forest	Woodfuel	Dry	**+ 1% a year**
	Forest residues	Dry	**+ 1% a year**
Industry	Industrial residues	Dry	**+ 1% a year**
		Wet	**+ 2% a year**
		Black liquor	**+ 1% a year**
Waste	Regulated	Not landfilled BMW	**+ 1% a year**
		Demolition wood	**+ 1% a year**
	Non regulated	Landfilled BMW	**- 3% a year**
		Sewage sludge	**+ 2% a year**

Table 6.7 Biomass availability over the years in EU27 (Panoutsou et al, 2009).

Senternovem (2009b) also performed a research on the availability of biomass, including co-substrates, in the Netherlands for 2020. The research comes up with a quite detailed prediction for several co-substrates of the total amount of biomass and the availability for electricity/heat production. The prediction for 2020 is computed using four different scenarios, namely:

1. *Global Economy*: large economic growth and worldwide institutions. No renewable energy targets or additional subsidies.
2. *Transatlantic Market*: large economic growth and local networks. Less renewable energy targets and no change in subsidies.
3. *Strong Europe*: low economic growth and worldwide institutions. Digestate can be used as manure, large financial subsidies, worldwide biomass usage plan.
4. *Regional Communities*: low economic growth and local networks. Digestate can be used as manure, large financial subsidies, worldwide biomass usage plan.

General conclusion from this research is that in 2020 more biomass will be available for electricity/heat production than in 2009. Take for example straw which will be available in quantities ranging from 94 to 187 ktonnes of dry matter in 2020. This amount will rise due to the fact more grain is harvested. Another example is potato scrap, which rises from 0 ktonnes of dry matter in 2009 to 52-104 ktonnes of dry matter in 2020. On the other hand, there are also co-substrates with diminishing numbers. Take for example frying oil, which is very popular nowadays with 130 ktonnes of dry matter. In 2020, however, in all scenarios this has been decreased to 0 ktonnes of dry matter (Senternovem, 2009b).

Looking even further, until 2050, a lot of different projections for the biomass availability are outlined. In the article of Heinimö (2007) these projections are brought together and there is stated in 2050 there is between 40-1100 EJ of biomass available (see table 6.8). However, the supply of biomass will grow in the future, does not mean it is easier to source these biomass. This is because it is unsure whether the demand for biomass will also grow.

Biomass Category	Potential bio-energy supply up to 2050 [EJ/yr]
Energy farming on current agricultural land	0 to 700
Biomass production on marginal lands	60 to 150
Bio-materials	-40 to -150
Residues from agriculture	15 to 70
Forest residues	30 to 150
Dung	5 to 55
Organic wastes	5 to 50
Total	40-1100

Table 6.8. Global biomass potential (Heinimö et al., 2007).

What however can be stated is when the goals on biomass have to be met, large-scale trading of biomass is necessary in the Netherlands. This is due to the fact there are not enough co-substrates available in the Netherlands to feed all bio-energy installations. Reasons for this are that biomass cannot be used technically, there is no permission to use it, or the biomass use is just not efficient (Senternovem, 2005; Senternovem, 2009b). According to Heinimö et al. (2007) the most important biomass streams are ethanol, vegetable oils, fuel wood, charcoal and wood pellets. Besides, Junginger & Hoefnagels (2009) indicate when the targets need to be realized, more high risk waste streams and currently not utilized waste streams should be used. The main conversion route will then be anaerobic digestion, which produces gas and subsequently electricity and heat (Junginger & Hoefnagels, 2009).

6.3.3 Market efficiency

The co-substrate market can be typified in several ways depending on the fact if co-substrates are seen as a homogenous or heterogeneous products. The other two variables, amount of sellers and entry and exit barriers are quite clear. In general, it can be stated there are many sellers in the market because a lot of organizations are offering their waste streams on the market - they have to dispose them anyway. There are also no large entry or exit barriers to the market. There is some legislation on the market - products should not wear diseases in them - but these are just minor. The co-substrates, on the other hand, can be both marked as homogenous or heterogeneous from several viewpoints. First, because biomass is a container definition or product group according to Wohlgenant (1999), it can be stated the co-substrates are heterogeneous. The individual co-substrates are all heterogeneous on their quality. They have different features in terms of dry matter, raw ash, raw protein etc. and originate from different competing industries. Second, biomass can also be seen as homogenous, because a single co-substrate is always the same over the years. Although, the exact composition can differ slightly, this does not influence energy production that much. Third, individual co-substrates can also be marked as heterogeneous on their application. Take for example potato scrap, which can have one of the following applications:

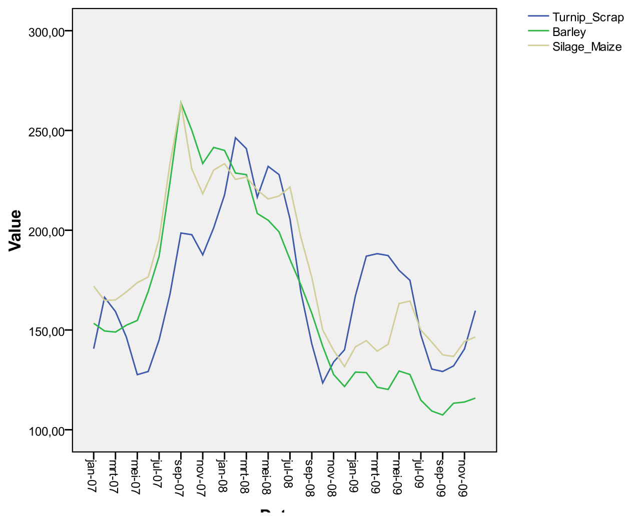

Figure 6.3. Price development co-substrates 2007-2009 (LEI, 2010).

- Animal food with a certain nutritious value.
- Energy production with a certain energetic value.
- Starch flour production.
- Ground cover for fruit orchards (natural root clothing).
- Future uses in the bio-chemical sector.

For this research co-substrates are marked as heterogeneous, because in the co-substrate market the products are no true substitutes but complement each other. The co-substrates should always be used together in an installation to foster optimal biogas production. It could therefore be stated in this co-substrate market, profit can be made in the short run, but on the longer term prices should reflect marginal values. However, there are a few submarkets which can be typified as full competition markets. An example is the grain market with a large amount of sellers, a homogeneous product and no entry/exit barriers.

The co-substrate market is currently in its first phase - where suppliers can make profit. This is mainly because the market is not transparent and information is not reported to the public quickly. There are some reports on the availability of biomass, but these are not released frequently and are often not based on data gathered from all suppliers. Therefore, the price emerges on the co-substrate market by bilateral trading heavily influenced by a supplier with greater knowledge of the market. On the other hand, the market can be marked as liquid, the right products are found often and traded bilaterally. It could therefore be stated the co-substrate market is a non-transparent, high value product, not efficient operating market still emerging and where information is key in determining right prices.

That the market is not functioning efficient can also be noted from the price volatility. A period from 2007-2009 is chosen to analyze prices, because around 2007 bio-energy installations emerged in larger proportion. As can be noted from figure 6.3 there were large price fluctuations in the past years for turnip scrap, barley and silage maize. This can also be concluded from table 6.9 where the standard deviations of the co-substrates range from 20% to 45%.

Co-substrate	Mean	SD	%
Turnip Scrap	€171.89	€35.63	20.73%
Barley	€107.40	€48.05	44.74%
Silage Maize	€131.65	€37.83	28.74%

Table 6.9 Average price and standard deviation co-substrates 2007-2009 (LEI, 2010).

In the end, it can be stated the co-substrate market is still developing and is not reflecting marginal price yet. For now and the future the following 'risks' are influencing the biomass availability and price:

- If products are listed on the positive list.
- High price volatility due to low transparency and liquidity.
- Price development fossil energy.
- Agricultural subsidies from the European Union.
- Development of labour and transport costs.
- Environmental and waste disposal laws.
- Efficiency improvements in agriculture.
- Development of alternative ways of using biomass (Senternovem, 2009b).

6.4 Conclusion

The biomass market is, in general, a market with profit and utilitarian traders, which can be divided in a manure market and a co-substrate market. The manure market is quite stable in nature and has a growing manure surplus in the Netherlands in the coming years. Therefore, the price of manure shall increase in the near future, which is a good development for Raedthuys. However, in the future some problems can arise with the availability of phosphate worldwide, but these will likely not effect projects at Raedthuys developed nowadays. The main risks from these markets are: the prices of artificial manure, the animal population, possible diseases and governmental law on manure.

The co-substrate market, on the other hand, is a still developing market with high value products when compared to the manure market. The market is still growing, with on average, more biomass availability in the future for the generation of electricity and heat. However, the prices are still very volatile in the market due to non-transparency and heterogeneous products, which pose a great risk for biomass sourcing. Besides, the governmental policy of creating a positive list has a negative influence on price volatility and the value of contracts. Other risks in this co-substrate market are European agricultural subsidies, waste disposal laws and alternative ways of using biomass (green chemicals).

7. Contracts in the biomass market

As was already stated earlier in this report, contracts are a quite new phenomenon in the biomass market. This can be explained using the four social analysis levels of Williamson (1998). In the first level - embeddedness - more awareness emerged for the environment in the last 10 to 15 years. Therefore, it became possible to develop renewable energy projects nowadays. Also the second level - institutional environment - developed favouring renewable energy projects. Take for example the introduction of the SDE subsidy regulation and the positive list. However, this level is still developing with the ever changing rates of the SDE subsidy and the emergence of a 'grey' area in the positive list. The bio-energy installation operators can therefore not rely on the legal system at this moment. Besides, the fourth level - resource allocation and employment - also developed. Due to some pioneering digestion installations one knows what quantities and kinds of biomass to use and what price is paid for electricity and heat (subsidy and energy market price). This level is although still in development and new research influences the way digestion installations are operated. The third level - governance - has never been given too much attention, mainly due to the fact the institutional environment and resource allocation levels are still in development. To make the market work efficiently, the institutional environment and resource allocation levels should be linked using governance structures and contracts. Therefore, this section pioneers on contracts in the biomass market and focuses mainly on contract duration. The information used is gathered from previous sections and the experience of the author in the bio-energy field.

This section is divided in three subsections, which will all three analyze the manure and co-substrate market. The first subsection applies the agency theory to the biomass market. The second subsection does the same for transaction cost economics. Subsection three analyzes contract duration and renegotiation in the biomass market. In a concluding fourth subsection the following research question will be answered:

> *What are the conditions under which contract structures should be developed in the biomass market?*

7.1 Agency theory

As was already outlined in section 5, the agency theory concerns incentives and risk sharing, but also has a more general goal of describing conflicting goals and deducting contract structures. In this section the agency theory is mainly used to describe the conflicting goals of the contract partners on the manure and co-substrate market, but also looks for conditions which need to be part of a contract structure.

7.1.1 Manure market

In the manure market, when closing contracts, Raedthuys is the principal. In the principal-agent theory, this principal should be risk-neutral and uninformed, but in the case of Raedthuys the principal can be marked as risk-averse and well informed. This is due to the fact the manure market is functioning efficient and information is reported to the public quite quickly. The agent is a manure supplier - mostly farmers, who is also informed and risk-averse. In these markets the agent can undertake three general actions with its manure, namely: use the manure on its own property, sell the manure to Raedthuys or sell the manure to a third party - another digestion installation operator or farmer. The utility of the famer is: the disposal of manure against a certain cost (manure price) - which diminishes the utility - and the obligation to regulations. When using the manure on own property, no costs are incurred. When, however, disposing to Raedthuys or a third party the manure price and some other costs (transport) have to be paid. Because the utility is the sum of the value of the action (manure disposal) and the payment to the agent (manure price), the utility is diminished when costs for disposal have to be paid. For a farmer, the best incentive is a low manure price. The utility for the principal is: the production of biogas, the manure price received (gate-fee) and the obligation to regulations - 50 % manure is required in digestion installations.

The utility of the farmer depends on the future state of the market environment, which is heavily influenced by regulation, manure availability and possible new applications of manure. For a farmer, the best choice is to use the manure on its own property, because it is quite sure the manure can be used and no disposal costs have to be paid. Besides, the manure price is not a competition vanguard in this market, due to the fact the price is determined now and in the future by the efficient functioning manure market. The long-term market developments, like the phosphate shortages and EU regulations, are reflected in the price immediately. Therefore, the competition for contracts will mainly focus on duration and risk avoidance.

Due to the fact information is available for both contract partners, there is no information asymmetry between partners and therefore no incentive constraint. There is no private information for one of the contract partners and a contract is influenced by general market uncertainty only. In this case an outcome-based contract structure can be best used to govern the relationship. One of the main reasons for using these contract structures is because manure is a low value product and the outcome - delivery of a certain amount of manure - can be measured easily and is quite stable in quality. Besides, it is hard to put information systems in place for a non-programmable production process of the agent. The costs of developing and introducing a monitoring system to control for manure production is just too costly for this low value product. Therefore, outcome-based contracts can be used best when closing a contract between Raedthuys and an animal manure supplier.

7.1.2 Co-substrate market

The principal in the co-substrate market is Raedthuys again, who is risk-averse in nature. The agent can be different actors, depending on the co-substrate submarket. In general the agents are agricultural organizations, the food industry or the animal feed industry and are mostly risk-averse. An agent in this market can take three possible actions concerning its co-substrates, namely: sell the streams to farmers/animal feed industry, sell them to Raedthuys or sell the biomass to another digestion installation operator. When selling the streams, the agent obtains an incentive in the form of a price paid for the co-substrates. The utility of the animal feed industry totally depends on the this incentive. The food industry, on the other hand, has an additional incentive in the form of waste disposal. The utility for Raedthuys is that it can now produce additional biogas and make profit, whereby the profits are heavily influenced by the price paid.

The utility of the principal and agent depends on the future state of the co-substrate market. Especially disposal laws, the positive list and the availability of biomass are influencing the price forming and the actions taken. When biomass becomes rarely in a market with higher demands, the actions of the food and animal feed industry will favour supply to biomass installations instead of farmers or the animal feed industry. Main competition for contracts in these markets will be prices, because supply security, due to infrequent availability of biomass, cannot be guaranteed. A contract with supply security, in the form of the basket contract paying an additional risk premium, is further researched in section 9. Its conclusion is, however, that the risk premium which has to be paid to gain security is too high. Therefore, supply security is currently not a base for contract competition.

When analyzing the information asymmetry in the co-substrate market, through the eyes of one of the most important suppliers – the animal feed industry – it can be stated this actor has some private information which can be used to act opportunistically. This private information emerges from the fact the co-substrate market is non-transparent for the digestion installation operator, it has no information on what products are available in which quantities. The animal feed industry, on the other hand, know from their secondary suppliers exactly what products will be available at what quantities over a year. This information is used strategically by the animal feed industry offering or withholding co-substrates from the market and influencing the price setting. Therefore, when the contracts are actually closed, it depends on the complexity of the contract and the amount of freedom of the agent if there is information asymmetry and therefore incentive constraints. When the contract is quite simple, and a certain amount of a specific co-substrate with a fixed price is specified, there is no information asymmetry. In this case the supplier delivers the biomass, and when he does not, the contract can easily be enforced on the terms stated in the contract. In the co-substrate market, however, it is difficult for contract partners to close these kinds of simple contracts, because co-substrates are not available frequently. When, for example, a contract is closed with an organization in the animal feed industry, the search process is outsourced to this organization. For the digestion installation operator this means it can save its search cost (see also 7.2.2.), but it is unsure which co-substrates are delivered. This is due to the fact the search effort put in to the process, and therefore the available co-substrates and price setting, cannot be controlled by the digestion installation operator. One can close a contract with the supplier on how much energy should be delivered by the co-substrates, but because the quantity of biomass that can be inserted into the installation is limited by permit, the animal feed organization is also limited in its operation. Therefore, an intensive search process is needed on behalf of the animal feed organization to supply the right co-substrates. Putting more or less effort in the search process – and thereby gathering more private information - gives the animal feed industry the possibility of gaining higher profits.

In addition, in this market, the outcome measurability is low - co-substrates can have different qualities over time - and the outcome uncertainty is high - co-substrates are available infrequently. In the food industry, on the other hand, the actions can be programmed and information systems can be installed to control the production process and thus the quality and availability of waste. In the animal feed industry, however, these kinds of systems are not possible. Therefore, a contract structure with both outcome-based as well as behaviour-based characters can be used best.

7.2 Transaction cost economics

The transaction cost economics is mainly concerned with finding the right governance structure for a particular transaction. Main goal of a governance structure is to accomplish order in a relation, so particular conflicts are solved and mutual gains are achieved. This subsection will identify the governance structures which can be used best in the manure and co-substrate market using the main variables of the transaction cost economics - frequency, uncertainty and relationship-specific investments. In addition, the transaction costs for the particular submarket will be identified.

7.2.1 Manure market

On the manure market 18,000 tonnes of manure need to be purchased. Because manure is a very voluminous product, all the purchased manure cannot be stored up front due to high costs. Therefore, recurrent transactions are necessary, or one transaction whereby the manure is delivered during the year. Besides, market uncertainty can be marked as quite low, because the market is safeguarded by competition. This low risk was also identified in subsection 6.2 which outlined a growing manure surplus in the near future.

Due to this competition, in theory, the market incurs no or little transaction costs. The search costs are relatively low, because when one knows where the digestion installation is situated one also knows which agricultural organizations will most probably have a manure surplus. Evaluating these possible contracting partners is, although, more difficult, when an agricultural organization is not already supplying manure to another trading partner. The contracting costs are also relatively low, because the trading position of the agricultural organization is weak and weakens in the future with an increasing manure surplus. In addition, there is also information available on market prices. Therefore, the contracting costs are low and a quite simple contract can be drawn. Due to little changes in quality and the possibility to easily measure the amount of manure delivered on a weighbridge, the monitoring costs are also low. The enforcement costs are relatively low, because the contract can be quite simple, and can be easily enforced.

Although a digestion installation operator invests, these investments cannot be marked as relationship-specific. First, one could identify site-specific investments. Due to the fact manure is a voluminous low-value product, the transportation costs per tonne of manure are high compared to profit per tonne. Therefore, a digestion installation should be located in or near a region with a large manure surplus. By locating in a specific region a digestion installation operator narrows the manure market down to a specific region. Second, it could also be stated a digestion installation operator invests in specific physical assets. A digestion installation is designed, so it is able to digest more than 50% manure and can suffice to regulations. A digestion installation operator is, therefore, locked-in to manure in a specific region. Besides, it could be stated some operators invest in dedicated assets to make the digestate produced more valuable. Examples are: a digestate water extractor (dryer) or a digestate separator, which separates digestion sediment from the liquid matter. Although there is a lock-in to a certain region with some dedicated assets, a digestion operator is not locked-in to one specific supplier. So, there are no relationship-specific investments in the manure market.

When using figure 5.2 it can be stated market governance should be used for transactions on the manure market. In market governance the market with its rules and norms is used as the main regulator. Contracts closed in this market governance are quite simple and all the problems are dealt with in the contract itself. Due to the fact there are just little relationship-specific investments and the transaction costs are low, short-term contracting with repeated bargaining can be used best according to transaction cost economics.

7.2.2 Co-substrate market

In the co-substrate market two kinds of transaction frequencies can emerge. The first type of transactions, mainly with the animal feed industry as partner, shall be recurrent, because most co-substrates cannot be stored up front in large quantities for a longer time. So, multiple transactions are necessary to gather the biomass for one year. On the other hand, there are also occasional transactions in the market - some co-substrates are not available structurally. An example of such a co-substrate is fruit juice. This co-substrate is only available when the initial production process fails and the fruit juice cannot be used for human consumption. Besides, the market is still developing on the supply and demand side and can be marked as uncertain.

The transaction costs are higher in the co-substrate market than in the manure market. First, the search costs are higher due to the fact the market is non-transparent. Therefore, a digestion installation operator does not know where certain co-substrates can be bought and should incur a long search process. Some search costs can be saved by using an intermediary, like the animal feed industry. These industries have far greater knowledge of the market and can find the co-substrates a lot faster. Although, this search process has to be paid for. Second, the initial contracting costs are higher, due to the fact contracting with digestion installation operators is not common yet in the co-substrate market. Therefore, a lot of negotiation should be performed up front. When the right contract has been found, the contracting costs of further contracts are lower. Third, the monitoring costs are also higher in the co-substrate market than in the manure market, because it is costly to assess the quality of a co-substrate. The quality can be assessed by analyzing co-substrate monsters in a laboratory. When for every delivery this task has to be performed, the monitoring costs are high. Therefore, in this market, a digestion installation operator should rely on the reliability of the supplier. Fourth and last, the enforcement costs can be higher in the co-substrate market depending on the complexity of the contract. When the contract is more complex the enforcement costs can be higher, because there can be a discussion on the contract clauses and if they have occurred. In general, the transaction costs in this market are higher than in the manure market.

In the co-substrate market no large relationship-specific investments can be identified. First, there can be site-specific investments. A digestion installation can be located near a factory producing a large co-substrate supply, such as a bio-ethanol factory. However, this is not necessary, due to the fact co-substrates have higher values and therefore lower transportation costs per tonne compared to manure. Second, there are no physical asset investments. It does not matter what kind of co-substrates are used in the installation, it is the mix of different co-substrates that matters. Third, there can be some investments in dedicated assets, but these are just minor. An example are silos where only specific kinds of biomass can be stored. Think of, for example, the difference between liquid and solid biomass. However, most silos can be used to store multiple kinds of co-substrates. In the end, it can be stated there are no large relationship-specific investments which influence transactions.

According to figure 5.2, transactions without relationship-specific investments, no matter if they are recurrent or occasional, are best guided by market governance. In this case, the market with its rules and norms is used as governor and other market actors need to be trusted. In this governance structure the legal system of the market and the information supplied by other actors which have traded with the supplier, are used to prevent opportunistic behaviour and to make a rational investment decision. In the biomass market the problem, however, is it is still in development and quite uncertain (transaction costs), so that market governance can probably not perform its task as government structure well. Besides, a digestion installation operator cares about the quality and other attributes of the product. Therefore, a combination needs to be made between trilateral governance (contracts) and market governance. The operator should not make large investments on one transaction partner and need to keep monitoring the market for other, more profitable, deals.

7.3 Contract duration and renegotiation

In subsections 5.4 and 5.5 a lot of theory has been outlined on contract duration and renegotiation. In general, these subsections identified relationship-specific investments, price volatility, codifiability and trust as important variables in determining contract duration. Besides, information asymmetry and cost of processing are important variables in assessing contract completeness and renegotiation. In this subsection the theory will be applied to the manure and co-substrate market.

7.3.1 Manure market

When taking Williamson (1972) and his transaction cost theory in mind, short-term contracts are the better choice in the manure market. Reason for this conclusion is that in the manure market no relationship-specific investments are incurred, which need to be earned back using a long-term contract. Although recurrent transactions are necessary in the manure market, these transactions do not incur high transaction costs as was outlined in 7.2.1. In cases with low transaction costs, repeated bargaining can be used over the subsidy regulation period, whereby new contracts are arranged often. These conclusions are supported by Li et al. (2009), who state that in a market with low price volatility, short-term contracts can be best used. As was already noted in subsection 6.2, the manure market is quite stable and should therefore use short-term contracts. Besides, when taking the codifiability variable - developed by Kleindorfer & Wu (2003) it can be stated short-term contracts should be used in the manure market due to high codifiability. The product can be easily specified, for example one tonne of pig manure. Besides, the delivery and settlement requirements are quite clear. An organization demands a certain amount of manure on a specified day. In addition, Kleindorfer & Wu (2003) state that when the product has low value, compared to other products and easily addressable quality, short-term contracts can be used best. A large drawback of these short-term contracts is that supply cannot be guaranteed between early September and late January. This is due to the fact a 'land treatment ban' is in effect - the farmer cannot use manure on its own land. In this period prices increase and a farmer is not willing to pay such a high price for the disposal of manure. In these cases storage capacity needs to be build (Uitrijverboden, n.d.).

By taking the theory of Ganesan (1994) about long-term orientation and trust, it can be stated the digestion installation operator has low mutual dependence on a single manure supplier. However, the supplier has high mutual dependence on the manure region the digestion installation is situated in. Taking in mind the fact that supply is difficult in certain periods using short-term contracts and that there are no large contingencies in the near future influencing contracts, there is also some support for the use of longer term contracts which are demanded by banks. These long-term contracts are necessary, because supply security is key in the digestion installation. In such cases Williamson (1972) advises the use of incomplete long-term contracts with profit sharing. If profit changing developments emerge, the supplier and buyer will share the risk. In such a contract the buyer/seller does not bear all risk when negative developments occur. The advantage is none of the contract partners force renegotiation then (Williamson, 1972).

To conclude, it can be stated short-term contracts can be used best in the manure market according to theory. In practice, however, long-term contracts are demanded for supply security. When, although, such long-term contracts are used, trust should be an important part of this contract. Goal is to find a credible supplier, so short-term problems are fixed on the longer term and opportunistic behaviour on the side of the supplier is reduced.

7.3.2 Co-substrate market

As identified in paragraph 7.2.2 the co-substrate market has low relationship-specific investments. According to Williamson (1972) in those cases short-term contracts can be used best. This idea is supported by Kleindorfer & Wu (2003) using their codifiability variable. In the case of co-substrates, the codifiability is quite high. This is due to the fact the product can be specified quite well - the delivery of a certain amount of tonnes of a product. However, the product quality can be codified easily, but is harder to test in practice. Besides, the delivery and settlement requirements can be addressed easily. An operator demands delivery of a certain amount of tonnes on a specified day. So, when using these two theories, short-term contracts can be used best.

On the other hand, there are some signs long-term contracts can be used best. First, due to the fact not all biomass can be stored up front, recurrent transactions are necessary. This continuous renewal of transactions has high transaction costs in the form of bargaining. Especially the search costs in these markets are high when using another supplier for a co-substrate. An advise by Williamson (1972) is to use continuous renewal of spot contracts, so some transaction costs can be saved. Besides, there is high price volatility in the market as was outlined in subsection 6.3. According to Li et al. (2009) long-term contracts are the better choice in these markets, because learning effects can emerge. In case of digestion installations these learning effects can be that the supplier learns over time what co-substrates can be used together and already reserves a mix of co-substrates in its planning. Li et al. (2009) advise to use long-term contracts with a minimum purchase quantity in these cases. On cases where the prices decrease, an operator can purchase the minimum quantity and purchase the rest of the co-substrates from the spot market. The immediate revelation of information is a large advantage of this long-term contract in the non-transparent co-substrate market.

However, the option of renegotiation is necessary in the co-substrate market for several reason. First, the information asymmetry in the market is high, due to the fact the animal feed industry has larger knowledge of the market and the co-substrates available for their customers. Second, the cost of processing contingencies in contracts is very high, due to the fact the market is still in development and due to increased demand price will increase. Third, there is no verifiable way of communication, because trade is bilateral and messages are often not recorded for the public. Besides, the suppliers are not committed to only one customer, because the food industry needs several customers to dispose all waste. Therefore, trust and renegotiation are key for contracts in the co-substrate market.

7.4 Conclusion

To make the biomass market work more efficiently, the institutional environment and the resource allocation level should be linked in the future by the governance level using contracts. In this section the contract conditions for the manure and co-substrate market are outlined.

In the manure market contract competition shall focus on duration and risk avoidance instead of price, using outcome-based contract conditions. The governance structure used should be market governance, due to the fact no relationship-specific investments are incurred and the transaction costs are low. In this market, according to theory, short-term contracts are the better option, due to low investments, high codifiability, low volatility and easily addressable quality. Long-term contracts are, on the other hand, needed, especially due to the fact manure is difficult to deliver in certain periods. Goal in these long-term contracts should be to find a credible supplier, who is able to fix short-term problems on the long term.

In the co-substrate market, the main basis for contract competition will be prices, because supply security cannot be provided due to the infrequent availability of biomass. Therefore, a contract structure with both outcome-based as well as behaviour-based characters can be used best. The governance structure which should be used, is a combination between market governance and trilateral governance. In the market there are both signs for using long-term and short-term contracts. Long-term contracts should be used, because there are recurrent transactions, the transaction costs are high and the market is price volatile. On the other hand, short-term contracts can be best used due to the fact there are no relationship-specific investments and the products can be codified quite easily. A general advice for an operator is not to get locked-in to one supplier, because due to rapid developments new profitable market possibilities can arise. When, although, long-term contracts are closed the option of renegotiation should be included, because the co-substrate market has some information asymmetry, the cost of processing contingencies is high and there is no verifiable means of communication due to bilateral trade.

8. Contract structures

Section 6 identified the current risks on the manure and co-substrate market and section 7 pioneered on the conditions under which biomass contracts are developed. In this section contract structures which can be used on both markets are outlined using the conclusions from sections 6 and 7. These conclusions or conditions which influence the contract developments are summarized in appendix 7.

This eight section is divided in three subsections. The first subsection outlines contract structures for the manure market. The second subsection does the same for the co-substrate market. In the third and final subsection an answer is given to the following research question:

> *What contract structures can be used in the biomass market taking the current organization and conditions of the biomass market in mind?*

8.1 Manure market

As was identified in sections 6 and 7, the manure market has a growing manure surplus in the future, whereby the price will be mainly influenced by artificial manure developments and governmental law on manure. Therefore, in the short-term the manure price will rise, but on the longer term will drop again. Besides, due to the fact no relationship-specific investments are incurred, short-term contracts with market governance which are outcome-based can be used best. In addition, competition should focus on contract duration and risk avoidance.

In the manure market two different contract structures can be used. Due to the fact short-term contracts can be used best in the manure market, the continuous renewal of short-term contracts - contracts of 1 year - is one option. In this contract structure, a fixed price is set for the next year with an option of a contract renegotiation at the end of the year. Such a contract structure should be used in a region where the manure surplus is large. The renegotiation of short-term contracts is possible in the manure market, due to the fact the transaction costs are rather low. Especially, when using repeated bargaining with the same supplier of manure, also the search costs can be saved. A disadvantage of this contract is, however, that the supply security demanded by financial institutions cannot be guaranteed.

A second contract structure is a long-term contract for the full period of the SDE subsidy, which can be obtained for a period of 12 years. When closing a contract for a longer period, the risk of both contract partners - Raedthuys and a farmer - is covered for a very long period, which gives a utility to both partners in the form of supply/demand security. The manure price paid by the farmer can, for example, be fixed on the average manure price in the specific region over 2009. However, as identified in section 6, the general trend is the prices will rise due to stricter regulations and a larger manure surplus in the near future. For a farmer, this average manure price of 2009 is a good incentive, due to the fact in the coming years it has to pay more to dispose its manure. For Raedthuys, on the other hand, this price is not good, because it can earn more in the future. Therefore, the best contract to use is a long-term contract with profit sharing, whereby the price paid is determined by a base price (the average DCA manure price over 2009) plus 50% of the price drop/rise on the manure market. If, for example, the average manure price over 2009 was €15, and during a certain month the prise has risen to €16, the manure price in the contract will be €15,50. Another system can also be used, but the goal is to adjust the contract price to actual market prices, although security of supply is guaranteed. In this case, the farmer has an incentive to remain the contract till the end, because it now has to pay less to dispose a tonne of manure. However, it has to be noted when on the longer term the prices of manure will drop, due to phosphate shortages, the contract structure works the other way around. With this contract structure Raedthuys has supply security on the longer term, a contract partner which receives an incentive to remain the contract till the end, and a contract which follows the positive developments on the manure market. Another option is to close a longer-term contract for a period of 3-5 years with a fixed price. This is due to the fact in the years 2013 to 2015 changes occur in European law on animal manure. The trend shall be that the law will be stricter and the manure surplus will be larger. When the contract is for a longer period than 5 years, Raedthuys will ultimately force renegotiation, because due to rising manure prices the market becomes more profitable. After this 3-5 year period another contract with new clauses could be negotiated.

8.2 Co-substrate market

As identified in sections 6 and 7 more biomass is available in the future on a currently very price volatile market due to non-transparency and heterogeneous products. However, one does not know how much demand will increase, can supply keep up with demand in the future? Besides, the market is influenced in the future by governmental risk in the form of the positive list and SDE subsidies. Contracts in the co-substrate market should focus on price, because supply security cannot be guaranteed and can be of the outcome-based as well as behaviour-based type. Besides, short-term and long-term contracts with market and trilateral governance can be used. An operator must, however, be aware not to get locked into one supplier and should keep the option of renegotiation open. When developing contract structures for this market a distinction needs to be made between products which are structurally available (grass and maize) and products which are not structurally available. In this last category products are situated originating from failing production processes, also called Good Manufacturing Process (GMP) invaluable products.

For the structurally available products the continuous renewal of contracts can be used. When continuously renewing the contracts with one contract partner, a trustworthy relationship can be build, and on the other hand the developments of the fluctuating co-substrate market can be followed. The contract is composed of two subcontracts. The first subcontract is one of longer-term (3-5 years) where the supply of a certain tonnage of co-substrates is negotiated (volume contract). With this contract the supply security can be guaranteed. The second subcontract focuses on a shorter-term (1 to 6 months) and determines the co-substrates actually delivered against a certain price (price contract). For different co-substrates the contract duration can differ, so that risk is spread over several periods. With this system of two subcontracts, transaction costs can be saved, although supply security is guaranteed and market movements can be followed.

In the market where products are not structurally available short- and long-term contracts cannot be closed, due to the fact the supplier does not know what products will be available in the future and does not want to take the risk. In this market one should buy on a bilateral spot market. A possibility, however, is to make a kind of energy-mix, a product with around the same quality figures over time but composed of different products. The contract structure for this energy-mix is the basket contract. Within this long-term contract structure (trilateral governance) a basket of different co-substrates is supplied to Raedthuys, whereby the supplier is given the possibility to vary with the co-substrates in this basket. For example, a supplier can put barley, wheat and distillers' wash in the basket, but can for the next month also substitute barley for energy maize. This basket has, however, always the same energy density for the digestion installation, so Raedthuys can pay a fixed price for the basket. With this contract, the heterogeneous products are made homogeneous by putting them in a basket with a certain energy density. The supplier can be controlled on the average energy density of the basket and therefore this contract can be marked as outcome-based. Besides, within this contract structure, the supplier is given the incentive to look for a basket with lower cost. In the end, this can give innovative mixes against low costs, which could be used in basket contracts with other suppliers for a lower fixed price. With this contract structure, the digestion installation operator is not locked-in to one specific co-substrate, so the risk can be spread. Although, the operator should trust its contract partner in searching for innovative co-substrate baskets. This contract structure is empirically tested in section 9.

8.3 Conclusion

When taking the developments on the biomass market and the conditions under which contracts need to be developed, five contract structures can be developed. The first three contract structures can be used on the manure market, the latter two on the co-substrate market.

- Continuous renewal of short-term contracts of 1 year
- Long-term contract for the full length of the SDE subsidy with profit-sharing
- 3-5 year contract with a fixed price
- Combination of a long-term volume contract and a short-term price contract
- Basket contract for an energy-mix of co-substrates

9. The basket contract

The basket contract is a contract structure where financial theory meets the biomass market. The goal of the contract structure is to arrange a long-term fixed price for a basket of biomass co-substrates. At the same time the contract allows the supplier, within certain limits, to vary with the kind of biomass co-substrates supplied. The basket contract is able to solve the problem of large price fluctuations in the market by giving the buyer a fixed price. Besides, also part of the information asymmetry between actors can be solved, due to the fact price and quantity information needs to be shared to make the system work. Starting point for the development of this new contract structure is the modern portfolio theory developed by Harry Markowitz (1952).

In this section the current situation of determining what biomass to use is described first. Second, the general principles on modern portfolio theory and a simple example are outlined. Third, the modern portfolio theory is applied to the biomass market. In this subsection also the fixed price and biomass variation mechanisms are explained. Fourth, the contract structure is tested in practice by using price and quality data from the biomass market. Fifth, the drawbacks of the system are outlined. Sixth and last, a conclusion is drawn on the relevance and effectiveness of the basket contract in the biomass market.

9.1 Determining biomass use

Nowadays, Raedthuys receives information on the availability, quality and price of the co-substrates (biomass streams) which can be delivered by a supplier. A co-substrate is a 'high' quality product which can be added to the manure to heighten the gas production. From this long list of co-substrates, Raedthuys picks a few which are used as input for the digestion installation. Selection criteria for these streams are: dry and organic matter, gas production, toxic by-products, gate-fee (price Raedthuys receives), cost price (price Raedthuys pays), revenues from gas production, and the revenues/costs from digestate disposal. There are a lot of selection criteria, but most important is the biomass streams are, on balance, making profit. This profit, which can be derived from a mathematical calculation, is then used to determine the Internal Rate of Return (IRR). A graphic representation of this process is provided in figure 9.1.

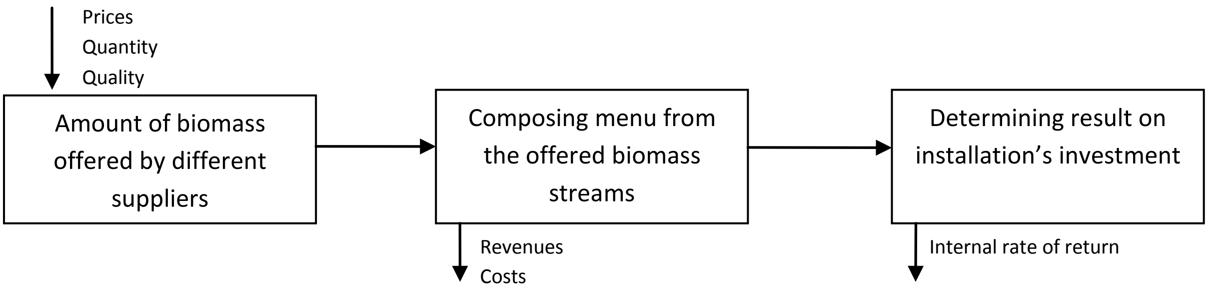

Figure 9.1. Determining biomass use at Raedthuys nowadays.

This current situation has, however, some disadvantages. First, the price information used is often of one period and not of multiple periods. Due to this fact, the price development cannot be observed and a too high or too low price can be paid. Besides, the current situation does not assess the risks involved. It only takes yield, costs and profit into mind, and does not pay attention to possible price fluctuations. The basket contract is developed to solve these kind of disadvantages.

9.2 Modern portfolio theory

In this section the basis of the basket contract - modern portfolio theory - is outlined. This subsection contains two parts, namely a description of the general theory and a simple example.

9.2.1 General theory

Modern portfolio theory was developed in the 1950's by Harry Markowitz and was awarded the Nobel prize in Economics in 1990. The most important publication on the modern portfolio theory was already published in 1952 in The Journal of Finance and is titled *'Portfolio Selection'*. In this article Markowitz describes his theory on the optimization of portfolios - a combination of securities. The idea behind these portfolios is that by combining several securities, the expected return can be optimized against the risk beard. In finance, risk and return are always positively correlated. When risk increases, an investor demands higher returns to compensate for the extra risk. Markowitz (1952) defined expected return as the discounted value of future dividend streams (formula 1). Risk can be quantified by determining the standard deviation of a security. In finance, the standard deviation is often also referred to as volatility (formula 2). For example, a security can have an expected return in the following 3 years of 11% and a standard deviation of 2.8% (Moore & McCabe, 2005: p43).

Formula 1: $E(R_s) = \frac{1}{n} \sum R_s$

Formula 2: $\sigma_s = \sqrt{\frac{1}{n-1} \sum (R_s - E(R_s))^2}$

R_s = Return Security
$E(R_s)$ = Expected return security
n = Amount of cases
σ_s = Standard deviation security

As was already outlined, the idea behind portfolio theory is by combining securities in a portfolio, risk can be minimized against a certain return. This is possible, because every security has two kinds of risk, namely systematic and unsystematic risk. Systematic risk can be seen as events or changes effecting all securities. Examples are; changes in tax laws or fiscal and monetary policies. On the other hand, unsystematic risk only effects one type of security. For example, when a company loses a large customer, the securities of that company will devalue. Modern portfolio theory states unsystematic risk can be avoided by diversifying the portfolio - the investor is then left with only systematic risk. However, in literature there is still discussion about what is exactly systematic and what is unsystematic risk. Lubatkin & Chatterjee (1994) state factors often defined as unsystematic risk also have an influence on systematic risk. Examples are; transaction costs, entry barriers and competitive advantage (Lubatkin & Chatterjee, 1994). In the end, this does not mean unsystematic risk cannot be reduced by diversifying, but not all unsystematic risk can be avoided.

Unsystematic risk can be minimized due to the fact returns of securities are not moving in perfect lockstep with each other. This means when the expected return of one security increases with 10% another security can increase with 5% or any other amount. There are even securities where the expected return decreases when those of other securities are increasing (Markowitz, 1952; Markowitz, 1991). In statistics these movements can be measured with a correlation coefficient, which can be defined as: '*the strength and direction of the linear relationship between two quantitative variables*' (formula 3). The correlation can be perfectly positive (+1) or perfectly negative (-1), but can also take every value in between (Moore & McCabe, 2005, p101). When the correlation is perfectly positive two securities move in the same direction with the same amount. When the correlation is perfectly negative, two securities move in opposite directions with the same amount. Searching for securities which have negative correlations reduce portfolio's risk.

Formula 3: $\rho = \frac{1}{n-1} \sum \left(\frac{R_{s1} - E(R_{s1})}{\sigma_{s1}} \right) \left(\frac{R_{s2} - E(R_{s2})}{\sigma_{s2}} \right)$

ρ = Correlation coefficient
S_1 = Security 1
S_2 = Security 2

William Sharpe developed the idea by Markowitz further and introduced beta (β) to modern portfolio theory. With β the security's sensitivity to market movements can be measured. However, to determine β an organization needs to know what the most efficient market portfolio is. For stocks this is quite easy and indexes such as the NASDAQ or AEX can be used. However, for a lot of other derivates this is quite difficult or impossible, because there is no index available. Therefore main variance analysis is still widely used today.

Besides, Sharpe added the Sharpe ratio to modern portfolio theory. With this ratio the most efficient portfolio can be found by searching for the highest risk premium to standard deviation. In this case the risk premium is the return on the portfolio minus the return on a risk free investment (often state owned bonds) (Brealey, Myers & Allen, 2008).

9.2.2 Simple example

To make this theory more clear, a simple example is outlined below. For this example the formulas 1 to 6 are used to determine the expected portfolio return and the portfolio standard deviation. The formulas originate from Markowitz (1952) and Brealey, Myers & Allen (2008).

Formula 4: $E(R_p) = \sum_i w_i E(R_i)$

Formula 5: $\sigma_p^2 = \sum_i w_i^2 \sigma_i^2 + \sum_i \sum_j w_i w_j \rho_{ij} \sigma_i \sigma_j$

Formula 6: $\sigma_p = \sqrt{\sigma_p^2}$

$E(R_p)$ = Expected portfolio return
w_i = Share security in portfolio
σ_p^2 = Portfolio variance
σ_p = Portfolio standard deviation

Imagine an investor has the choice to buy 100 stocks and he can choose from security A with an expected return of 15% (formula 1) and a standard deviation of 10% (formula 2), or from security B which also has an expected return of 15% but a standard deviation of 20%. An investor without knowledge of modern portfolio theory would invest all his money into security A, because this security has lowest risk to return (15% return against 10% risk). However, when the investor knows the stocks have a negative correlation of -0.5 (formula 3), another combination of stocks is more profitable (see calculations below). By diversifying in a portfolio with 60 securities X and 40 securities Y, the investor has reduced risk to 7.21% with the same expected return of 15%.

$E(R_p) = 0.6 * 15 + 0.4 * 15 = \mathbf{15\%}$ (Formula 4)

$\sigma_p^2 = (0.6)^2 * (10)^2 + (0.4)^2 * (20)^2 + 2(0.6 * 0.4 * -0.5 * 10 * 20) = 52$ (Formula 5)

$\sigma_p = \sqrt{52} = \mathbf{7.21}\%$ (Formula 6)

9.3 Modern portfolio theory applied to the biomass market

This subsection addresses the issue of applying the modern portfolio theory to the biomass market. First, in a general section, the communalities between the modern portfolio theory and the biomass market are outlined. Second, the fixed price mechanism is explained using normal distributions. Third and last, the biomass variation mechanism is outlined.

9.3.1 General

Biomass streams can be compared to securities in different ways. First, both can be combined in portfolios. Just like an investor can choose from a lot of different securities offered on the market, a biomass digestion installation operator can choose different kinds of biomass streams. These biomass streams can be combined in a portfolio or, like they call it in the biomass sector, a biomass menu. Within these menus, biomass streams are combined; and through a mathematical model; the joint composition in terms of gas production, toxic by-products, digestate and profit can be computed. This menu can be used to determine the effect of biomass sourced from all suppliers or just from one supplier. For the development of a contract structure the latter is of utter importance.

A second similarity is that both securities and biomass have systematic and unsystematic risk. Take for example the stream distillers' wash which was already used earlier in this research. When the government issues a law to increase the tax on alcohol, less alcohol is demanded and therefore the production is decreased. Due to this production cut, there is also less waste product in the form of distillers' wash. On the other hand, there can also be unsystematic risk involved. Take for example a case where due to bugs the whole hop harvest is lost. So, both systematic and unsystematic risk influence biomass availability.
Third, the prices of biomass are also fluctuating over time, just like securities do. However, biomass prices are also not moving in perfect lockstep with each other. Therefore, for biomass streams it is possible to compute correlations and to reduce risk.

A problem for biomass streams is that you cannot compute a return or risk just like in modern portfolio theory. First and foremost, within the biomass market there are no organizations or persons occupied with price and return forecasting as is the case in the securities market. To solve the problem of making biomass streams comparable to securities, history prices are taken (p_i). The risk is then assessed by taking the fluctuation on prices (σ_i). The drawback is, however, by taking the prices over time an error occurs. This error occurs, because the quality of biomass also fluctuates over time. For example, in 2005 the stream distillers' wash had a dry matter percentage of 22% and in 2007 this percentage has dropped to 20%. To control for this problem the price per tonne of dry matter (%dm) can be used (p_{di} and σ_{di}). See also formula 7 and 8 below. Drawback of this system is that when streams have the same price per percentage of dry matter, those streams with higher dry matter percentages per tonne of product are more valuable. This is due to the fact the licence only permits a certain usage of tonnes.

Formula 7: $p_{di} = \frac{p_i}{\%dm}$

Formula 8: $\sigma_{di} = \frac{\sigma_i}{\%dm}$

Besides, to be able to derive correlations, as much data points as possible are needed. This is necessary, because more data points give higher reliability. To derive reliability, the research opts to gather data from early 2005 to late 2009. When this is not possible correlations are only used when reliability exceeds 95%. When not exceeding 95%, correlations are excluded from the dataset or handled more careful.

With the information about prices and quality and the 8 formulas listed above the same exercise can be executed as was mentioned in paragraph 9.2.2. There are, however, two differences. First, the exercise is more complex, due to the fact there are more than 2 biomass streams involved. Second, before the exercise, the contract duration needs to be chosen. This is the case, because for different contract durations different average prices and standard deviations can be computed. For example, a longer contract duration can have more risk involved, and therefore a higher standard deviation. In the end, the basket contract searches for a basket (e.g. 60% maize, 20% soy and 20% animal fat) which has highest profit to risk - just like the Sharpe ratio was developed for. However, because this research uses profit instead of return the Sharpe ratio cannot be used. Therefore, the Raedthuys ratio - profit to standard deviation (profit to risk) - is used. This Raedthuys ratio is used as the parameter which needs to be maximized.

Formula 9: $Raedthuys\ ratio = \frac{P_m}{\sigma_m}$

P_m = Menu's profit per tonne
σ_m = Menu's risk per tonne

Now, all ingredients are in place to map modern portfolio theory to the use of biomass in digestion installations; by reducing unsystematic risk with the maximization of the Raedthuys ratio. However, before the idea is empirically tested, the two paragraphs below reflect on the two most important parts of the basket contract - the fixed price and biomass variation mechanism.

9.3.2 Fixed price mechanism

An important part of the basket contract for Raedthuys is the fixed price. This fixed price is important, because it gives more price certainty to the investment model. However, the question is what fixed price to set in a basket contract?

From the calculations of the basket contract two variables are important, namely the average price (π_m) and the risk (σ_m) of the basket. The average price is calculated using formula 4 and risk by using formulas 5 and 6. Besides, it has to be taken in mind the average of a lot of cases can be mapped by μ and the distribution of cases around this mean can be approached by a standard normal distribution . This is also called the central limit theorem (Moore & McCabe, 2005).

Left exception value	Z-value
50%	0
60%	0.26
70%	0.53
80%	0.84
84%	1
90%	1.28
97.7%	2

Table 9.1. Left exception values and z-values ($\mathbf{\mu = 0 \text{ and } \sigma = 1}$).

When the relationship between the supplier and customer was one of pure risk-sharing they would choose to set the fixed price π_m (see also figure 9.2). This price would be arranged, because in this case 50% of the price risk is beard by the supplier and the other 50% by the customer. So the supplier is paid a fixed price and in 50% of the cases the price is lower/higher than π_m. However, some suppliers are not willing or able to close a contract of pure risk-sharing and demand a risk premium for the fixed price. In these cases σ_m comes into play - the spread of the values around π_m. If the supplier demands more security, a risk premium should be added to the fixed price of π_m according to the amount of security demanded. This risk premium can be found by using the z-values outlined in table 9.1. If a supplier, for example, demands 70% security, then 0.53 * σ_m should be added to π_m (Formula 10). So, the fixed price will depend upon π_m, σ_m and the risk position of the supplier.

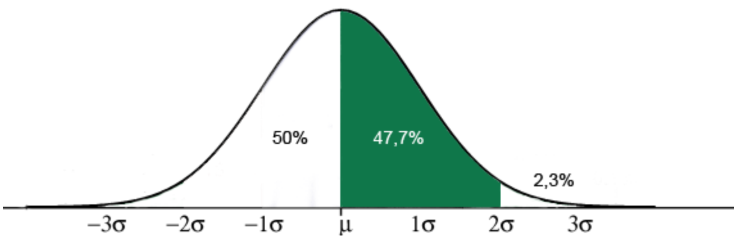

Figure 9.2. Normal distribution

Formula 10: *Fixed price* = $\pi_m + z * \sigma_m$

9.3.3 Biomass variation mechanism

Another important part of the basket contract is the biomass variation mechanism. This mechanism is necessary, because the suppliers do not want to fix the price until they have the possibility to vary with the biomass supplied. At the outset of the contract, a standard menu will be set for a fixed price with a fixed quantity and can contain all sorts of biomass. This standard menu has the highest Raedthuys ratio possible. An example is 3000 tonnes of maize, 2000 tonnes of fat and 1000 tonnes of soy hulls. However, it is difficult for the supplier to always purchase the right quantity of biomass, and is therefore given the opportunity to vary. So, if for example in December maize is not available any longer, the supplier can offer barley instead of maize.

Two kinds of negative side effects do emerge when this mechanism is implemented. First, the supplier now has an incentive to deliver all the waste to the customer, because it is getting the fixed price anyway. Therefore, some kind of punishment should be introduced for not supplying the at first demanded menu. One can think of a fixed price punishment or a discount on the fixed price for every time the supplier substitutes a stream. This idea can also work the other way around - give an incentive to the supplier every time it delivers the at first demanded biomass streams. A second negative side effect is that another type of biomass can have a negative effect on the profit, because all biomass streams have their own composition of raw fat, raw protein, raw ash, raw fibre and dry matter. When a stream is substituted, the gas production can be distorted, and the profit can drop. Therefore, the supplier should always have to search for streams which are comparable to the stream which cannot be delivered.

This substitution can also be translated into a financial ratio. Let´s call it the substitution ratio (formula 11). When substituting a stream, this ratio should be maximized.

$$\boldsymbol{Formula\ 11}: Substitution\ ratio = \frac{P_{m2}/\sigma_{m2}}{P_{m1}/\sigma_{m1}}$$

m_1 = Standard menu
m_2 = Menu after substitution

9.3.4 Conclusion

To summarize, the following steps need to be taken, in theory, to construct a basket contract:

a. Gather historic data on price developments of biomass streams.
b. Determine the contract duration.
c. Determine correlations between biomass streams.
d. Determine μ and σ for every biomass stream separately for the given contract duration.
e. Determine a basket of biomass by varying with the shares and maximizing the Raedthuys Ratio for the given contract duration.
f. Determine basket's profit before fixed price using average prices over the contract period.
g. Choose risk perception and accordingly the fixed price.
h. Determine basket's profit after the fixed price is set and compare this profit to the wishes of the board of directors.
i. Let the basket contract do its work, and vary with the biomass according to the substitution ratio.

9.4 The basket contract in practice

To test the basket contract in practice, data on prices and quality are gathered from the biomass market. An animal feed organization was willing to supply price and quality data on biomass streams. Below, a basket contract for this supplier is designed using the steps identified in paragraph 9.3.4. How and when other programs, such as SPSS and Excel are used, is also mentioned below.

9.4.1 Animal feed organization

a. <u>Historic data</u>

Historic data from 45 products is supplied, dating back to 2005. The total amount of cases is 61, and the duration between two measure points is around one month. This can be a few days more or less, depending on the date the list was produced. However, from January 2008, no data could be obtained and this month is left out.

Not from all products data could be obtained from all 61 data points. After leaving out products without enough data or products not on the market any longer, 39 products remain. These products are listed with their quality figures in appendix 8.

b. Contract duration

Five different contract durations can be used, ranging from 1 to 5 years. For this research, a contract of 5 years is used. This is done, because the influence of longer duration on a contract is interesting for Raedthuys.

c. Correlations

The correlations between the biomass streams are summarized in appendix 8. These correlations were computed, using the statistical/mathematical program SPSS. The following option is used: Analyze -> Correlate -> Bivariate -> Pearson. However, before computing the correlations, the variables were first normalized using formulas 7 and 8. The correlations are therefore not per tonne of product but per tonne of dry matter.

As can be noted from appendix 9, some correlations are flagged with a red background colour. These are correlations not exceeding the 95% reliability. Because these are quite a few correlations, the correlations are not excluded from the dataset, but need to be handled with more care. However, one biomass stream is excluded from the dataset, because all its correlations were not exceeding the 95% reliability. This is product AM. In the end, 38 streams are left and can be part of the basket contract.

d. Determine μ and σ

The average price and standard deviation were computed for all five years using SPSS. The following option was used: Analyze -> Descriptive Statistics -> Descriptives. A summary of the values can be found in appendix 10. These values are per tonne of product, so it is easier to make a marketable contract.

e. Optimal biomass menu

The optimal biomass menu can be determined by using an internal mathematical Excel based system developed by Raedthuys. The most important input parameters of this system are: gate-fee (positive or negative prices) and quality figures (%dry matter, raw fat, raw protein, raw fibre and raw ash). Using all sorts of different formulas, the model computes several output parameters, such as the amount of biogas, digestate, total profit and toxic by-products. In the end, a linear optimization function is run to determine a biomass menu which has highest total profit. In the case of Raedthuys profit after biomass purchase and digestate disposal is used. In the new situation the optimization function does not use total profit, but instead uses the Raedthuys Ratio (RHR) as optimization variable. Due to the fact the Raedthuys Ratio uses a quadratic function to determine its risk parameter, also a quadratic function is used to determine the optimal biomass menu. When using this quadratic optimization function, one has to be aware of the fact quadratic functions compute multiple optimizations. Therefore, the optimization needs to be run from different base situations in Excel - which give different optimal ratios. After comparing these optimization ratios one can determine what the optimal Raedthuys ratio is.

To compare both systems an optimization has been run on two parameters: profit after biomass purchase and digestate disposal; and the Raedthuys ratio. The biomass streams used as input are the biomass streams as outlined above, as well as some other biomass streams necessary to keep the installation in accord with law and operating effectively. For the sake of clarity these (extra) streams are not called by name. Instead they are called: manure 0, manure 1, manure 2, co substrate 0, co substrate 1 and co substrate 2. However, due to the fact for these extra streams no information on correlations and risk are available, the output needs to be split in two different parts. At first, there is the menu with streams from other suppliers and the animal feed organization. Second, we have a basket - which can be fitted into a contract - of streams from the particular animal feed organizations. Both are outlined here, but the analysis focuses on the streams from the animal feed organization in the next steps. Besides, it need to be noted a single biomass stream can never exceed 2,000 tonnes. This rough premise is built into the model to keep the model more realistic, else shortages on the side of the supplier can arise.

After running the optimization, the mathematical system determined the streams with their amounts - as outlined in appendix 11 - give the optimal result. Both systems use 36,000 tonnes as input for the installation of which 18,000 tonnes is manure. The profit optimizing menu has a profit of €1,490,992 and the basket (/b) contributes €274,076. The Raedthuys ratio menu has a total profit of €1,254,493 and the basket contributes €423,557. As can be noted the profit is higher in the Raedthuys ratio menu, but the overall profit is higher in the profit optimizing menu.

	Profit optimization	RHR optimization
Amount /t	9,341	9,736
Profit /b	€274,076	€423,557
Profit /t	€29.34	€43.51
Price /t	€29.77	€61.60
SD €	€6.07	€4.95
SD %	20.4%	8%
RHR	4.84	8.79

Table 9.2. Key information profit optimization and RHR optimization of the basket.

When analyzing the basket further it can stated the risk of the RHR basket is lower than of the profit basket. The risk is **€4.95** for the RHR basket and **€6.07** for the profit basket, or **8%** and **20.4%** respectively. Besides, it can be noted the Raedthuys ratio for the RHR basket is higher than for the profit basket, namely **8.79** against **4.84** (see also table 9.2). In the end, it can be concluded the RHR basket has lower risk than the profit basket, but profit of the total menu is lower.

f. <u>Basket's profit before fixed price</u>

As was already noted, the profit before fixed price of the profit basket is **€274,076** and of the RHR basket is **€423,557**. Due to the fact both baskets use a different amount, the profit per tonne (/t) is also of importance. For the profit basket the profit per tonne is **€29.34** and for the RHR basket is **€43.51**.

g. <u>Choose risk perception and fixed price</u>

The risk perception of the supplier is for this example put at 80%. When using tables 9.3 and 9.4 it can be stated the risk premium to be paid per tonne for the profit basket is **€5.10** or **17.12%** of the price per tonne. The fixed price per tonne of biomass would then be **€34.86**. On the other hand, when taking the RHR basket, the risk premium is lower and is only **€4.16** per tonne of biomass or **6.75%** of the price per tonne. The fixed price per tonne of biomass would then be **€65.76**.

	Price /t	RP €	RP %	Fixed price	Profit /t	Total profit
50%	€ 29.77	€ 0.00	0.00%	€ 29.77	€ 29.34	€ 274,066.13
60%	€ 29.77	€ 1.58	5.30%	€ 31.34	€ 27.76	€ 259,330.36
70%	€ 29.77	€ 3.22	10.80%	€ 32.98	€ 26.12	€ 244,027.84
80%	**€ 29.77**	**€ 5.10**	**17.12%**	**€ 34.86**	**€ 24.24**	**€ 226,458.28**
84%	€ 29.77	€ 6.07	20.38%	€ 35.83	€ 23.27	€ 217,390.12
90%	€ 29.77	€ 7.77	26.09%	€ 37.53	€ 21.57	€ 201,520.84
97,7%	€ 29.77	€ 12.13	40.77%	€ 41.90	€ 17.21	€ 160,714.11

Table 9.3. Risk perception profit basket.

	Price /t	RP €	RP %	Fixed price	Profit /t	Total profit
50%	€ 61.60	€ 0.00	0.00%	€ 61.60	€ 43.51	€ 423,597.43
60%	€ 61.60	€ 1.29	2.09%	€ 62.89	€ 42.22	€ 411,067.29
70%	€ 61.60	€ 2.62	4.26%	€ 64.23	€ 40.89	€ 398,055.22
80%	**€ 61.60**	**€ 4.16**	**6.75%**	**€ 65.76**	**€ 39.35**	**€ 383,115.44**
84%	€ 61.60	€ 4.95	8.04%	€ 66.55	€ 38.56	€ 375,404.59
90%	€ 61.60	€ 6.34	10.29%	€ 67.94	€ 37.17	€ 361,910.59
97,7%	€ 61.60	€ 9.90	16.07%	€ 71.50	€ 33.61	€ 327,211.74

Table 9.4. Risk perception RHR basket.

h. Determine profit after fixed price
The profit after fixed price is **€226,459** for the profit basket and **€383,115** for the RHR basket. It can be stated the profit of the profit basket has been decreased by **€47,618** or **17.12%** to arrange a fixed price. The profit of the RHR basket has been decreased with only **€40,442** or **6.75%**.

Conclusion
In the end, it can be concluded the system chooses another composition of biomass streams for the profit optimized basket and the RHR optimized basket. For the profit basket those streams are chosen which have highest profit per tonne and for the RHR basket those streams which have highest profit to risk. The effect of the optimization on the RHR is a lower amount of profit lost when arranging a fixed price with the supplier than in the case of the profit optimization.

9.5 Drawbacks of the system

The system as was outlined in subsection 9.3 and 9.4 has some drawbacks which make the system less dependable besides the fact historic developments cannot be easily mapped onto the future. The drawbacks can be centred around four problems: the normal distribution, reliability, structural availability of biomass streams and the biomass variation mechanism. These problems are further outlined below.

To make the system of fixed prices to work, the biomass streams need to be normally distributed around their respective means. The streams are, however, not normally distributed. This can be proven by using two statistical variables, namely: skewness and kurtosis. Skewness tells something about how skew the distribution is or in other words if the median is located left or right of the mean. If the skewness is positive, then the long end of the distribution tail can be found at the higher values. The kurtosis tells something about the curve of the distribution. If the kurtosis is positive the top of the distribution is higher than of a normal distribution. A normal distribution has a skewness and kurtosis of 0 (Huizingh, 2006).

The kurtosis and skewness of the biomass streams are outlined in appendix 12. As can be noted, the skewness and kurtosis of most biomass streams does not approach 0. The cause of this problem are not the outliers, because they do not exist for most streams. Therefore, it can be stated most of the biomass streams offered by the animal feed organization are not perfectly normally distributed and cannot be used in the system as developed in this section.

The general perception in the biomass market is, however, prices are fluctuating more during the last years. Therefore, it could be possible for the system to work for earlier years when this trend was not in place yet. Due to the fact the animal feed organization only offers data from 2005 onwards, data is taken from the Landbouw Economisch Instituut (LEI), just like in subsection 6.3, to test this hypothesis. Data on prices was gathered from 2000 to 2009 for three streams which are also on the list of the animal feed organization, namely turnip scrap, barley and silage maize. Their respective skewness and kurtosis are outlined in table 9.5. In this case a period of 5 years is chosen, because the data also encompass a 5 year period. As can be noted, the skewness was between 0.3 and 0.7 points lower in 2000-2004 than in 2005-2009. Therefore, according to this data, it can be stated there is more price variability in the later years.

Years	Product	Skewness		Kurtosis	
		Statistic	*SE*[4]	*Statistic*	*SE*
2000-2004	Turnip Scrap	.116	.309	-.201	.608
	Barley	.958	.309	.566	.608
	Silage Maize	.653	.309	-.329	.608
2005-2009	Turnip Scrap	.857	.309	-.275	.608
	Barley	1.248	.309	.295	.608
	Silage Maize	.923	.309	-.272	.608

Table 9.5. Skewness and Kurtosis for LEI data 2000-2004 and 2005-2009 (LEI, 2010).

This conclusion is, however, rather rough, because the standard error is not taken into mind. This brings us to another large problem of the system - reliability. The drawback was already addressed in subsection 9.4 when the correlations were computed. Besides, also the kurtosis and skewness computations are not reliable, because their standard errors of the mean are higher than 5%. The reliability drawback is a general thread throughout the whole basket contract and can in the end lead to false conclusions. The largest cause of this drawback is the lack of testable data.

A third drawback is the fact the basket contract can only be used for structural available biomass streams. However, in the biomass market a lot of biomass streams are only available during one season or when a production process fails. Because these occurrences cannot be predicted the availability of these streams are unsure. Therefore, also the correlations and risk are difficult to determine for these streams. When over the years enough data is gathered for these streams a conclusion can be drawn on its risk. However, when computing correlations one has to be very aware of the large time gaps between data points and possible developments outside the biomass market which can have caused the correlation.

The fourth and last drawback is the biomass variation mechanism. As already outlined, there is high probability Raedthuys is not supplied the products asked for on first instance, because there is an incentive for the supplier to supply the 'left-overs' to Raedthuys. When a certain product cannot be delivered to all the customers of the supplier, it starts delivering alternative products to Raedthuys first and then cuts on supply to other customers. In the end, this can lead to large negative effects on the electricity/heat production.

9.6 Conclusion

In this section a contract structure, called the basket contract, is developed using the modern portfolio theory by Markowitz. As was stated, the modern portfolio theory can be mapped onto the biomass market for three reasons. First, biomass streams can be combined in biomass portfolios or menus. Second, biomass streams show systematic as well as unsystematic risk. Third, price fluctuation is an important feature of biomass streams and therefore correlations can be computed. To work in theory, the model should be based on prices instead of returns, the fixed price and biomass variation mechanisms should be added; and two optimization ratios should be introduced (Raedthuys and substitution ratio).

[4] SE = Standard Error

In practice, however, the basket contract shows some drawbacks. First, the biomass streams are not perfectly normally distributed, which results in a not working fixed price mechanism. Second, there is a reliability problem, which makes the chance of false conclusions pretty high. Third, some biomass streams are not structurally available. Fourth, the biomass variation mechanism gives an incentive for the supplier to deliver the 'left-overs' to Raedthuys. Taking these drawbacks into mind, the general conclusion is the basket contract is too uncertain for a million Euros contract, and should therefore not be used in practice right now. However, when the price fluctuation stabilized, and is not influenced by the large run on biomass and the credit crunch any longer, the basket contract should be reconsidered again.

An alternative is to use the basket contract as an internal rule of thumb to enhance the profit/risk orientation of the company. The system can be used in step 2 of figure 9.1; determining the optimal biomass menu. Different short- or long-term orders, with their correlations, can be added to the menu and the optimal biomass menu can be determined using the Raedthuys and substitution ratios.

10. Conclusion

In the previous sections all research questions formulated in section 2 were answered. In this conclusion the information gathered by answering the research questions in used to answer the problem definition in subsection 10.1. Subsection 10.2 identifies recommendations from this conclusion. The problem definition as formulated in section 2 states:

> *How can Raedthuys use contract structures in the biomass sector to obtain more investment security on the purchase of biomass?*

10.1 Conclusion

The production organizations in the bio-energy market, like Raedthuys, need to source biomass from the market to operate their installations. The biomass market is, however, a container definition of several submarkets, containing all sorts of products. This research mainly focused on positive list digestion installations sourcing biomass from agricultural organizations, the food industry and the animal feed industry. This conclusion is divided in two parts, concluding on the manure market and co-substrate market for positive list digestion installations.

The manure market is nowadays a quite stable market with low volatility. In the future, according to several outlooks, the manure surplus is increasing and the manure price will rise on the short-term. However, governmental developments and the price of artificial manure have a large influence on future prices. For contracts to work in the manure market the focus should not be on price competition, but on contract duration and risk avoidance to solve farmers' problems. When closing contracts a contract partner does not have to make relationship-specific investments and the transaction costs are low. Therefore, short-term contract structures can be used best in this market. One contract structure which can be used is the continuous renewal of short-term contracts of one year. In this contract structure, a fixed price is determined for the next year with an option of contract renegotiation at the end of the year. Another possibility is a long-term contract for the full length of the SDE subsidy with profit sharing. In this contract the price is set at the average manure price of 2009 and this price increases/decreases with market movements. Both market actors then have an incentive to remain the contract till the end of the period. Due to the fact in the period between 2013 and 2015 changes emerge in the manure market, another option is to use a long-term contract for 3 to 5 years with a fixed price. When changes occur in the market the contract can be renegotiated. So, for this efficient functioning market, rational investment decisions can be taken, by using the free available market information and by trying to predict the future. Investment security, can then be gained by using subsequent short-term contracts or by closing a longer-term contract with profit sharing. However, the future poses a lot of uncertainties in the form of regulations and new techniques which can hamper a rational investment decision.

The co-substrate market is a still developing market with more biomass availability in the future. Due to the increased demand of biomass, the general trend in the future shall be that biomass prices are increasing. The market is however non-transparent; and with heterogeneous products and an inconsistent governmental policy, the future is unsure in the Netherlands. Due to this uncertainty, contracts cannot focus on duration and risk avoidance, but instead should focus on prices using market or trilateral governance. Long-term contracts can provide investment security in this market, but the uncertainty makes market actors anxious to close these contracts. In addition, the heterogeneous products in the different submarkets ask for different contract structures. For products which are structurally available a possible contract structure is the continuous renewal of contracts, using a longer-term contract for the security of supply (certain amount of tonnes) and a shorter-term contract for determining the price and actual co-substrates delivered. For a submarket with products not structurally available, spot market purchases can be used best, due to the fact suppliers are anxious to use longer-term contracting on these products. A possible contract structure which can supply investment security in this submarket, is the basket contract. This contract structure puts several co-substrates together in a basket with a certain energetic value and fixed price. Within this contract the supplier has the possibility to vary with the co-substrates of the basket. In the end, in the co-substrate market investment security can be obtained within certain limits. Security cannot be obtained for the whole subsidy period and can only be obtained for the supply of a certain amount of co-substrates. Therefore, a rational investment decision is hard to take, because one is unsure of what happens in the future on availability and prices. The option of renegotiation is therefore key in the co-substrate market.

In theory, investment security can be obtained for some biomass, using contract structures suited to the biomass market. However, practice shows other results, as was noted in developing the basket contract. The market is currently not ready for these kind of complex contract structures, due to the fact the market is low on standardization. Therefore in these markets, trust between contract partners and renegotiation are even more valuable in creating investment security than contract structures. In addition, rational investment decisions can only be taken in this market when the SDE subsidy regulation is stabilized, and all market partners have the same grounds to act on.

10.2 Recommendations

The conclusions from the previous subsections also have an influence on the principal of this research: Raedthuys. This company is still developing its biomass projects, although they already closed a contract for the supply of manure and one co-substrate for a certain project. The case that the company is still in the development phase is a strength, making the company free in assessing all market opportunities.

For the manure market, Raedthuys can use one of the contracts mentioned in subsection 10.1. Due to the fact this market is quite transparent and functions efficient, a market newcomer has the necessary information to close complete contracts. In the market, investment security can be gained by closing a long-term contract with profit sharing, so that market movements are followed and incentives are in place to remain the contract till the end of its duration. However, due to the fact the market functions efficient, there are no relationship-specific investments and the transaction costs are low, Raedthuys should not use a contract longer than 3 years at first. The company is then not locked-in to a contract and has to possibility to close better contracts when market changes occur due to regulation changes in the future.

The co-substrate market, on the other hand, is not that developed yet and therefore the advice is to start small in this market by, at first, using one supplier which gathers all sorts of co-substrates. Main reason for this is most market information is available on the side of the supplier. By closing longer-term contracts with such a supplier, it is likely a contract is closed which favors the supplier most. The general recommendation is therefore to find a suitable supplier in the market and start developing a trust relationship with this partner. This partner can be used as a guidance on the market, supplying information on the market structures and operation. On the other hand, an incentive to the supplier needs to be given in the form of how a combination of streams is performing in the digestion installation. With this partner what is working on the market and inside the digestion installation can be assessed. An example are standardization rules in contracts. After a while, innovative new contract structures can be developed. A possibility is to use two subcontracts with this supplier. First, a supply contract for the next three years and second a price contract on the actual delivery of co-substrates and their price. This gives the freedom to experiment.

Raedthuys should, however, be aware not to get locked-in to one supplier's knowledge and should therefore assess other market possibilities during these three years with the information gained from its supplier. After these three years, this market assessment, together with the developed contract structures, can be used on the wider market, closing more profitable contracts.

11. Discussion

In this section the added value of the research to the biomass market and contract theory in general are outlined. In addition, the quality of the research is addressed using reliability and validity. In the end, some possible additional research fields are identified.

By identifying market developments, contract conditions and actual contract structures, this research pioneered on contract research in the biomass market. For individual organizations in the bio-energy market, like Raedthuys, the research showed possible contract structures based on the conditions in the market and the market outlook for the next years. When following the advice of this research, these organizations do not waste time any longer by researching contract structures not applicable to the market. Besides, these bio-energy organizations are now able to show commercial banks what is possible in the current biomass market. Commercial banks should probably adjust their expectations towards bio-energy operators on only providing finance when long-term security on the supply of biomass is guaranteed. In addition, this research introduced risk in the form of the Raedthuys ratio in the menu determination of digestion installations. With this introduction, digestion installation operators do not only think about profit any longer, but also about profit security and risk premiums which could possibly be paid. In addition, organizations can now actively search for streams which correlate negatively and can therefore choose for more profit or more investment security. However, this research is just the beginning of a more 'mature' biomass market. Especially on standardized rules and the development of a 'playing field' by the government, developments are necessary to evolve the market to an efficient functioning commodity market.

The added value of this report to scientific research mainly comes from the application of the modern portfolio theory to a whole new field - the theory as basis of a contract structure. It has to be noted, the modern portfolio theory performs quite well in its new field, and most of the assumptions behind it could be transferred. Besides, the report added to scientific research on the application of multiple theories on contracting. However, this research field is quite broad, containing research on power relationships, long- and short-term contracting, risk positions, competition and much more. Especially, two rivalry theories - the agency and transaction cost theory - were used. Most important lesson from using these theories is that they should not be used separately but complement each other. Due to the broadness of this field a thorough overview could never been given and thus a selection was made. This selection influenced the information gathered on the biomass market.

To address the quality of the research, the threads to the reliability and validity are outlined below. In general, the reliability says something about the consistency of the research. The validity says something about the correctness or degree of support for an inference (relation between cause and effect). For this discussion the classification of validity in four subcategories is used as was developed by Shadish, Cook & Campbell (2002). The four subcategories identified are: statistical conclusion, internal, construct and external validity.

A research is reliable or consistent when the outcomes, methods and situations of the research can be replicated (Campbell et al., 2002). In the case of this research the reliability can be doubted on the application of contract theory to the biomass market and the subsequent development of contract structures. Because this part could not be based on qualitative research performed in the field, it is based on the experience of the author gained at Raedthuys. Other persons can carry different experiences and would probably come to other conclusions. In addition, the market is developing rapidly and in the future other, more sophisticated, data could be gathered with other conclusions as effect.

Two threads can be identified to statistical conclusion validity - inference about co-variation between two variables (Campbell et al., 2002). The threads are the low statistical power and the unreliability of measures on the basket contract. These threads can lead to large confidence intervals and weakens the relation between two variables. This problem was already addressed in section 9, where is stated the measurement errors are large and therefore the reliability of this section is low. Therefore, this section may have incorrectly concluded there is a relationship between variables which are part of the basket contract. On the other hand, the correlations between two co-substrates with large errors may have been downplayed and their relationship was in fact stronger. This problem could be easily solved in the following years - additional data gathered shall decrease confidence interval size. Therefore, additional research should be performed in the future on the basket contract when the market is not influenced by the credit crunch any longer.

One thread can be identified to internal validity - whether the relationship between two variables is causal (Campbell et al., 2002). The thread is that several variables outside of the biomass market can have caused relationships between two co-substrates in the basket contract. A general influence throughout the whole research is the credit crunch, which has caused large drops on raw material pricing. Therefore, because all prices dropped, it could have been incorrectly concluded the co-substrates are correlated to each other.

The construct validity - the degree to which inferences are warranted from the persons, settings and operations sampled with a study to the construct these samples represent - is quite good (Campbell et al., 2002). First of all, the research tried to find multiple authors on the same ground theory, such as the transaction cost economics. This was done to prevent a mono-operation bias, and to place the theory against some counter arguments by other authors. A thread to the construct validity is that on some theories the assumptions behind the theory had to be ignored. An example is the assumption that the agency theory rules out risk attracted behaviour, whereby the principal is risk-neutral and the agent risk-averse. Due to the fact the principal Raedthuys is risk-averse, this theory could have lower predictability.

The external validity - does the causal relationship holds over variations in persons, settings, treatment and measurement variables - is quite good but has a few threads. First, the conclusions on the basket contract could have been different if other co-substrates were used with other correlations. This is, however, a general thread throughout the whole research. Biomass is a container variable with lots of different categories and products. Therefore, a conclusion on the digestion category cannot hold for other categories in the biomass market. Besides, the same story can be outlined for the units analyzed. For this research a sample is taken of individual farmers, the animal feed industry and the food industry in general. When focusing on other kind of suppliers or single suppliers other factors could emerge which are important in closing contracts.

As was stated throughout this research the biomass market is still in development. Therefore a lot of additional research can be performed which can shape the market to more mature development stages. This is one of the fields where additional research can be performed, mapping the market development stages in the biomass market. As was noted in the introduction, the market developed rapidly, but is still in a stage where it is not suited to the demand of the market actors. Research could focus on how the biomass market can be transferred to the next development stage.

Another important development, necessary to transfer the market to the next development stage, is the standardization of biomass products. This is necessary to give a bio-energy operator the possibility to assess prices easily for products of a certain quality. The development is already going on in the combustion sector. The wood pellets often used in combustion installations have become standardized commodities already. For the digestion sector this standardization is harder - the quality of the products can fluctuate - but necessary, when the use of co-substrates increases with the growing amount of installations. The wood pellet market can function as a starting point for this additional research.

Main starting point of this research was theory and not practice. However, practice can also be used as starting point, namely by performing actual market research. Questions can be asked to multiple kinds of market actors - digestion installation operators, food industry, famers, animal feed industry and bio-ethanol producers - on what contracts they already use, what contract structures are demanded and what other possibilities they might have identified in the market. This quantitative survey research should identify what works in the market and this can then be combined with what contract structures work in theory.

Additional research could also be performed on governmental policy development. The current policy of positive list biomass creates market imbalances and volatility. Additional research can focus on how the government could create a better 'playing field' with stable possibilities of biomass trade. One could, for example, think of creating a nationwide biomass index. Such policy can help in creating a stable investment climate.

A last possible research could focus more on the production process of the installation. Due to the fact most co-substrates are not available structurally, one has to buy co-substrates when they are available against a profitable price. Therefore, an installation operator has to use the biomass in the installation directly or should store the biomass near the facility. The research could focus on what is technically possible in the installation and what the costs are for storing biomass instead of using it directly into the digestion installation.

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Appendix 1: Research strategy

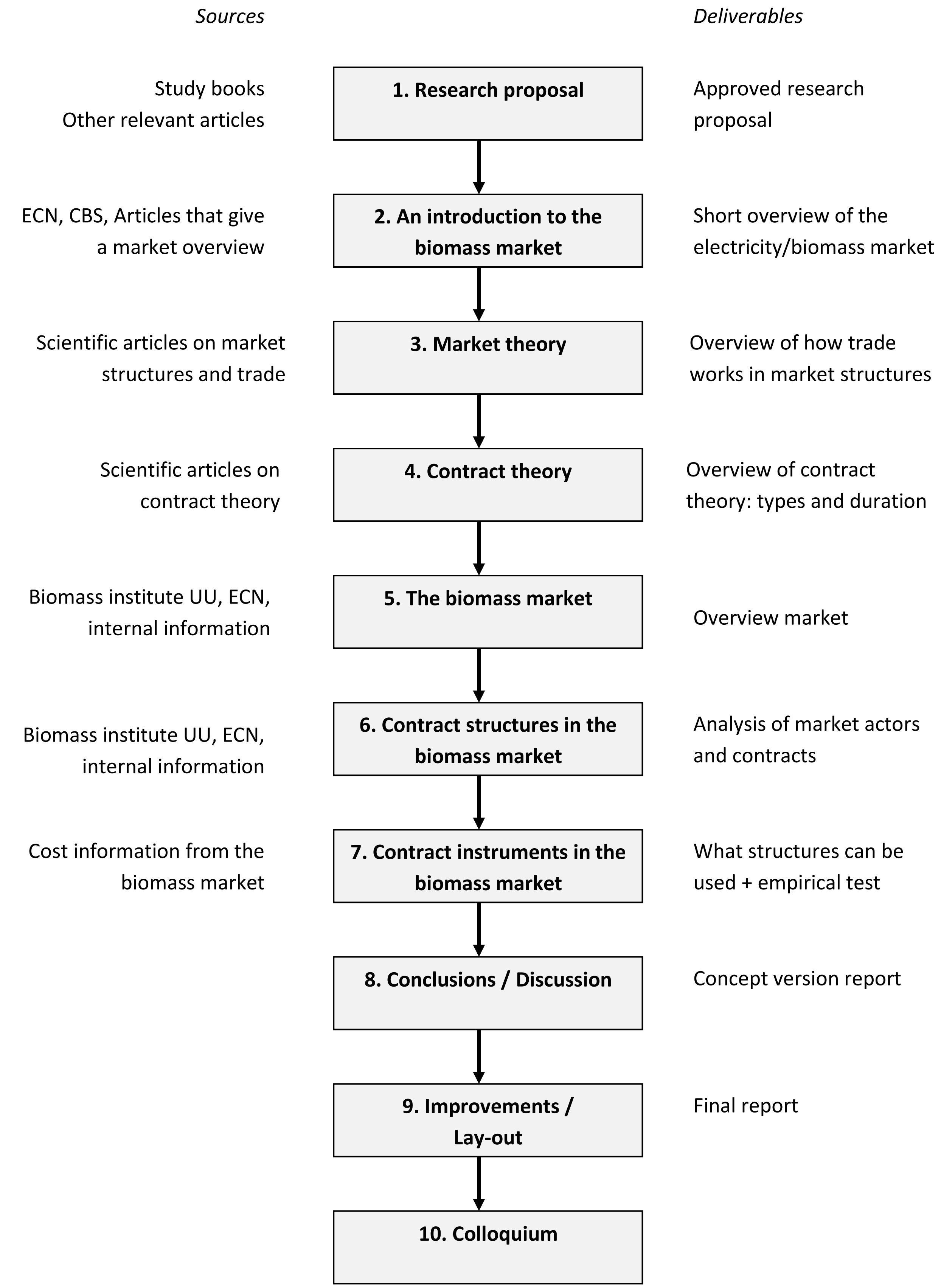
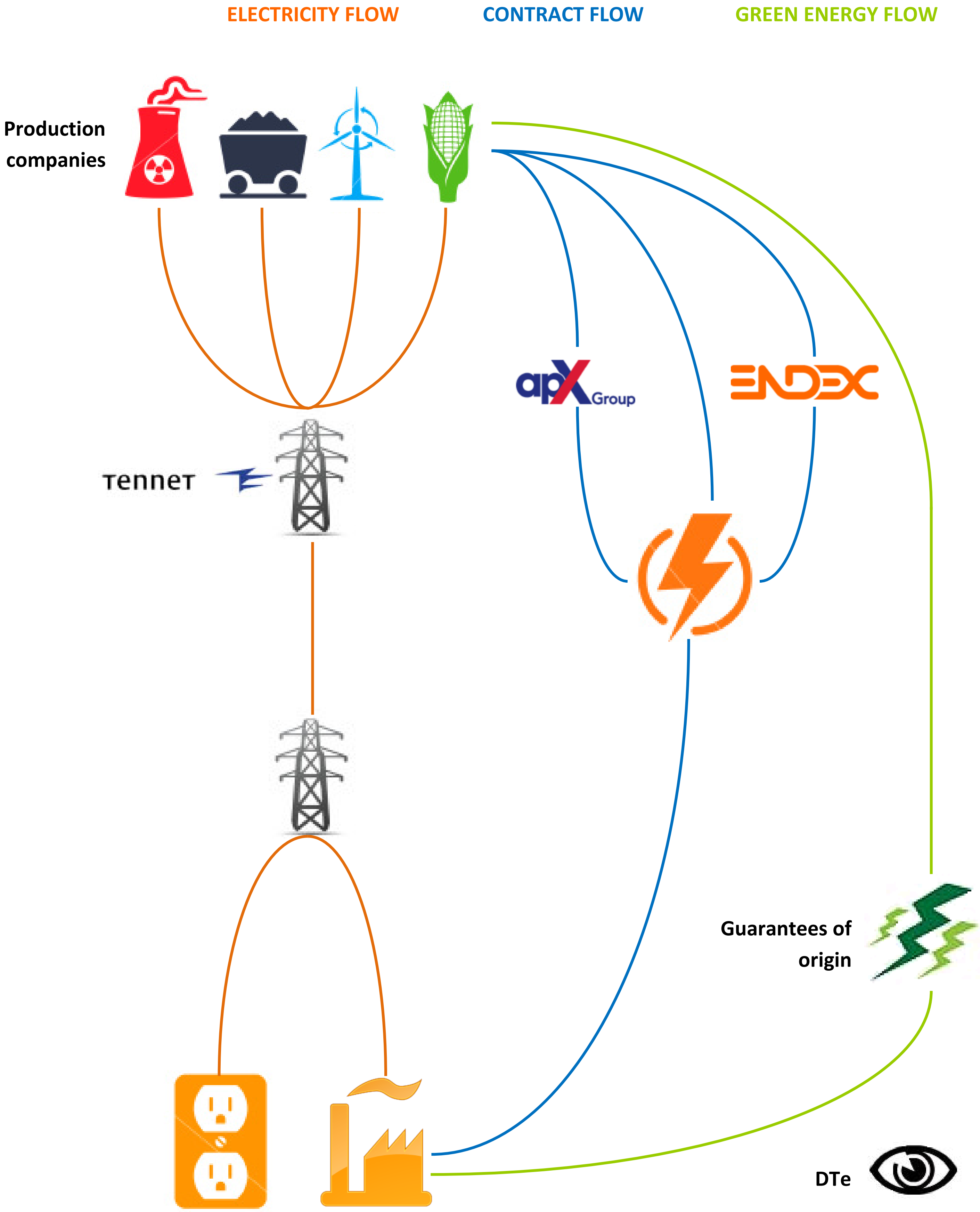


Figure 1. Research Strategy.

Appendix 2: The electricity market structure



Appendix 3: Statistics renewable energy in the Netherlands

Technique used	1990	1995	2000	2005	2006	2007	2008	%[1]
Water power	0.8	0.8	1.2	0.7	0.9	0.9	0.8	0.7
Wind energy	0.5	2.8	6.9	17.2	22.5	28.2	35.1	30.7
Solar energy	0.1	0.2	0.5	1.1	1.1	1.1	1.2	1.1
Surroundings energy	0.0	0.3	0.8	2.3	3.2	4.1	5.4	4.7
Biomass	16.7	18.7	28.2	59.3	62.2	61.5	71.6	62.8

Table 1. Fossil energy avoidance in TJ for different types of renewable energy.
[1] Share in renewable energy.

Technique used	1990	1995	2000	2005	2006	2007	2008	%[2]
Waste incineration	6.093	6.117	11.417	11.874	12.400	12.979	12.716	17.8
Co-firing of biomass in energy plants	0	0.033	1.755	30.522	29.445	15.702	19.692	27.4
Wood stoves in companies	1.308	1.636	1.806	1.914	2.145	2.382	2.508	3.5
Wood stoves of individuals	6.231	5.334	5.701	5.464	5.464	5.464	5.464	7.6
Other biomass burning	0.440	0.577	2.317	4.397	5.319	5.632	9.111	12.7
Biogas from landfill	0.336	2.050	1.934	1.580	1.500	1.406	1.307	1.8
Biogas from waste water treatment plant	1.866	2.197	2.299	2.127	2.068	2.132	2.262	3.2
Biogas on agricultural companies	0	0	0	0.078	0.456	1.441	2.845	4.0
Other biogas	0.497	0.834	1.013	1.151	1.364	1.412	1.679	2.3
Biofuels for road transport	0	0	0	0.101	1.979	13.031	14.032	19.6
Total	16.770	18.778	28.242	59.208	62.140	61.581	71.617	100

Table 2. Fossil energy avoidance in TJ for different types of biomass techniques.
[2] Share in total biomass production

Year	Biogas collection (TJ)	Electricity production (GWh)	Heat production (TJ)	Gas usage (million m³)	Fossil fuel avoidance (TJ)	CO2 emission avoidance (kton)
1990	468	4	15	14	497	29
1995	826	7	69	22	834	48
2000	974	16	155	22	1013	59
2005	1158	31	119	24	1151	69
2006	1382	42	197	25	1364	82
2007	1475	65	171	21	1412	87
2008	1782	97	189	20	1679	105

Table 3. Renewable energy from other biogas.

Source: Centraal bureau voor de statistiek. (2009). *Duurzame energie in Nederland 2008*. Den Haag / Heerlen.

Appendix 4: Different kinds of biomass

Main Group	Group	Sub Group	Examples
1. Woody biomass	1.1 Fresh garbage wood		Pieces of wood Wood scrap Wood for energy production
	1.2 Wood processing industry	1.2.1 Chemical non treated wood	Saw-dust Wood pellets Cut wood (from trees)
		1.2.2 Chemical treated wood	*Not mentioned*
	1.3 Used wood	1.3.1 Chemical non treated wood	Separately collected A-quality wood
		1.3.2 Chemical treated wood	Separately collected B-quality wood Separately collected c-quality wood
2. Not-woody biomass	2.1 Agriculture	2.1.1 Grain crops	Grain (straw)
		2.1.2 Grasses	Bank grass, Grass straw, Hemp, Flax, Miscanthus
		2.1.3 Oil seeds	Oil, Straw, Skin, Shred
	2.2 Industry by-product		*Not mentioned*
3. Fruit	3.1 Fruit and tree cultivation		*Not mentioned*
	3.2 By-products from fruit industry		*Not mentioned*
4. Other	4.1 Other biomass from processing industry	Food industry	Food industry products Deep-frying oil Filter clay Fat acids Dry waste streams Animal fat
		Kitchens	Swill
	4.2 Garbage collection	Kitchen and Garden waste	Kitchen and garden waste
		Garbage	Garbage
		Waste paper and cardboard	Waste paper and cardboard
		Textile	Textile
		Shredder waste	Shredder waste
		Municipality cleaning waste	Municipality cleaning waste
	4.3 Manure	Manure	Chicken manure Bovine animal manure Pig manure
	4.4 Water treatment	Sludge	Sludge from water treatment
5. Recovered fuels	5.1 Recovered fuels		Compost waste
			Wood waste from construction industry
			Paper sludge
			Paper and plastic pellets

Table 1. Biomass categorization (Senternovem, 2005).

Appendix 5: Biomass from the food industry

Kind of waste stream	Waste stream
Animal	Fats
	Other butcher waste
	Greaves
	Reservoir fat
	Feathers
	Specified risk material
	Blood
	Low fat fish waste
	Not born manure
Vegetable	Deep frying oil from catering industry
	Dried beet pulp
	Beet molasses
	Distillers' wash
	Vinasse (distillery residue)
	Potato peels
	Wet beet pulp
	Potato fiber
	Potato tick juice
	Potato parts
	Cacao hulls
	Rejected potatoes
	Potato proteins
	Grain concentrate
	Cacao waste
	Potato cutting loss
	Deep frying oil from potato industry
	Coffee sediment
	Beet root tails
	Union selection waste
	Filter clay
	Vegetable waste

Table 1. Waste streams from the food industry which can be used efficient (Novem, 2002).

Appendix 6: Biomass availability in 2020

Stream	Present (ktonne dry matter)					Available (ktonne dry matter)				
	2009	***1***	***2***	***3***	***4***	***2009***	***1***	***2***	***3***	***4***
Straw	935	935	935	935	935	-	94	140	94	187
Grass straw	85	85	85	85	85	-	4	6	4	9
Wet vegetation agriculture	985	742	742	742	742	-	-	148	186	297
Wet vegetation horticulture	356	280	280	280	280	-	-	70	84	140
Green manure	70	70	70	70	70	-	-	14	14	28
Fruit and arboriculture	80	130	130	80	80	80	52	78	64	64
Wood from no harvest forest	376	376	376	376	376	-	-	38	38	75
Wood from harvest forest	1244	1244	1244	1244	1244	150	62	249	373	498
Landscape wood	480	480	480	480	480	1	48	96	144	192
Nature grass	1080	1080	1080	1080	1080	-	54	162	270	378
Berm grass	640	640	640	640	640	8	32	168	320	512
Heath land	146	146	146	146	146	-	-	-	29	44
Cane	40	40	40	40	40	1	-	-	12	16
Energy crop (agriculture)	9900	9900	9900	9900	9900	-	50	99	-	50
Energy crop (no agri)	500	500	500	500	500	-	25	50	125	250
Wood from residents	280	280	280	280	280	280	280	280	280	280
Wet biomass residents	490	490	-	-	490	-	25	-	-	-
Grass for bio refinery	10000	10000	10000	10000	10000	-	-	-	100	200
Scrap wood processing	576	576	576	576	576	383	383	383	383	383
Solid (chicken) manure	2972	2933	2538	2933	2538	1501	2346	2030	2346	2030
Semi-liquid manure	4892	5131	3624	4222	3321	978	257	181	2533	1993
Water treatment waste	341	349	349	349	349	341	349	349	349	349
Biomass from water	0	-	-	3	5	-	-	-	3	5
Swill	2	-	-	-	-	2	-	-	-	-
Potato scrap	178	178	178	178	178	45	45	45	22	22
Oil seed scrap	3093	3093	3093	3093	3093	9	9	9	93	93
Animal wheat	213	213	213	213	213	213	213	213	85	85
Potato starch	415	415	415	415	415	-	104	104	52	52
Cacao hulls	56	56	56	56	56	56	56	56	56	56
Coffee sediment	16	16	16	16	16	16	16	16	16	16
Sugar beet waste	132	132	132	132	132	-	33	33	17	17
Distillers' wash	100	100	100	100	100	-	-	-	-	-
Vegetable waste	23	23	23	23	23	23	6	6	3	3
Fish waste	15	15	15	15	15	-	0	0	0	0
Fat waste	100	100	100	100	100	100	100	100	100	100
Frying oil	130	130	130	130	130	130	-	-	-	-
Kitchen and garden waste	659	738	738	738	738	74	738	738	738	738
Paper sludge	256	317	289	284	264	232	288	262	258	239
Textile	95	95	95	95	95	15	15	15	15	15
Old wood	1337	2072	1764	1858	1564	1089	1824	1517	1610	1089
Waste HHA	2758	3895	3493	3307	2921	2700	3895	3041	3307	2483
Waste industry	827	1082	1017	998	916	810	1082	885	998	778
Waste KWD	1104	1226	1173	1170	1082	1080	1226	1021	1170	919
Auction waste	32	32	32	32	32	25	25	25	25	25
Compost overflow	30	30	30	30	30	30	30	30	30	30
SRF	0	-	-	-	-	108	-	-	800	800

Table 1. Biomass availability in 2020 (Senternovem, 2009b).

Appendix 7: Conditions influencing contract development in the biomass market

Manure Market	Co-substrate market
Market developments	
Efficient functioning market with full information Increasing manure surplus in the near future Phosphate shortages in the future	Inefficient market (still developing) Increasing supply and demand in the future Price volatile market Positive list changes can emerge
Agency Theory	
Focus contract competition on duration and risk avoidance Outcome-based contracts	Contract competition on prices Information asymmetry up front or when search process outsourced to intermediary Outcome-based and behaviour-based contracts
Transaction Cost Economics	
Recurrent transactions No or little transaction costs No relationship-specific investments Market governance	Recurrent or occasional transactions High transaction costs No relationship-specific investments Market governance and trilateral governance
Contract Duration	
Short-term contracting is the best according to theory Long-term contracting can also be used due to little contingencies in the future	Short-term contracts due to absence of investments and possibility to codify Long-term contracts due to high transaction costs Renegotiation due to large contingencies in the market

Table 1. Conditions influencing contract development in the biomass market.

Appendix 8: Quality of products

	Quality[5]					
	%DM	*RP*	*RF*	*RC*	*RAS*	*Unit*
Product A	33	74	25	180	44	ds
Product B	12	145	10	65	75	ds
Product C	15-18	245	35	70	140	ds
Product D	40-50	20	5	30	15	ds
Product E	22	80	4	25	30	ds
Product F	28	95	15	125	40	ds
Product G	15-18	73	215	40	235	ds
Product H	60	95	10	40	40	ds
Product I	24	110	10	50	65	ds
Product J	20-22	247	106	178	42	ds
Product K	25-27	247	106	178	42	ds
Product L	26	98	7	199	74	ds
Product M	24	85	12	236	99	ds
Product N	25	285	70	35	95	ds
Product O	42	150	28	85	33	ds
Product P	83	145	28	280	105	ds
Product Q	84	43	12	420	80	ds
Product R	84	41	26	435	60	ds
Product S	83	83	28	375	85	ds
Product T	87	82	44	22	12	Product
Product U	86	111	13	24	15	Product
Product V	87	104	17	46	21	Product
Product W	88	23	5	53	57	Product
Product X	90	80	10	170	80	Product
Product Y	92	105	7	128	77	Product
Product Z	90	80	10	170	80	Product
Product AA	91	63	20	121	61	Product
Product AB	90	155	45	350	50	ds
Product AC	91	147	83	196	43	Product
Product AD	89	187	36	73	60	product
Product AE	87	458	19	62	59	Product
Product AF	97	469	19	36	65	Product
Product AG	87	335	26	120	67	Product
Product AH	87	329	36	131	67	Product
Product AI	89	313	19	223	66	Product
Product AJ	89	277	26	268	60	Product
Product AK	91	168	25	271	109	Product
Product AL	92	330	70	74	54	Product

Table 1. Quality of products.

[5] %DM = percentage dry matter, RP = Raw Protein, RF = Raw Fat, RC = Raw Fibre, RAS = Raw Ash, Unit = g/kg dry matter or g/kg product.

Appendix 9: Correlations products

	Product A	Product B	Product C	Product D	Product E	Product F	Product G	Product H	Product I	Product J	Product K	Product L	Product M	Product N	Product O	Product P	Product Q	Product R	Product S
Product A		,905	,782	,900	,851	,895	,824	,891	,796	,876	,879	,746	,733	,873	,663	,182	,774	,767	,578
Product B			,854	,978	,951	,964	,933	,943	,904	,935	,931	,889	,866	,865	,841	,222	,866	,855	,617
Product C				,891	,821	,860	,806	,747	,875	,767	,765	,937	,936	,815	,658	-,029	,622	,583	,356
Product D					,941	,983	,939	,931	,933	,908	,905	,920	,901	,858	,936	,177	,837	,826	,597
Product E						,954	,924	,920	,942	,865	,861	,833	,815	,955	,494	,045	,784	,770	,495
Product F							,935	,947	,941	,892	,889	,885	,864	,870	,928	,147	,806	,797	,578
Product G								,800	,965	,804	,798	,867	,863	,824	,957	,030	,852	,826	,514
Product H									,822	,931	,927	,767	,738	,875	,890	,308	,840	,849	,706
Product I										,786	,784	,903	,900	,890	,904	-,072	,717	,687	,383
Product J											,999	,820	,799	,855	,447	,392	,842	,832	,726
Product K												,818	,794	,855	,447	,391	,839	,829	,725
Product L													,994	,661	,772	,102	,679	,647	,466
Product M														,662	,696	,030	,666	,632	,416
Product N															-,046	-,505	,584	,516	,005
Product O																,512	,898	,940	,468
Product P																	,383	,430	,701
Product Q																		,992	,774
Product R																			,800
Product S																			
Product T																			
Product U																			
Product V																			
Product W																			
Product X																			
Product Y																			
Product Z																			
Product AA																			
Product AB																			
Product AC																			
Product AD																			
Product AE																			
Product AF																			
Product AG																			
Product AH																			
Product AI																			
Product AJ																			
Product AK																			
Product AL																			

Product T	Product U	Product V	Product W	Product X	Product Y	Product Z	Product AA	Product AB	Product AC	Product AD	Product AE	Product AF	Product AG	Product AH	Product AI	Product AJ	Product AK	Product AL
,699	,702	,648	,612	,865	,752	,802	,707	,772	,683	,866	,751	,741	,854	,860	,858	,781	,921	-,269
,756	,782	,745	,731	,928	,828	,901	,784	,836	,772	,921	,750	,733	,867	,869	,869	,745	,959	-,663
,632	,646	,658	,621	,905	,777	,834	,764	,741	,706	,796	,413	,396	,613	,588	,625	,507	,877	-,903
,755	,777	,752	,700	,946	,856	,923	,809	,861	,796	,925	,691	,673	,858	,847	,834	,688	,959	-,627
,818	,817	,766	,728	,896	,858	,897	,833	,858	,822	,896	,692	,673	,821	,809	,840	,740	,918	-,528
,757	,768	,728	,648	,925	,855	,922	,800	,852	,788	,926	,705	,689	,857	,848	,833	,660	,937	-,540
,831	,864	,856	,824	,941	,933	,933	,871	,917	,871	,912	,497	,466	,835	,770	,777	,762	,918	-,490
,676	,692	,625	,620	,818	,731	,828	,682	,762	,682	,853	,865	,859	,867	,903	,847	,661	,911	-,537
,845	,852	,836	,761	,958	,936	,934	,897	,909	,883	,909	,483	,458	,750	,699	,754	,638	,892	-,668
,654	,694	,648	,656	,859	,703	,789	,665	,752	,672	,864	,798	,792	,852	,882	,851	,713	,926	-,560
,652	,692	,646	,652	,858	,703	,787	,664	,749	,670	,864	,795	,789	,849	,878	,848	,713	,923	-,560
,590	,640	,655	,516	,922	,838	,920	,760	,740	,721	,866	,382	,373	,631	,611	,516	,332	,856	-,980
,647	,689	,711	,701	,916	,844	,900	,794	,765	,762	,850	,368	,354	,610	,581	,533	,380	,840	-,984
,714	,693	,680	,404	,890	,852	,859	,860	,801	,783	,829	,313	,249	,740	,726	,802	,782	,963	-,412
-,078	,328	,674	,611	,896	,896	,859	,204	,703	,412	,786	-,340	-,349	,552	,518	-,167	-,116	,779	-,442
-,155	-,080	-,106	-,075	,041	-,125	,044	-,182	-,023	-,138	,123	,502	,517	,316	,413	,223	-,152	,165	,017
,651	,724	,679	,683	,795	,720	,783	,679	,747	,699	,847	,744	,733	,847	,862	,808	,671	,826	-,504
,609	,683	,629	,630	,758	,681	,753	,630	,708	,653	,816	,781	,772	,850	,875	,785	,619	,804	-,408
,249	,333	,255	,152	,492	,306	,472	,226	,380	,254	,572	,758	,766	,672	,750	,566	,150	,571	-,299
	,979	,958	,900	,874	,908	,822	,926	,934	,941	,871	,432	,396	,720	,642	,820	,858	,756	,311
		,976	,918	,906	,924	,851	,937	,950	,951	,915	,442	,408	,747	,672	,840	,868	,771	-,047
			,946	,909	,922	,852	,941	,947	,964	,894	,356	,317	,692	,598	,802	,816	,749	-,417
				,881	,850	,800	,875	,871	,889	,825	,441	,409	,571	,519	,790	,713	,698	-,964
					,980	,963	,935	,947	,931	,955	,560	,536	,805	,761	,817	,761	,961	-,706
						,937	,966	,951	,959	,925	,416	,382	,732	,658	,789	,697	,819	-,655
							,883	,902	,879	,928	,544	,515	,754	,718	,803	,610	,861	-,825
								,947	,976	,875	,367	,331	,686	,609	,769	,738	,810	-,648
									,965	,935	,495	,458	,805	,734	,866	,834	,848	-,124
										,897	,391	,353	,714	,628	,796	,770	,797	-,502
											,639	,619	,869	,839	,880	,788	,907	-,552
												,996	,827	,897	,787	,527	,726	,785
													,804	,884	,765	,454	,709	,807
														,978	,916	,878	,866	,409
															,903	,820	,859	,460
																,975	,879	,851
																	,801	,880
																		-,600

Appendix 10: Average price and standard deviation of products

Product	2005 (5 years)		2006 (4 years)		2007 (3 years)		2008 (2 years)		2009 (1 year)	
	μ	σ	μ	σ	μ	σ	μ	σ	μ	σ
Product A	39.53	7.25	40.94	7.12	43.27	6.82	44.42	7.67	39.54	3.93
Product B	21.54	4.35	22.53	4.20	24.03	3.84	24.59	3.97	21.48	2.07
Product C	24.86	5.51	24.56	6.05	23.63	6.77	20.28	5.11	16.42	1.30
Product D	67.28	14.00	70.20	13.85	75.04	12.84	76.13	14.35	64.73	7.47
Product E	33.20	6.31	34.95	5.53	36.86	5.06	36.96	5.80	32.50	2.04
Product F	24.26	5.32	25.63	4.89	27.83	3.50	28.82	3.61	26.74	2.69
Product G	21.88	5.48	23.06	5.47	24.89	5.74	23.20	5.63	20.00	3.81
Product H	95.57	18.00	100.10	16.75	107.70	12.09	111.46	11.62	102.69	3.04
Product I	29.08	6.09	30.52	5.61	32.14	5.51	31.90	6.48	26.73	2.61
Product J	34.04	7.83	35.83	7.44	38.65	6.52	40.48	5.50	36.22	2.89
Product K	41.79	9.62	44.02	9.09	47.44	8.00	49.68	6.75	44.45	3.55
Product L	36.64	13.08	38.04	13.47	43.69	14.33	42.54	14.84	31.23	9.67
Product M	30.20	10.06	31.50	10.55	34.63	11.75	33.48	11.83	24.22	7.37
Product N	36.21	8.49	36.21	8.49	36.21	8.49	35.79	9.28	26.56	1.74
Product O	56.89	5.84	56.89	5.84	56.89	5.84	56.89	5.84	56.18	5.43
Product P	158.20	8.76	158.60	8.92	160.54	8.64	164.58	7.51	168.46	7.47
Product Q	100.45	24.73	105.60	24.34	115.54	19.96	117.92	19.39	107.69	9.92
Product R	100.78	24.28	106.00	23.69	116.08	18.56	119.58	17.99	111.54	11.25
Product S	108.13	30.06	113.45	29.96	124.39	27.08	135.83	23.85	137.31	26.82
Product T	192.80	36.36	200.77	35.40	208.50	37.21	196.71	34.01	176.12	11.02
Product U	185.25	43.31	194.90	41.98	205.00	43.58	191.15	38.15	166.31	8.57
Product V	177.47	42.95	184.22	44.71	194.22	47.46	177.23	38.68	149.96	7.68
Product W	168.92	35.90	174.94	36.20	178.00	35.40	169.53	25.48	138.60	12.64
Product X	168.54	44.11	177.03	45.66	192.00	46.92	185.71	47.50	146.31	17.29
Product Y	153.16	45.15	161.83	45.38	174.93	45.80	160.31	47.96	122.69	14.12
Product Z	138.58	37.78	143.88	38.85	158.33	34.99	153.12	37.29	123.08	17.62
Product AA	145.95	38.88	153.15	39.33	162.23	41.91	148.73	42.74	114.73	5.05
Product AB	137.57	35.33	144.31	35.47	154.57	35.61	144.54	34.53	120.12	10.46
Product AC	121.85	37.55	128.81	38.10	139.23	39.09	123.83	35.66	96.81	5.86
Product AD	159.72	40.72	169.26	39.43	183.56	36.98	182.60	41.24	152.88	20.81
Product AE	258.88	60.30	270.96	60.03	296.41	47.99	323.19	30.57	322.85	19.69
Product AF	289.25	65.52	302.44	65.25	329.95	52.56	361.06	29.26	362.08	21.41
Product AG	163.25	41.74	171.75	41.40	186.91	37.19	193.63	40.84	176.08	24.24
Product AH	188.51	48.01	199.09	46.59	217.62	39.51	231.33	38.17	215.31	24.71
Product AI	171.45	38.36	178.70	38.98	193.21	35.83	196.83	36.86	179.27	9.65
Product AJ	178.44	39.63	178.44	39.63	178.44	39.63	177.96	38.91	159.81	9.13
Product AK	164.54	45.87	173.61	46.70	189.09	44.98	192.92	46.40	155.00	9.85
Product AL	181.33	8.55	181.33	8.55	181.33	8.55	181.33	8.55	183.85	5.83

Table 1. Average price and standard deviation of products.

Appendix 11: Basket and menu compositions

Profit optimization	
Biomass stream	*Amount /t*
Product A	2,000
Product E	2,000
Product F	2,000
Product I	2,000
Product N	1,341
Manure 0	11,000
Manure 1	5,000
Manure 2	2,000
Co substrate 0	5,000
Co substrate 1	2,000
Co substrate 2	1,629
Total	**36,000**

Table 1. Basket and menu profit optimization.

RHR optimization	
Biomass stream	*Amount /t*
Product A	1,570
Product E	509
Product F	2,000
Product I	2,000
Product O	2,000
Product AL	1,656
Manure 0	18,000
Manure 1	0
Manure 2	0
Co substrate 0	5,000
Co substrate 1	2,000
Co substrate 2	1,234
Total	**36,000**

Table 2. Basket and menu RHR optimization.

Appendix 12: Skewness and kurtosis of products

Product	Skewness		Kurtosis	
	Statistic	*SE*	*Statistic*	*SE*
Product A	.955	.306	.632	.604
Product B	.737	.306	-.792	.604
Product C	-.189	.306	-.160	.604
Product D	.780	.306	-.712	.604
Product E	.419	.306	-.562	.604
Product F	.284	.306	-1.018	.604
Product G	.825	.369	-.482	.724
Product H	.347	.306	-.976	.604
Product I	.520	.309	-.725	.608
Product J	.502	.306	-.981	.604
Product K	.485	.306	-.980	.604
Product L	.880	.378	-1.056	.741
Product M	.834	.365	-1.028	.717
Product N	-.048	.472	-1.691	.918
Product O	-.310	.597	-1.166	1.154
Product P	-.019	.306	.043	.604
Product Q	.694	.306	-.297	.604
Product R	.532	.306	-.595	.604
Product S	.577	.309	-1.091	.608
Product T	.970	.306	-.065	.604
Product U	1.121	.306	.478	.604
Product V	1.417	.306	1.117	.604
Product W	.978	.388	.307	.759
Product X	.963	.325	-.567	.639
Product Y	.712	.306	-1.052	.604
Product Z	.565	.314	-1.283	.618
Product AA	.855	.306	-.708	.604
Product AB	.972	.306	-.399	.604
Product AC	.984	.306	-.370	.604
Product AD	.870	.314	-.136	.618
Product AE	.399	.306	-1.339	.604
Product AF	.373	.306	-1.480	.604
Product AG	.897	.306	-.070	.604
Product AH	.669	.306	-.615	.604
Product AI	1.101	.311	.262	.613
Product AJ	.702	.414	-.938	.809
Product AK	1.097	.316	-.296	.623
Product AL	-1.567	.580	.779	1.121

Table 1. Skewness and kurtosis of products.