Exploring Sourcing Strategies in the midst of an 'Unknown' Sourcing Object

The Large-Scale Sourcing of Biomass

MASTER THESIS

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e·on Benelux

Preface

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List of abbreviations

EBX	E.ON Benelux
FOB	‘Free-on-board’ (or ‘freight-on-board’), covering the costs of purchase, loading and shipment up to the port of destination; in this case Rotterdam.
GHG	Greenhouse gas

1 Introduction: Challenges of meeting a demand increase of biomass for co-combustion

1.1 Introductory overview of E.ON Benelux and how it uses biomass for co-combustion in its coal-fired power plants: increasing biomass demand sixfold

1.1.1 Biomass, co-combustion, and their changing roles within the Dutch energy market: from a marginal to substantial feedstock

Biomass encompasses all organic matter, either living or dead, and can be found virtually anywhere. Wood chips, plant matter, fungi, algae, fruit-, vegetable-, and animal residues: these are all examples of biomass. Given their often low prices, it is an attractive feedstock for the production of sustainable energy. This is illustrated by the fact that biomass currently encompasses some two-thirds of renewable energy in Europe.[1] The importance of biomass is expected to grow in the future, where it is to provide renewable feedstocks for heat, electricity and biofuels.[2]

Co-combustion is the practice of combusting biomass feedstocks with regular feedstocks (i.e. coal) to create energy. This offers major advantages, in that existing coal-fired plants need no major modifications in order to be used for co-combustion, there are more (types of) feedstocks to choose from thus adding to the flexibility and security of supply, and higher overall efficiencies can be attained for power generation from biomass. As biomass saves fossil fuels such as coal, which is rich in CO_2, NO_x, SO_x, co-combustion reduces these emissions.[3]

In the Netherlands, co-combustion is largely represented. Of the seven coal-fired units, divided over five locations, all have experience with co-combustion. Six units co-combust on a commercial basis, with biomass percentages ranging from 5% to 15%. This co-combustion is subsidized through the Dutch MEP-subsidy program, offering 6.5 EURct per kWh_e for wood pellets, and 3.8 EURct per kWh_e for agro residues and mixed biomass. Although biomass types vary, most are wood based materials as wood pellets and waste

[1] See European Environment Agency (2012), p. 180-181.
[2] See Fischer et al. (2010), p. 174.
[3] See VGB PowerTech (2008), p. 2.

and demolition wood. Other materials are also used, such as paper sludge pellets, meat and bone meal, and various agricultural rest products.[4]

By the year 2020, the Renewable Energy Directive (2009/28/EC) states a European target amounting to a 14% share of renewable energy in the total energy production of the Netherlands. In order to do so, the Dutch Ministry of Economic Affairs, Agriculture and Innovation is involved in discussions to attribute a mandatory role to co-firing biomass in coal-fired power plants.[5]

1.1.2 The case of E.ON Benelux: a major coal-fired power producer and supplier in the Dutch energy market

E.ON Benelux (EBX) produces and distributes electricity and heat for businesses and consumers. It is part of the major German energy company E.ON Energie AG, founded in 1941. In total, E.ON Benelux employs 681 FTE at various locations. The Corporate Strategy department, who have offered support and valuable insights for the realization of this thesis, is situated at the head office in Rotterdam.

Generation sites owned and operated by EBX are located throughout the province of Zuid-Holland and at two sites in Belgium. Besides two coal-fired Maasvlakte power plants (MPP1 and 2) and one under construction (MPP3), EBX also operates eleven gas-fired power stations. The annual capacity currently totals 2.840 MW; when the MPP3 plant becomes operational in 2013, this total will rise to 3.940 MW.[6]

In 1996, EBX was one of the first to co-combust biomass with coal in its Maasvlakte power plants (MPP) I and II. Currently, 10% biomass is co-combusted in both power plants I and II, equaling a total 250 kt. In anticipation of the 14% renewables targets stated for 2020, EBX aims for 30% biomass co-combustion in MPP1/2, as well as in their new MPP3. According to recent EBX estimates, reaching these co-combustion targets would annually require 26,5 PJ of biomass. This amount of energy is equal to roughly 1.560 kt of biomass from wood pellets, meaning a 624% growth in to biomass demand compared the current demand of 250 kt.

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[4] See Cremers (2009), p. 36-38.
[5] See Ministry of Economic Affairs (2011), p. 25.
[6] See Company profile E.ON Benelux (2009), p. 5-6.

All three power stations are easily accessible by sea. They are located at the outer edge of the port of Rotterdam, where they are connected by transport belt to the nearby coal offloading site EMO. Here, large bulk carrier vessels can offload up to 175.000 tons of coal a day[7]. This strategic setup taken together with the fact that transport costs per ton are lower by sea than by land, lead to E.ON's intention to source the majority of its biomass demand from overseas import.

1.2 Research question: Selecting the type of biomass and an adequate sourcing strategy for E.ON Benelux

The main research problem addressed within this thesis is formulated as follows:

"WHICH TYPES OF BIOMASS ARE FEASIBLE FOR CO-COMBUSTION AND WITH WHICH SOURCING STRATEGY ARE THEY BEST ASSOCIATED IN ANTICIPATION OF A GROWING DEMAND?"

The first part of the research question addresses which biomass types are feasible for co-combustion, thereby addressing the issue of biomass being many different things. The second part of the research problem, "…in anticipation of a growing demand" is in accordance with the biomass demand development as presented in *1.1.1: Biomass, co-combustion, and* . The seven research questions (RQs) follow directly from the research problem.

1. Which requirements must biomass meet in order to qualify as an option for co-combustion?
2. What types of biomass meet co-combustion requirements?
3. What biomass properties directly influence sourcing strategy selection?
4. With which quantitative ranges are the biomass properties matched in order to adequately classify biomass types?
5. Which biomass property combinations offer realistic options in respect to economic feasibility and sustainability?
6. With which sourcing strategy is each biomass property configuration best matched?
7. Which combination of sourcing object and sourcing strategy is best for EBX?

[7] Port of Rotterdam (2009), p. 1.

The first five research questions follow from the supply market analysis, while the remaining two follow from a combination of sourcing strategy analysis and sourcing strategy assessment.

Starting the supply market analysis off, RQ_1 and RQ_2 establish a list of pre-selected biomass types suitable for co-combustion, thereby focusing the research by excluding biomass types on forehand which, for instance, may be harmful to the power plant.

RQ_3 and RQ_4 then address the influence of biomass on the sourcing strategy, providing a number of biomass properties (i.e. price, quality) as independent variables. To facilitate the comparison of various sourcing strategies, these biomass properties are classified into three groups (i.e. *high*, *medium*, and *low*). These groups correspond to different quantitative ranges as addressed in RQ_4. To give an idea of this process, a biomass type categorized as 'high quality' is described in a certain high range of net caloric value (NCV), which is expressed in Joules. Likewise, a biomass type categorized as 'low price' is described in a certain price range, expressed in price per ton.

RQ_5 examines the biomass property combinations. These are the combinations of biomass properties (i.e. price, quality, sourcing distance) as independent variables. These are examined in two respects: first, it is established whether the chosen combination is economically feasible. This may generate a preselection where for instance combinations with a high price and low quality are excluded. Second, the sustainability of the combination generates a further preselection by comparing the sourcing distance to other biomass properties. In doing so, RQ_5 acts as a filter which generates all combinations of biomass properties that are realistically possible. This concludes the supply market analysis.

RQ_6 then aims at finding a match between the preselected biomass property combinations and their respective sourcing strategies. This is done by using a sourcing strategy framework to configure a sourcing strategy in a fashion much like using building blocks to create a construction. Which blocks are to be chosen is determined by a portfolio model. Together, this construction will form a solid sourcing strategy.

After matching a number of biomass property combinations to the best sourcing strategies, the biomass property ranges are used to make the sourcing strategy concrete in RQ_7. In other words, actual biomass types are coupled through their properties to the developed sourcing strategy, effectively answering the research problem.

1.3 Researching prescriptive sourcing strategy design for E.ON Benelux while contributing to the problem of sourcing strategy development in the face of an 'unknown' sourcing object

As this research is aimed at designing the logistical process and considering all related problems between the source and the power plant, its focus is prescriptive. Keeping in mind that there are many different forms of biomass, any product that meets EBX's requirements may be sourced. Biomass is then a category of objects, whereas sourcing strategies usually revolve around sourcing a particular object, such as a spring for a ballpoint pen or brake pads for an automobile. Then because biomass is not a single object, the sourcing strategy will surround an object that can be one of many different things. Therefore, this thesis considers the sourcing object to be largely 'unknown'.

In the past two decades, biomass has attained a substantial share of devoted literature. The majority of papers are written on the subject of future bioenergy potential[8], where explorations are undertaken into the potential global supply of bioenergy, often ranging in scope up to the year 2050. More recently, the focus has spread to biomass trade[9]. Within these papers the demand of biomass is also considered. Biomass trade papers mainly aim to uncover developments within international trade flows and identify their respective drivers and barriers, but do not cover the development of sourcing strategies in detail; as to date a particular sourcing strategy or strategies have not formed the subject or end-result of biomass-focused research.

In this context, it is important to clarify the following three terms: *purchasing*, *procurement* and *sourcing*. *Purchasing* reflects a one-dimensional focus on the goal of reducing the acquisition cost of goods and services, primarily using instruments focused on price- and quantity politics. It is a part of the broader term *procurement*, which also considers communication and supplier issues[10] such as supplier quality, expediting, traffic

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[8] See Hoogwijk et al. (2003); M. Hoogwijk (2004); Smeets et al. (2004); Faaij/Domac (2006); Kaltschmitt (2006); Moreira, (2006); Field et al. (2008).
[9] See Damen/Faaij (2006); Geidl et al. (2007); Junginger et al. (2008a); Junginger et al. (2008b).
[10] See Arnold/Essig (2000), p. 122.

and logistics, and *sourcing*. Sourcing then focuses on finding what services and goods are to be purchased from where.

The large variety of characteristics that distinguish different biomass types generally have a strong influence on the development of the associated sourcing strategy. For instance, 'wet' biomass has entirely different shipping requirements than 'dry' biomass does. Therefore, in order to develop a solid sourcing strategy, a holistic approach is required. Although the academic research covering sourcing strategies is quite elaborate, no papers have been devoted to a holistic approach. Generally stated, the broad categorical nature of biomass uncovers a knowledge gap in the application of normal sourcing literature to such a sourcing problem. By addressing the issue of such a gap, this thesis aims to generate an academic discussion regarding the implications of 'unknown' sourcing objects for the creation of sourcing strategies, and thus make an academic contribution to sourcing literature.

1.4 Thesis overview: developing a framework for sourcing strategy development and its application to the case of biomass

The descriptive research is formalized by using and combining theoretical constructs and frameworks, on which the consequent data analysis capitalizes.

The most part of this thesis is based on secondary data. For one, the different biomass properties comprise of secondary data, as well as the underlying quantitative ranges of properties with which certain biomass types are selected. Theory regarding which underlying sourcing strategy element is best for certain biomass property combinations is also secondary data.

As stated earlier, both the supply market and the sourcing strategy are the two main subjects of descriptive research within this paper. In order to facilitate a solid basis to approach this, an extensive literature study is done into both subjects. First is the supply market analysis. The goal of a supply market analysis is to thoroughly understand the supply market in such a way that enables the formulation of a well-considered sourcing strategy. Research in trade literature and online, together with informal interviews and conferences, form the main input. This will then lead to a report on supply trends, changes, pricing, capacity, and other relevant details.[11] Importantly, the supply chain is regarded upwards to determine what types of biomass are available and where it may come from, as well as downwards to find any interesting opportunities within the port of Rotterdam area.

The second stage in this research is aimed at creating a range of all possible sourcing strategies, and then choosing those that fit best within the research problem. A framework will be selected which will describe the different properties belonging to a sourcing strategy, and offer different sub-strategies for each property. Choosing sub-strategies for each property will in the end lead to a complete sourcing strategy. Different sourcing strategy configurations including EBX-suggested strategies are subsequently assessed using supplier evaluation criteria (i.e. price, distance, quality). These will return in the recommendations, where concrete examples of each strategy are presented for a more practical outcome.

[11] See Handfield (2009), p. 205.

2 Frameworks for a supply market analysis and for analyzing and evaluating sourcing strategies

2.1 Portfolio models based on power and dependence: an overview of their practical use and theoretical roots

The following chapter provides an introduction into power and dependence in buyer-supplier relationships. Consequently, a number of power- and dependence-based portfolio models are presented as tools to together facilitate a supply market analysis and, in doing so, a basic choice of the general sourcing strategy. Then, a framework for analyzing and evaluating sourcing strategies is presented. By splitting up sourcing strategies into their respective elements, different configurations of sourcing strategies can be made. Finally, possible selection parameters are explored. These can be used to configure different sourcing scenarios, each of which is to be fitted to a specific configuration of sourcing strategies.

2.1.1 Power and dependence as the most important influences on buyer-supplier relationships

As trade presupposes the participation of a minimum of two parties, every trade is accompanied by a certain relationship. Such a relationship may be brief or shallow, as in the case of a small consumer purchase. But in sourcing large amounts of raw material, where long-term contracts and large money transactions are common, relationships often span a significant time period. It is within these relationships that the parties involved, the buyer and the supplier, acquire substantial economic interests in each other. Thus, the parties involved will likely make an effort to establish and maintain a good relationship.

2.1.1.1 The presence of one firm's power to influence the other implies target dependence on the source

The power-focus regards the ability of one firm (the source) to influence the intentions and actions of another firm (the target).[12] Defined in relation to the supply chain, "the power of a supply chain member [is] the ability to control the decision variables in the supply

[12] See Emerson (1962), p. 32.

strategy of another member in a given chain at a different level of the supply chain."[13] Within portfolio models such as the Kraljic matrix, power is often expressed in general terms such as complexity, material scarcity, innovation pace, substitution threats, logistics costs or complexity, level of competition (i.e. perfect competition, oligopoly, monopoly), and market entry barriers.[14] The fundamental prerequisite for such market power is often found in market entry barriers.[15] These barriers are different resources present within other firms, for example established biomass markets of scale, markets of experience, or the presence of necessary logistical systems for large-scale transport.

The dependence-focus considers how dependent a firm is on a certain sourcing object. In buyer-supplier relationships, dependence is related to the strategic importance of sourcing in terms of the sourcing object's value to the company.[16] Or, phrased more colloquially, how bad a firm wants something; be it a sourcing object for the buyer or a sourcing contract for the supplier. This is often expressed in general terms such as value, profit potential or impact, economic profile, and strategic importance.[17] Generally described, "[t]he dependence of actor A upon actor B is (1) directly proportional to A's motivational investment in goals mediated by B, and (2) inversely proportional to the availability of those goals to A outside of the A-B relation.".[18] For example, if A wants a resource which B owns, and there are limited alternative sources for this valued resource, A's dependence on B is high. It is important to note that with dependence comes power: the notion of power in an inter-firm relationship implies target dependence on the source; otherwise the target would not need to subject itself to the unbalanced relationship.[19] Applying this to the previous example, B would have more power than A.

2.1.1.2 Power and dependence result in opportunism, a damaging relationship dynamic

Opportunistic behavior can occur in any relationship, and all companies are vulnerable to it. In unbalanced buyer-supplier relationships, as most are, there is always a threat of opportunism leading to one firm taking advantage of the other in some form or other. For instance, having to rely on a single source makes a firm dependent on that source. This

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[13] Benton (2007), p. 201.
[14] See Kraljic (1983), p. 110.
[15] See Baumol et al. (1982), p. 496.
[16] See Kraljic (1983), p. 110.
[17] See Kraljic (1983), p. 110.
[18] Emerson (1962), p. 32.
[19] See Emerson (1962), p. 32.

leads to a supply risk, as a source may act on the opportunity to exploit its own power thus taking advantage of the buyer.[20] When bargaining from a position of dependence, long-term contractual obligations or higher prices can help ensure security of supply.[21] In contrast, when bargaining from a position of power, an opportunistic firm is better able to press for preferential treatment.

It must also be noted that if a firm indulges in opportunistic behavior itself, it may also do damage itself in the long run. When powerful multinational companies source from numerous suppliers, they tend to promote competition among these suppliers, enlarge security of supply over a longer period of time, and often exploit the benefits of changing market conditions. By attempting to continue to do so as well as to optimize bargaining power, firms may tactically spread their purchases thus controlling the size (i.e. power) of their suppliers. It is practices like these that damaged Intel, leading to supplier's bankruptcies along with the predictable negative effects on the security of supply. The main cause for such problems is the large degree of supplier uncertainty (will the order be placed), shortening its planning horizon and forcing decisions that increase long-term operating costs.[22]

As often argued, relationship types vary among different business, social, and cultural contexts. Although many managers are aware of this, it is still difficult for them to distinguish different types of contexts and thus optimize their business relationship. This failure is often not due to a relationship being inappropriate for a particular context, but rather due to problems caused by both buying and supplying firms when moving from a competitive relationship into a strategic alliance. Buyers can then suddenly become reluctant in committing because of the risks associated with being dependent on one or only a few suppliers, buyers can revert to old habits by focusing only on price instead of advantages to be gained from supplier expertise, and suppliers may fear opportunistic behavior and mistrust buyers.[23]

Indeed, "[b]oth parties come naturally to expect conflict due to the asymmetry in information [i.e. power] and threat of opportunism that lies at the core of arm's length relationships, and therefore engage in activities that over time become engrained in their

[20] See Spekman/Carraway (2006), p. 11.
[21] See Kraljic (1983), p. 114.
[22] See Kotabe/Murray (2004), p. 12.
[23] See Spekman/Carraway (2006), p. 10.

respective cultures and lead to unintended outcomes"[24]. It is then important to be able to rely on mutual expectations and agreements.

2.1.1.3 Trust complementing legal agreements as the glue holding together relationships

Mutual expectations and agreements within a business relationship are formally made explicit and agreed upon with the control of legal agreements. And although mutual expectations and agreements can be adhered to informally, by merely relying on trust, it is also through formalizations such as legal agreements that trust within a relationship increases[25]. Trust has various definitions, for one: "the belief that a party's word or promise is reliable and a party will fulfill his/her obligations in an exchange relationship"[26]. Within a relationship, trust signifies "a willingness to be vulnerable [i.e. dependent], based on the positive expectations of another's actions or intentions."[27] For any reason, buyers fear a position of vulnerability in the relationship with a supplier. In the case of vulnerability, trust becomes an issue. Accordingly, without vulnerability, trust is not an issue as outcomes are inconsequential for the buyer. This is the same for uncertainty. Vulnerability and uncertainty, then, are critical to trust.[28] It can then also be said that if a relationship bears a great deal of trust, the parties involved will engage in increasingly risky exchange[29] and, accordingly, will accept a higher level of dependence. The highest level of dependence is a state of mutual commitment, "an implicit or explicit pledge of relational continuity between exchange partners"[30]. Moreover, it has been shown that the trust of a buyer in their supplier, taken together with the buyer's bargaining stance, significantly affects the buyer's attitude toward the supplier. Accordingly, within buyer-supplier relationships, trust lowers transaction costs and facilitates investments in relation-specific assets.[31] Hence, as a buyer has a higher degree of trust in his supplier, the attitude, communication, and bargaining behavior become more favorable.[32]

[24] Spekman/Carraway (2006), p. 11.
[25] See Murray (2001), p. 44.
[26] Schurr/Ozanne (1985), p. 940.
[27] Spekman/Carraway (2006), p. 18.
[28] See Moorman et al. (1992), p. 315.
[29] See Murray (2001), p. 42.
[30] Dwyer et al. (1987), p. 19.
[31] See Heide/John (1992); Dyer (1994); Zaheer et al. (1995) cited according to Murray (2001), p. 41-42.
[32] See Dwyer et al. (1987), p. 18.

Grounded in the social exchange theory, social bonding refers to business relationship bonds that are mainly trust-based.[33] These bonds do not rest on legal agreements, but can complement or replace them as the social bond grows closer, as a stronger social bond corresponds to less opportunistic behavior.[34] This is the first of three ways in which trust is said to affect a relationship, by replacing contracts. The second way would be that trust plays a part in estimating the outcomes of strategies in weighing the perceived value of an action versus the probability that the second party will act as promised. The final way that trust affects relationships is by growing larger as two parties interact over time,[35] thereby strengthening the social bond. Thus, as has been written about trust, “perhaps there is no single variable which so thoroughly influences interpersonal and intergroup behavior.”[36]

Lenin once stated that trust is good, but control is even better. After finding research confirmation that non-financial performance will be highest when it is based on both control-based behavioral transparency and social bonds, Kaufmann updated this sentiment to “While trust and control are both good, they are even better together.”[37]

2.1.2 Portfolio models in general, and the Kraljic matrix in particular, are extensively used as a strategic tool for supply market analysis

2.1.2.1 The origin and popularization of portfolio models: how strategic development leads to increasing portfolio model use

In order to establish which sourcing strategy best fits a certain situation, it is necessary to analyze the supply market. With an increased emphasis on manufacturing and organizational philosophies such as *just-in-time* (JIT) and *total quality management* (TQM), and the growing importance of supply chain management concepts, the need for considering supplier relationships from a strategic perspective became apparent within the literature.[38] Strategically approaching global sourcing involves “proactively integrating and coordinating common items and materials, processes, designs, technologies, and suppliers across worldwide purchasing, engineering, and operating locations.”[39] Many authors devoted themselves to underlining the importance of the global sourcing strategy as a

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[33] See Thibaut/Kelley (1959); Blau (1964) cited according to Kaufmann/Carter (2006), p. 659.
[34] See Kaufmann/Carter (2006), p. 659.
[35] See Spekman/Carraway (2006), p. 18.
[36] Dwyer et al. (1987), p. 18.
[37] Kaufmann/Carter (2006), p. 668.
[38] See Sarkis/Talluri (2002), p. 19.
[39] Trent/ Monczka (2003), p. 1.

strategic tool[40] and emphasizing the profitability of a strategic approach to global sourcing[41]; describing it as "a key element in creating […] strategic advantage", and "an integral part of the overall corporate strategic plan"[42]. It is found that "successful supply chain management requires the effective and efficient management of a portfolio of relationships"[43], which implies a set of differentiated supplier strategies to be of use, leading to a need for a certain classification of these relationships. An easy method for classification is the development of a portfolio model.

After being suggested by Porter in 1980[44], many portfolio models have been developed in the literature. Portfolio models have been widely used as an analytical tool to organize information and create a framework useful for the classification of competitors, customers, and suppliers. Most of these portfolio models have been used in strategic planning. Examples of such strategic portfolio models are the BCG model or the Ansoff matrix[45]. Their aim is to optimally distribute investments or resources over businesses or strategic business units. In this case, the logical choice is a purchasing portfolio model.

Strategic purchasing portfolio models have been found to positively contribute to purchasing sophistication and professionalism[46], as an "effective tool for discussing, visualizing and illustrating the possibilities of differentiated purchasing and supplier strategies"[47]. They have gained ground in both research and practice,[48] and in a survey of Dutch manufacturing companies, a widespread utilization of some kind of portfolio model approach was found among 80% of the large companies surveyed[49]. For instance, the portfolio purchasing technique is fully integrated into daily sourcing practice of, among others, DSM, Akzo Nobel Coatings, and Te Strake.[50] Considering the purchase of vast amounts of raw materials, it is helpful to focus strategies and gain insights into potential opportunities and threats that lie within the mix of purchased raw materials, commonly

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40 See Trent/Monczka (2003), p. 1.
41 See Trent/Monczka (2003), p. 27; Kotabe/Murray (2004), p. 7.
42 Samli et al. (1998), p. 178.
43 Bensaou (1999); Frohlich/Westbrook (2001) cited according to Gelderman/Semeijn (2006), p. 2-3.
44 See Michael E. Porter (1980).
45 See Ansoff/Leontiades (1976).
46 See Gelderman/van Weele (2005), p. 25.
47 Gelderman/van Weele (2002), p. 10.
48 See Gelderman/Semeijn (2006), p. 2-3.
49 See Gelderman/Semeijn (2006), p. 2-3.
50 See Gelderman/Van Weele (2003), p. 209.

referred to as the *purchasing mix*.[51] The purchasing portfolio model provides an insight into the balance of power, addressing how to exploit the domination of a relationship, how to reduce dependence, and what this all means to the overall purchasing portfolio. Or, as Albronda and Gelderman formulate an interesting summarizing question: "what are the possibilities of purchasing for influencing the balance of power?"[52]

2.1.2.2 The Kraljic matrix as a blueprint for power-and-dependence-based portfolio models

With the message "purchasing must become supply management"[53], Kraljic developed the first comprehensive portfolio approach for strategic sourcing in the year 1983. Its use is often recommended for purchasing and supply management problems[54] and comprises a supply market analysis to structure data gathered in such a way that the purchasing portfolio can be weighed up while minimizing supply dependence and optimizing buying power. Indeed, Kraljic assumes that a firm can adapt a successful (global) sourcing strategy by assessing risk and power, and thus optimizing its respective supplier relationships. In order to do so, a firm must execute the following four phase plan.

The first phase of this approach, a *classification* is made of all a firm's purchased items into categories within a 2x2 matrix. This is a subjective stage and it is strongly recommended that the decision makers within the company reach agreement on this classification.[55] Kraljic proposes an approach that focuses on two criteria: the profit impact of a given supply item on the one side, and the supply risk on the other.[56] These criteria distinguish four supplier relationship idealtypes: *noncritical* (low profit impact, low supply risk), *leverage* (high profit impact, low supply risk), *bottleneck* (low profit impact, high supply risk), and *strategic* (high profit impact, high supply risk) items.[57]

Second, a market analysis systematically reviews the supply market for the availability of desired sourcing objects.[58] Or as defined by Fearon in 1976: "Systematic gathering, classifying and analyzing data considering all relevant factors that influence the procurement of goods and services for the purpose of meeting present and future company

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[51] See Gelderman/Semeijn (2006), p. 4-5.
[52] Gelderman/Semeijn (2006), p. 4-5.
[53] Kraljic (1983), p. 109.
[54] See Olsen/Ellram (1997), p. 102-103; de Boer et al. (2001), p. 78.
[55] See Olsen/Ellram (1997), p. 105.
[56] See Kraljic (1983), p. 111.
[57] See Kraljic (1983), p. 112.
[58] See Kraljic (1983), p. 112-113.

requirements in such a way that they contribute to an optimal return."[59] This is done in terms of quality and quantity, as well as the relative strength of existing suppliers, much like the well-known SWOT analysis.

Third, items that are deemed strategic in the first phase are positioned in the purchasing portfolio matrix. This plots the buying firm's power and dependence against that of the supplier firms. The cells in which the strategic items have been inserted correspond with certain sourcing sub-strategies, or as Kraljic names them, strategic thrusts.[60] In the end, this step shows companies how to adapt different roles (i.e. exploit, balance, diversify) with respect to different suppliers.[61]

The fourth and final phase of the portfolio approach consists of the development of an action plan, calling a firm to explore its supply scenarios, resulting in a multiple systematically documented sourcing strategies.[62]

Although the criteria vary slightly among different Kraljic-inspired models (Elliott-Shircore and Steele[63], Hadeler and Evans[64], Turnbull[65], Olsen and Ellram[66], Bensaou[67], Lilliecreutz and Ydreskog[68], and Gelderman and Van Weele[69]), the fundamental assumption of all such models is that they assess a company's purchasing portfolio based on relational differences in power and dependence.[70] This is not mentioned explicitly by Kraljic, but his strategies are aimed at the power structure (exploit) and at reducing dependence on suppliers (diversify). Also, supply strategies are shaped "[t]o minimize their supply vulnerabilities and make the most of their buying power"[71]. Although examples in the literature on how power and dependence in buyer-supplier relationships

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[59] Fearon (1976), p. 5.
[60] See Kraljic (1983), p. 113.
[61] See Kraljic (1983), p. 114.
[62] See Kraljic (1983), p. 114.
[63] Elliott-Shircore/Steele (1985).
[64] Hadeler/Evans (1994).
[65] Turnbull (1995).
[66] Olsen/Ellram (1997).
[67] Bensaou (1999).
[68] Lilliecreutz (2001).
[69] Gelderman/Van Weele (2002).
[70] See Dubois/Pedersen (2002), p. 37.
[71] Kraljic (1983), p. 112.

enter the Kraljic matrix are not exhaustive[72], empirical research on the impact of power and dependence on buyer-supplier relationships is even scarcer.[73]

2.2 Selecting a tool for sourcing strategy development

2.2.1 A strategic focus on sourcing: presenting the most prominent strategic sourcing models developed within German and American literature

While basic economic theory surrounding production and sales focuses in part on optimizing the production supply along quantity, quality, time and place objectives[74], sourcing activities have a more subordinate role. The broad coverage of sourcing within economic literature is based primarily on administrative supply management functions and associated secondary activities.[75] Some economic literature has focused on the importance of considering supplier relationships from a strategic perspective[76], and as such certain authors have devoted themselves to underlining the importance of global sourcing as a strategic tool[77]. But, though strategies show paths to new goals, as is the aim of sourcing, economic literature seems to fall behind as far as sourcing goes[78].

Existing sourcing strategy literature can be generally divided into four different approaches. The first approach is portfolio approach. As extensively discussed in paragraph 2.1.1, this approach leads to a comparison of sourcing options using two dimensions. It is also the most widely covered approach within sourcing literature. The second approach is one where a specific research question is addressed. Options are structured, alternatives are compared through discussion and recommendations for implementation are formulated.[79] This approach is often used on highly specific problems for which there is no apparent toolbox. The third approach is the comprehensive approach to process development and the subsequent implementation of sourcing strategies. It builds upon the process of addressing a particular research problem (as in the second approach) by adding a more prescriptive orientation. This is achieved by offering the firm a

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[72] See Gelderman/Van Weele (2003), p. 208-209.
[73] See Caniels/Gelderman (2005), p. 142.
[74] See Grochla/Schönbohm (1980), p. 19-23.
[75] See Grochla/Schönbohm (1980), p. 5; Arnolds et al. (1996), p. 22; Dobler/Burt (1996), p. 7.
[76] See Bai/Sarkis (2010), p. 252.
[77] See Trent/Monczka (2003), p. 26.
[78] See Boutellier (2003), p. 79 cited according to Hess (2008), p. 34.
[79] See Hess (2008), p. 34.

systematic procedure for deducing sourcing strategies by structuring the decision field and by providing detailed checklists and heuristic decision making tools.[80]

The fourth and final approach is that of sourcing concepts. Here, sourcing strategies are split up into individual sub-strategies. These sub-strategies (e.g. location) are split up into alternative typologies or *sourcing concepts* (e.g. global or local). In order to find the appropriate sourcing strategy, specific opportunities and risks of individual sourcing concepts are discussed, and one sourcing concept is chosen for each sub-strategy. Together, the selected sourcing concepts form the sourcing strategy.[81]

Numerous sourcing concept approaches have been developed over the years. Originating in German publications, a strategic approach to procurement appeared in literature in the early and mid-80s. All authors acknowledged that future competitive advantages can only be achieved through an increasing procurement market orientation. They specifically described an executive function[82], procurement and its associated strategic tasks[83], strategic opportunities[84], and strategic components[85]. Occasional attempts have been made within German literature to simultaneously optimize purchasing, procurement and logistics issues through the concept of integrated materials management[86]. However, as stated earlier, procurement differs from these terms as it also considers communication and supplier issues[87], like material management and logistics. American literature surfacing throughout the 90s established the concept of supply management or supply chain management for procurement[88]. This refers to the strategic, simultaneous optimization of all goods and related information flows both within the firm as well as between buyer and supplier.[89] Meanwhile, in Germany, Meyer (1990) looked into sub-strategies and their sourcing concepts, stating that although a large number of possible concept typologies exist for each sub-strategy, it is recommended that only two extreme forms (e.g. many or few suppliers)

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[80] See Hess (2008), p. 36.
[81] See Essig (2000), p. 19.
[82] See Grochla/Schönbohm (1980), p. 49.
[83] See Arnold (1982), p. 67.
[84] See Hammann/Lohrberg (1986), p. 4; Arnold/Essig (2000), p. 121.
[85] See Arnolds et al. (1996), p. 23.
[86] See Melzer-Ridinger (1991), p. 9); Hartmann (1993), p. 18.
[87] See Arnold/Essig (2000), p. 122.
[88] See Bechtel/Mulumudi (1996); p. 2; Leenders/Fearon (1997), p. 6 cited according to Arnold/Essig (2000), p. 123.
[89] See Arnold/Essig (2000), p. 123.

are taken into account within a model.[90] In the early 90s, strategic and tactical and operational tasks were consistently mixed in different sub-strategies. For instance, the systematization approach by Koppelman[91] distinguishes between product strategy, purchase strategy, communication strategy, service strategy and payment strategy. These include operational activities such as stock and price agreement.[92] Introduced in 1995, Corsten's sourcing cube is designed over three strategic sub-strategies: number of suppliers (single, dual, multiple), market scale (global, local) and object complexity (single, modular).[93] These three sub-strategies represent three individual dimensions, together forming the sourcing cube. In 1998 Krokowski introduced a very similar model. Although its differences were largely semantic[94], this model distinguished global sourcing not only from local, but also domestic: within German markets or European markets close by[95]. In 1998, Engelhardt and Freiling elaborated on the models by Corsten and Krokowski, adding a make-or-buy sub-strategy (make, make and buy, buy) and a time sub-strategy (just-in-time, stock).

Although the aforementioned research made progress regarding sourcing concepts, it is striking that Krokowski as well as Engelhardt and Freiling made no reference to Arnold's "Sourcing Toolbox"[96] published in 1996. It is mainly due to this contribution that Arnold is said to be the most prominent representative of the sourcing concept approach.[97] Later, Arnold criticized Koppelmann[98] for declaring operational activities such as stock and price agreement strategic, and would later on exclude operational activities in his own purely strategic model.[99] Corsten's sourcing cube was also criticized by Arnold for its restricting dimensions, which made it unable to reflect upon other significant sub-strategies.[100]

2.2.2 In-depth: Arnold's sourcing toolbox and its six sub-strategies

Similar to the aforementioned sourcing concept models, Arnold's concept of the sourcing toolbox is an approach that generates a sourcing strategy through the combination of a mix

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[90] See Meyer (1986), p. 240 cited according to Arnold/Essig (2000), p. 124.
[91] See Koppelmann (1995) cited according to Arnold/Essig (2000), p. 124.
[92] See Arnold/Essig (2000), p. 124.
[93] See Corsten (1995), p. 574.
[94] See Arnold/Essig (2000), p. 125.
[95] See Krokowski (1998), p. 6.
[96] See Arnold (1997), p. 93-126.
[97] See Hess (2008), p. 35.
[98] See Koppelmann (1995) cited according to Arnold/Essig (2000), p. 124.
[99] See Arnold/Essig (2000), p. 124.
[100] See Arnold/Essig (2000), p. 125.

of different sourcing concepts. As explained by Arnold, strategic sourcing concepts are created by effectively combining different sourcing sub-strategies with one another. These typical combinations can be described as sourcing concepts and they characterize the core of a sourcing strategy.[101] Within the sourcing toolbox, buying firms are to take into account six sub-strategies: the locational concept, the value creation model, the sourcing object, the supply chain model, the amount of suppliers, and the pooling concept. For each sub-strategy specified, a large number of possible typologies may exist, yet like Meyer he chooses only to mention the two or three sourcing concepts (e.g. many or few suppliers)[102]. By using this typological method, sourcing concepts can be differentiated on important characteristic dimensions.

As can be seen in *Figure 1, Arnold's sourcing toolbox for formulating sourcing strategies*, a typical non-complex and highly standardized sourcing object is matched to the following sourcing sub-strategy concept configurations: global location, external value creation, unit sourcing, stock supply, multiple suppliers, and consortium pooling.

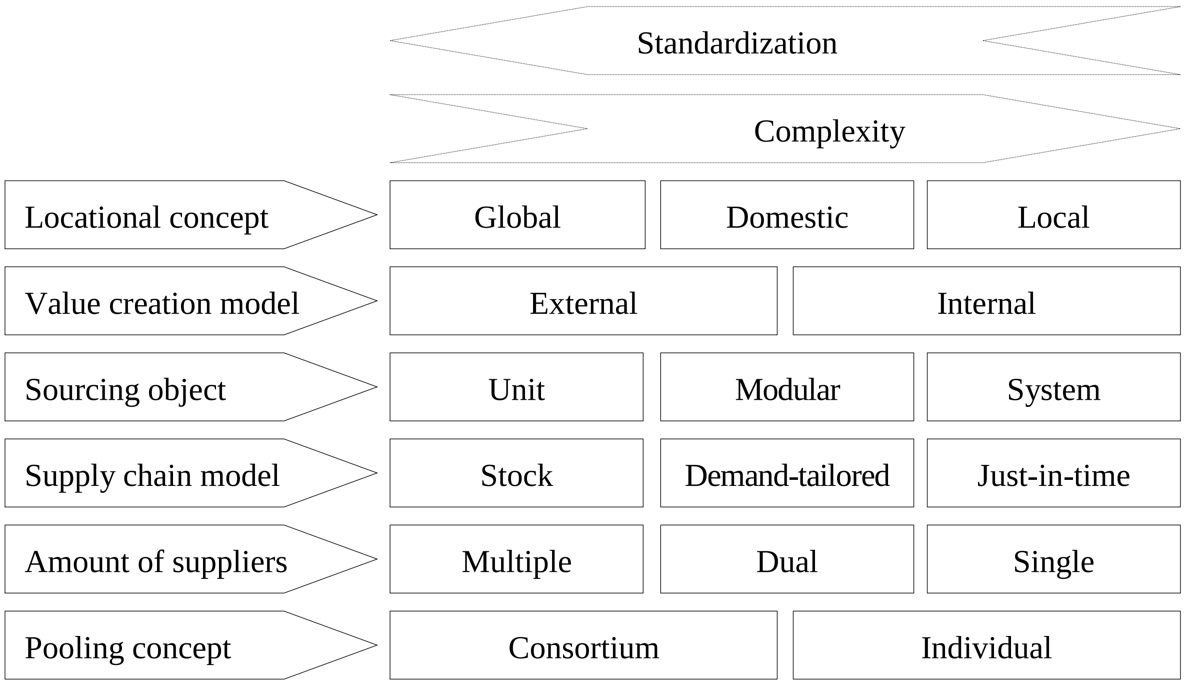

Figure 1, Arnold's sourcing toolbox for formulating sourcing strategies[103]

[101] See Arnold, (1997), p. 93.
[102] See Arnold/Essig, (2000), p. 124.
[103] Source: Arnold, (1997), p. 125.

2.2.2.1 Sub-strategy 1: Locational concept

Locational concept	Global	Domestic	Local

The locational concept simply regards where an object is sourced from. Three sourcing concepts define the possibilities. Local sourcing regards suppliers in the neighborhood or region, and is usually the sourcing concept with the least amount of logistical problems.[104] Domestic sourcing covers more distance than local sourcing, but less than global sourcing. Global sourcing demands long distance shipping from worldwide markets (i.e. other continents). Keegan and McMaster[105] were one of the earliest to use the term "global sourcing", found within their two-by-two global marketing matrix at an international and strategic purchasing strategy, opposite from a national and operative strategy. Monczka and Trent distinguish global sourcing from international purchasing due to its larger scope and complexity. In this regard global sourcing involves "proactively integrating and coordinating common items and materials, processes, designs, technologies, and suppliers across worldwide purchasing, engineering, and operating locations"[106]. Arnold terms global sourcing as "a corporate strategy aimed at the worldwide utilization of materials resources"[107].

A survey among CEOs recently indicated that nearly 95 percent considered becoming more global their top challenge for the next three to five years; nearly 80 percent mentioned cost reduction and improvement of global supply chains.[108] Such a global view facilitates the dispersement of activities in the value chain to locations that offer the best competitive advantage. In this way a firm lowers its costs by gaining competitive advantages such as large amounts of good-quality feedstock and access to well-equipped logistical facilities.[109] Indeed, surveys report sourcing globally to create 5 to 20 percent cost savings.[110] This is done by exploiting a competitive advantage among nations in a

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[104] See Essig (2000), p. 19.
[105] See Keegan/McMaster (1984), p. 101.
[106] Monczka/Trent (1993), cited according to Trent/Monczka (2003), p. 29.
[107] Arnold (1989a), p. 10.
[108] See Trent/Monczka (2003), p. 26.
[109] See Alguire et al. (1994), p. 63.
[110] See Frear et al. (1992); Petersen et al. (2000); Trent/Monczka (2003) cited according to Steinle/Schiele (2008), p. 4.

superior fashion.[111] As Porter states, “there is no excuse for accepting basic factor disadvantages”[112].

In the event of more than one supplier, the locational concept addresses the average position of these suppliers. They can be located adjacently, but also be globally dispersed, for instance when capitalizing on beneficial currency fluctuations relative to the Euro by following currency areas.[113]

2.2.2.2 Sub-strategy 2: Value creation model

Value creation model	External	Internal

The value creation model determines where the supplier’s value added activities take place. Traditionally, a buying firm purchases a product from a supplying firm, which is produced in a plant located elsewhere from the buyer’s premises. This is called external sourcing. The case of internal sourcing occurs when a buying firm decides to build a strategic alliance with the supplier. This can be done by installing its own manufacturing line on the supplier’s premises[114] or by vertically integrating by means of an upstream investment (e.g. acquiring a factory within a factory).[115]

Sourcing literature often mentions strategic alliance-based sourcing. In this case, strategic alliances can be made in regards to internal value creation. This is then an obvious case of a strategic alliance between buyer and supplier. It is said that long-term competitive advantages can be gained by the buyer through strategic alliance-based sourcing “only if its suppliers possess resources that are heterogeneous and immobile; if not, only temporary competitive advantages can be attained”[116]. Advantages such as strategic flexibility and operational effectiveness are readily achieved if an alliance is made between two parties with complementary strengths, allowing buyers more flexibility to deal with (supply) market uncertainty.[117] When making an upstream investment, the buyer may offer more than just the contract price, for instance in the form of knowledge of new technologies or

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111 See Alguire et al. (1994), p. 63.
112 Porter (1990) cited according to Alguire et al. (1994), p. 74.
113 See Arnold (1997), p. 114-115.
114 See Essig (2000), p. 19.
115 See Arnold/Scheuing (1997), cited according to Essig (2000), p. 19.
116 Mata et al. (1995) cited according to Murray (2001), p. 52.
117 See Murray (2001), p. 52.

markets, or services such as helping to improve the product or helping the supplier penetrate new markets.[118]

In light of strategic alliance-based sourcing, a few findings have been presented. First, in the event of resource constraints, such as a limited supply, strategic alliances are often used.[119] Second, if an asset is highly specific, the buyer often relies more on the use of strategic alliances. In the case of high asset specifity this is particularly so for achieving long-term objectives.[120] Third, as sourcing distances grow their reliance on trust is increasingly replaced by legal agreements.[121] For instance, it is more difficult to access information and to communicate face to face, while communication increases trust as it provides firms with clues as to the behavior and motivations of their trading partners.[122] Also, opportunistic behavior will result in less reputational consequences than with domestic firms.[123] Fourth, if an asset is highly specific, the amount of risk-avoidance or individualism that is engrained within a country's culture in plays a role in sourcing strategy. Thus, countries that are risk avoiding will seek strategic alliances in such a case, while countries with a higher level of individualism in their culture will be less eager to seek strategic alliances in such a case.[124] Both third and fourth points mirror the theory of character-based-trust[125], which implies that firms with larger social similarities, among which certainly country of origin, tend to form social ties with each other more easily, resulting in less formal and explicit agreements. Fifth, in the case of global sourcing, highly specific assets prompt companies to satisfy foreign governmental regulations. In order to deal with meeting these regulations, strategic alliances are often made. This also holds true for cases where there is a large need for local knowledge.[126]

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[118] See Christiansen/Maltz (2002), Ellegaard et al. (2003) cited according to Schiele/Steinle (2008), p. 12.
[119] See Murray (2001), p. 46-47.
[120] See Murray (2001), p. 45-46.
[121] See Gulati (1995), p. 102.
[122] See Murray (2001), p. 43.
[123] See Gerlach (1990), cited according to Gulati (1995), p. 95.
[124] See Murray (2001), p. 47-48.
[125] See Zucker (1986), cited according to Gulati (1995), p. 95.
[126] See Murray (2001), p. 48-49.

2.2.2.3 Sub-strategy 3: Sourcing object

Sourcing object	Unit	Modular	System

This sourcing sub-strategy is all about the complexity of the sourcing object. The simplest alternative, unit sourcing, is typically about items with low complexity that the buying company uses to manufacture an end product (e.g. raw materials or feedstock).[127] Modules and systems are not identical, as multiple modules form one system. Modules are characterized by their logistic and economic integration of manufacturing output, while systems represent an assembled technical object. In contrast to modular sourcing, system sourcing also includes the procurement of the associated comprehensive development tasks.[128]

A similar way of defining the sourcing concepts is as general-, industry-standard-, or special supplies. On the one hand, the general supplier offers low-value standard products used in many applications; process costs are the main cost driver. Any general supplier may be chosen, although it is often sourced locally. Industry-standard supplies are often chosen among variants and supply whole (often chemical) industries in a broad sense. Price is the largest element of the total cost of ownership. In the case of general supplies, selection is based on total cost of ownership.[129]

2.2.2.4 Sub-strategy 4: Supply chain model

Supply chain model	Stock	Demand-tailored	Just-in-time

The supply chain sourcing concept is closely linked to inventory optimization and all about the time strategy: when and how often is a product delivered. This part of the framework is of large influence, and it is said to "play a key role in the development of global sourcing business capabilities"[130] Supply chain orientation is defined as "the recognition by an organization of the systemic, strategic implications of the tactical activities involved in managing the various flows in a supply chain"[131] and relates to the degree of cooperation,

[127] See Essig (2000), p. 19.
[128] See Arnold/Essig (2000), p. 126.
[129] See Schiele/Steinle (2008), p. 7-8.
[130] Petersen et al. (2000), p. 33.
[131] Mentzer et al. (2001), p. 11.

coordination, interaction, and collaboration within a supply chain.[132] Indeed, the supply chain orientation has changed both in practice and in research from a short-term price-focused view to a long-term strategic view of supply chain management.[133] A well-managed and established supply chain thus creates a competitive advantage for both buyer and supplier.[134]

Stock sourcing means that sourcing objects are transported relatively less often and thus held for relatively longer periods of time. This helps avoid supply risks. If the goods are of higher value, a situation of capital lockup (stock capital that is not earning returns such as interest) is best to be avoided.[135] Demand-tailored sourcing occurs when the buyer is the only party actively avoiding owning stock. This is done by so-called *hand-to-mouth* buying (i.e. buying just enough to satisfy the demand). When both the buyer and the supplier avoid owning stock, it is called just-in-time sourcing. Although this way of doing business demands a close relationship between buyer and supplier in order to overcome supply risks brought about by the more complicated logistics, it is best for avoiding capital lockup and can thus lead to significant cost reduction.[136] In order for just-in-time sourcing to lead to a cost reduction, it is of course necessary that the additional logistical and operational costs are outweighed by the savings brought about by avoiding capital lockup. Therefore, this sourcing method works best for goods of high value.

For global sourcing, it is advised to take into account the management difficulties associated with global supply chains.[137] Naturally, a larger geographical distance increases transport costs, but its associated increase in supply chain lead-time is also found to complicate decisions because due to inventory cost tradeoffs and the increased complexity of demand forecasting. Sourcing globally is also prone to problems due to cultural and developmental differences, factors such as language barriers, different practices, transportation deficiencies, underdeveloped telecommunications, inadequate worker skills, and disadvantages in supplier quality, equipment, and technology. Altogether, these factors

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[132] See O'Leary-Kelly/Flores (2002), p. 226.
[133] See Arnold (1982); Lindner (1983); Dobler/Burt (1996); Leenders/Fearon (1997) cited according to Essig, (2000), p. 13.
[134] See Choi/Hartley (1996), p. 333-334.
[135] See Arnold (1996) cited according to Essig, (2000), p. 19.
[136] See Essig (2000), p. 19.
[137] See Dornier et al. (1998); Wood (2002); MacCarthy/Atthirawong (2003) cited according to Meixell/Gargeya (2005), p. 533.

may harm the competitive advantage of the supply chain.[138] Country-specific uncertainties are found in fluctuating currency exchange rates, tariffs, quotas, economic and political instability, and changes in the regulatory environment.[139] Together, it is important to factor in the aforementioned risks when designing a global supply chain.

2.2.2.5 Sub-strategy 5: Amount of suppliers

Amount of suppliers	Multiple	Dual	Single

This sub-strategy refers to the choice of sourcing from a single, two (dual), or more than two (multiple) suppliers. Single sourcing gives both firms the opportunity to engage in a close relationship, as establishing such relationship needs a certain amount of investment from both parties for it to work efficiently. This is mainly beneficial in the event of complex sourcing objects. Multiple sourcing gives the buying firm an advantage in negotiating price and other contractual terms by encouraging competition between suppliers. Supply risks are lower in the case of multiple suppliers as well: if one firm is unable to deliver, another firm can pitch in. Naturally, a compromise between sourcing from a single source and sourcing from multiple sources can be interesting as well. Dual sourcing enables the buying firm to invest in two relationships, while still benefiting from a certain amount of security of supply.[140]

There are several factors that lead to advantages for single sourcing over multiple sourcing, as can be seen in practical examples where firms discard the traditional multiple sourcing approach and drastically reduce the amount of sources[141]. The first factor relates to volume, “the main determinant of the company’s overall bargaining power, [which] is critical because economies of scale in purchasing often yield a decisive competitive cost advantage.”[142] Doubling the volume of a specific vendor’s contract can lead to significant overall cost reductions. Second, as managing multiple suppliers leads to more contracts, costs associated with actions such as supplier evaluation or negotiation are often incurred, leading to an increase in *transaction costs*. First discussed by Coase[143], transaction costs

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[138] See Meixell/Gargeya (2005), p. 533.
[139] See Dornier et al. (1998), cited according to Meixell/Gargeya (2005), p. 533; Kaufmann/Hedderich (2005), p. 135.
[140] See Essig (2000), p. 19.
[141] See Kekre et al. (1995), p. 387.
[142] Kraljic (1983), p. 113.
[143] See Coase (1937), p. 390.

are the costs associated with making and upholding each contract. These are not only the time and effort spent on negotiating and renegotiating contracts, but also opportunism, asymmetrical information, and bounded rationality. Therefore, a configuration with many contracts may make transaction costs a substantial item. But the cost is not the only issue negatively impacted by multiple suppliers. Third, research has shown that using a greater number of suppliers can generate an unfavorable variation in incoming quality[144] or otherwise decrease the relative product quality[145]. Finally, fourth, a multiple supplier base can lead to distrust between buyer and suppliers due to lack of communication.[146]

Referring to the amount of suppliers, the sourcing concepts vary among the different sourcing models. In 1996, Arnold's sourcing toolbox spoke of three concepts: single, dual, and multiple sourcing.[147] This typology is mirrored by the aforementioned Corsten, Krokowski, and Engelhardt and Freiling. Later, Arnold added sole sourcing to take into account the monopolistic markets.[148] As biomass markets are not strictly monopolistic, sole sourcing is of no use in this case; this paper therefore uses the three original typologies.

2.2.2.6 Sub-strategy 6: Pooling concept

Pooling concept	Consortium	Individual

Generally, consortium sourcing is spoken of in the case of cooperation between independent members of industry[149], encompassing "the operational, tactical, and/or strategic cooperation between two or more organizations in one or more steps of the purchasing process by pooling and/or sharing their purchasing volumes, information, and/or resources in order to create symbiosis"[150]. As shown in Essig's consortium sourcing matrix[151], the supply management concept of consortium sourcing is a combination of a symbiotic cooperation and a strategic focus. Terms related or synonymous to consortium sourcing are found within the literature as well, such as *cooperative purchasing*, *group*

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[144] See Treleven (1988), p. 104-105.
[145] See Kekre et al. (1995), p. 394.
[146] See Newman (1988), cited according to Shin et al. (2000), p. 321.
[147] See Arnold (1997), p. 95.
[148] See Arnold/Essig (2000), p. 126.
[149] See Essig (2000), p. 14.
[150] Schotanus (2007), p. 12.
[151] See Essig (2000), p. 16.

purchasing, and *buying offices*. Together, these cooperative forms are referred to as the pooling concept.

Within Arnold's sourcing toolbox, consortium sourcing is the alternative to individual sourcing, which is described as "a strategic decision which seeks to build up a strong individual demand position in supply markets" and, in Essig's opinion, ignores the advantages of the consortium model[152]. This is not unfounded, as a report published by Stanford University and Accenture finds that companies that have moved to more collaborative relationships in their supply chains, such as consortium sourcing, grew their market capitalization by eight percent or more and were rewarded with a premium of seventeen to twenty-six percent in their valuation.[153] Moreover, consortium sourcing creates advantages of economies of scale, reduced number of transactions between suppliers and buyers, better buyer-supplier relationships, and stronger negotiation positions. These advantages may seem obvious, as they are also found in individual sourcing within one organization. Other more typical advantages are better market access, a reduction of purchasing prices as well as workloads and transaction costs, knowledge gains through shared experiences and information, higher product and service quality, and reduced (supply) risks.[154]

Disadvantages of cooperative purchasing are also documented. Following from increased complexity of the purchasing process, as well as the loss of flexibility and control, typical disadvantages are increased coordination costs, member commitment issues, supplier resistance, and relationship tension, for instance due to the threat of free-riding. Also, anti-trust laws or non-disclosure agreements may lead to increased legal complexity. Interestingly, successful cooperative purchasing may lead to an increased price in the long run, as a group may become so large that the demand is greater than the supply. Unless the sum of the advantages outweighs the price increase in such a situation, it is advisable to (re)consider individual purchasing.[155] Moreover, consortium relationships often fail due to obstacles encountered during the transition phase from competition to consortium. For one, buyers can turn out to be reluctant to build closer ties after all due to a fear of overdependence. In addition, it has been observed that buyers are quick to revert to old

[152] See Essig (2000), p. 19.
[153] See Spekman/Carraway (2006), p. 10.
[154] See Schotanus (2007), p. 13.
[155] See Schotanus (2007), p. 13-14.

habits such as a singular focus on price thus losing potential supplier expertise related advantages.[156]

It has been found that if firms are involved in major global sourcing activities, their contracts are often of a longer term than those firms with smaller purchase volumes,[157] as it is often more difficult to switch suppliers globally than locally. Long-term contracts for large shipments do contribute to becoming a preferred customer, which contributes to a firm's competitive advantage. Schiele argues that membership of a cluster helps become a preferred customer.[158] This cluster is defined as "…a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementaries…"[159] Though not a cluster by definition, it is assumed that all major consumer and industrial goods markets, such as wood, oil, or energy, have oligopolistic structures. This means that a certain level of interdependence is present between the market reactions of EBX and its competitors. Thus, it is expected that if a firm decides to, for instance, open up a strategic market through an upstream overseas investment, other market participants may follow or even express interest in consortium sourcing opportunities.[160]

2.3 Using Kraljic's portfolio approach and Arnold's sourcing toolbox to develop a sourcing strategy for EBX

Purchasing portfolio models altogether can easily be used to indicate and identify typical supplier relationships[161] and organize the purchasing mix. However, instead of organizing the complete purchasing mix for EBX, this paper will improvise on Kraljic's portfolio approach to organize the purchasing selection in respect to biomass. The first phase of Kraljic's portfolio approach, where a firm's purchased items are classified as noncritical, leverage, bottleneck or strategic items, is therefore unnecessary for the current research problem.

[156] See Spekman/Carraway (2006), p. 10.
[157] See Samli et al. (1998), p. 182.
[158] See Steinle/Schiele (2008), p. 12.
[159] Porter (1998), p. 199.
[160] See Arnold (1989b), p. 4.
[161] See Olsen/Ellram (1997), p. 106; Nellore/Soderquist (2000), p. 246.

The second phase of Kraljic's portfolio approach is the supply market analysis. The market analysis is facilitated by the use of a descriptive framework that offers an understanding of the current state of the biomass supply market, as well as offering a way to structure and map out what types of biomass are available and what their specifications are. The biomass market is regarded along three focus points, as proposed by Arnold: the offer, the competition, and the supply chain.[162] In the end, conclusions are drawn from the *offer* in order to address which biomass types meet co-combustion requirements, thus answering the two preliminary questions $RQ_{1,2}$. Together, information gathered in the *offer*, *chains*, and *competition* form the biomass property configurations as described in $RQ_{3,4,5}$ to answer RQ_5: "Which biomass property combinations offer realistic options in respect to economic feasibility and sustainability?".

The third phase of Kraljic's portfolio approach calls for a purchasing portfolio matrix to assess EBX's power and dependence against that of supplier firms. It may be noted that while certain specifications of the sourcing object will be mapped out, doing so for specifications of the individual suppliers falls outside the descriptive focus of this research. The can make sense to address the actual supplier selection in further research, where economic, performance, technological, organizational, and cultural factors[163] can be scrutinized. Instead, a custom portfolio matrix will be developed. This will be done using theory on power and dependence in buyer-supplier relationships from paragraph 2.1 will be combined with theory on portfolio models from 2.1.1 to establish a custom portfolio matrix to classify the supply of biomass. This custom portfolio matrix will use Arnold's sourcing toolbox as a framework, thus incorporating Arnold's sub-strategies: the locational concept, the value creation model, the sourcing object, the supply chain model, the amount of suppliers, and the pooling concept. Realistic biomass property combinations from RQ_5 will be positioned within the matrix, thus answering RQ_6, *"With which sourcing strategy is each biomass property configuration best matched?"*

The fourth and final phase of Kraljic's portfolio approach, development of an action plan, will address the last research question, RQ_7, *"Which combination of sourcing object and sourcing strategy is best for EBX?"*

[162] See Arnold (1997), p. 256.
[163] See Olsen/Ellram (1997), p. 106.

3 Supply market analysis

3.1 Introduction

The supply market analysis is facilitated by the use of a descriptive framework that offers an understanding of the current state of the biomass supply market, as well as offering a way to structure and map out what types of biomass are available and what their specifications are. The biomass market is regarded along three focus points, as proposed by Arnold: the offer, the supply chain, and the competition.[164] The *offer* describes properties of biomass relevant to the sourcing problem. The *supply chain* describes logistical challenges associated with sourcing a large amount of biomass over a certain distance. The *competition* step will determine whether other large companies are seeking to acquire large amounts of the same biomass. Competition is also regarded in the respect of sustainability, as some forms of biomass can be used for more important goals (e.g. food). For each of the three focus points, this thesis aims to identify and establish the specific properties of interest to the sourcing problem, and describe the focus point using the established properties. Together, this will address which biomass types meet co-combustion requirements, thus answering the two preliminary questions $RQ_{1,2}$ and, by forming the biomass property configurations as described in $RQ_{3,4,5}$, answering RQ_5: “Which biomass property combinations offer realistic options in respect to economic feasibility and sustainability?”.

3.2 An introduction into supply market parameters

In order to determine what biomass, supply chain, and competition properties are of influence to the sourcing decision, it is best to start with a more general approach. Although there is no specific research concerning sourcing strategy selection criteria, much research has been done into supplier selection parameters[165]. It is assumed that supplier selection parameters are applicable to sourcing strategy selection; supplier selection criteria are thus used for this purpose.

[164] See Arnold (1997), p. 256.
[165] See Boer et al. (2001), p. 75.

In 1966, Dickinson reviewed more than 110 research papers in order to determine the critical success factors for supplier selection parameters. He concluded that there are essentially three crucial factors in supplier selection, namely the ability to meet quality standards, the ability to deliver the product on time, and performance history. Historically, quality and delivery have been considered order qualifiers to the extent that if a supplier cannot conform to specifications in these two areas, they will already be dropped as potential candidates during the screening phase. A supplier meeting requirements in both areas will make the buyer confident in choosing an alternative that offers uninterrupted production.[166]

Although offer price is notably not among the top three, Dickinson did state that when purchasing standardized and simple products, price is generally the primary selection parameter. Conversely, non-standardized and complex products create an increasing number of selection parameters.[167] The general lessons from Dickinson are that the type of sourcing object is of major influence in choosing selection parameters, and there is not one universal set of parameters that can be applied to all sourcing strategy decisions.

#	Factor	#	Factor
1	Quality	16	Long-Term Relationship
2	Delivery	17	Procedural Compliance
3	Price	18	Impression
4	Repair Service	19	Reciprocal Arrangements
5	Technical Capability	20	Process Improvement
6	Production Facilities and Capacity	21	Product Development
7	Financial Position	22	Inventory Costs
8	Management and Organization	23	JIT
9	Reliability	24	Quality Standards
10	Flexibility	25	Integrity
11	Attitude	26	Professionalism
12	Communication System	27	Research
13	Performance History	28	Cultural
14	Geographical Location	29	Reputation and Position in Industry
15	Consistency	30	Labor Relations Record

Table 1, sourcing selection parameters[168]

In *Table 1, sourcing selection parameters*, the results of more contemporary research by Cheraghi et al.[169] on the most popular selection parameters are presented. Compared to Dickinson, reliability, flexibility, consistency, and long-term relationship are shown to be

[166] See Cheraghi et al. (2004), p. 98.
[167] See Dickson (1966), p. 5.
[168] Source: Cheraghi et al. (2004), p. 97.
[169] See Cheraghi et al. (2004), p. 97.

new and significant parameters. These parameters serve as a good reference point from which to establish a set of parameters specific to the sourcing object and thus suitable to the research problem. This also holds true for sustainability criteria, as EBX and many other companies seek to manage their corporate legitimacy and reputations together with their suppliers. Following from this development, supplier selection issues are increasingly addressing in the light of sustainability.[170] The triple bottom line (TBL) theory, "a calculation of corporate economic, environmental, and social performance"[171], is among the best known non-financial reporting formats to be given serious attention over recent years. It requests that environmental and social performance are given equal priority by modern firms.[172] The TBL has formed the basis for a systematic integration of sustainability factors, as is found in the work of Bai & Sarkis who recently published a structured set of environmental supplier selection parameters as shown in *Table 2, environmental metrics in supplier selection decisions*.

Categories	Factors	Sub-factors
Environmental performance	*Resource consumption*	Consumption of energy Consumption of raw material Consumption of water
	Pollution production	Production of polluting agents Production of toxic products Production of waste

Table 2, environmental metrics in supplier selection decisions[173]

3.3 Offer

3.3.1 Identifying the biomass properties of interest to the sourcing problem

Biomass is a strange specific asset, as it is by definition organic mass. This means that it can be a great amount of different things. When considering biomass in terms of plant biomass used for fuel, lignocellulosic crops are the main subject of reference. Lignocellulosic crops are composed of lignin, cellulose and hemicellulose, and can be grouped into four main categories. First, dedicated energy crops, which are grown as a low-cost source of biofuel, and due to their ability to provide high energy yields they are most often used in transportation. These crops are fast-growing and can be harvested

[170] See Bai/Sarkis (2010), p. 253.
[171] Robins (2006), p. 1.
[172] See Robins (2006), p. 1.
[173] Source: Bai/Sarkis, (2010), p. 255.

multiple times per year. Dedicated energy crops can be herbaceous (e.g. miscanthus and switchgrass), or woody (e.g. poplar, willow, and eucalyptus). Second, residual wood, which is a residue or byproduct of logging, sawmilling, papermaking, or deforestation processes. Third, agricultural residues, such as bagasse (the residual material after sugarcane is crushed for its juice), and corn stover (the stalks and leaves of the corn). And fourth, industrial and municipal waste, such as recycled paper.[174]

Pretreatment is of large importance to biomass production. Generally, untreated biomass has a relatively high moisture content. After undergoing pretreatment at a conversion plant, biomass contains less moisture and is thus of a higher quality. There are three reasons for pretreatment. First, just after felling, woody biomass typically contains about 50% moisture. Depending on the feedstock criteria used, this might be too wet for co-combustion. A second reason for artificially drying is the decomposition risk associated with wet biomass, as smaller forms like wood chips can decompose within weeks, turning into rotting gasses and liquids and thus resulting in high dry matter loss, as well as fire and health hazards. A third reason for artificially drying wet biomass is a logistical one, as biomass containing 50% moisture is in effect twice as heavy as necessary. Artificially drying reduces biomass weight, which reduces transport costs.[175]

Depending on the pretreatment type, there are three types of biomass commodities: first, biomass which is only dried and/or chipped; second, pelletized biomass, which is compressed into pellets after drying, chipping, and/or milling; third, thermally pre-treated biomass. Recently, thermal pre-treatment techniques such as pyrolysis and torrefaction have gained popularity.[176] Pyrolysis is a treatment technique where biomass is decomposed within an inert atmosphere (with little or no oxygen) at temperatures from 400 to 1000 ºC. Depending on the length and temperature of the pyrolysis process, this generates char, gas, or oil (tar). Due to environmental hazards, pyrolytic oil is an unattractive product. Torrefaction is like pyrolysis, but milder, as it heats to a maximum temperature of 300 °C. Torrefaction yields a dry product with a higher energy content and almost no moisture (which reduces the risk of rotting). As torrefied biomass is devoid of its original fiber structure, it is easily pulverized in coal mills. An added advantage of torrefaction is that it costs roughly the same amount of energy as the alternative route of pelletization and

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[174] See Junginger et al. (2008), p. 13.
[175] See Suurs (2002), p. 27.
[176] See Cremers (2009), p. 15.

transportation. This is because the torrefaction process creates a gaseous byproduct which combusts and thus generates heat that can be used in the process itself. Also, the higher energy density makes transport more efficient. Depending on the moisture content, the net efficiency of torrefaction ranges between 70% and 90%, which is comparable to the efficiency of drying and pelletizing of untorrefied wood pellets.[177]

After identifying and categorizing the natural properties of biomass (i.e. its biological composition) and the types of pretreated biomass (ie. dried, chipped, pelletized and thermally pre-treated), another logical means for identifying biomass properties of interest to the sourcing problem is given by the sourcing selection parameters as shown in *Table 1, sourcing selection parameters* (i.e. quality and price).

In industrial companies, purchasing's share in the total turnover typically ranges from 50% to 90%.[178] This means that small price fluctuations of purchased feedstock have large financial concequences. Thus, when used as an industrial feedstock, biomass price is a large decision driver.

Quality for biomass is mainly determined by its calorific value (CV), also known as energy value or heating value and measured as gigajoules per ton (GJ/t). This is the amount of energy released when burnt in air and it can be expressed in two forms. First, the gross calorific value (GCV) or higher heating value (HHV), measuring the total energy released including latent heat contained in water vapor. This is also seen in condensing boilers as used in households, where the waste heat is used to pre-heat cold water entering the boiler (in the Netherlands, such condensing boilers are given an HHV of 100, 104 or even 107%). The amount of energy released when burnt in air can also be expressed as the net calorific value (NCV) or lower heating value (LHV), excluding the latent heat contained in water vapor. The NCV is the most practical for biomass co-combustion, as the latent heat contained in water vapor cannot be used effectively. Also, it makes sense to provide the CV of a particular biomass together with its moisture content, as moisture negatively influences the CV. One way of doing so is expressing the CV of biomass AR (as received)

[177] See Cremers (2009), p. 16-18.
[178] See Boer et al. (2001), p. 75.

including moisture percentage. Another way of expressing the CV of biomass is MF (moisture free).[179]

Apart from the calorific value, the physical structure and chemical composition of biomass also determines how it combusts in the boiler.[180] Moisture content has already been covered as a large influence. Another is the content of potentially harmful substances. It is important that the chosen biomass feedstock ameliorates the air quality in the power plant area. Thus, biomass used may not lead to higher emissions of harmful substances, such as NO_X, SO_2, HCl, HF, and PM_{10}.[181] Moreover, calculated over the entire supply chain, fewer emissions should be generated than is the case with normal fossil fuels.[182] Ash contents of biomass materials are also be taken into account, as ash may attach itself to the boiler wall or heater (i.e. slagging or fouling). Depending on the composition of this layer, it can either be corrosive (e.g. with chlorine), or non-corrosive (e.g. with high sulfur/chlorine ratios). Compared to coal, most biomass types have much lower ash content.[183] On the other hand, biomass often has a larger content of volatile matter. As volatile content is reactive, it may ignite earlier and with more flames. It is important that the power plant operator knows this, so necessary steps can be taken and there are no surprises in the combustion of the mix.[184] The physical structure of biomass determines the abrasive qualities. Biomass that is abrasive may wear out conveyor systems, mills, and other hardware.[185]

3.3.2 Describing the offer using the established biomass properties

Summing up the biomass properties of interest to the sourcing problem, these are biomass type (dedicated energy crops, residual wood, agricultural residues, or industrial and municipal wastes), pretreatment process (none, only dried and/or chipped, pelletized, pyrolized, or torrefied), price, calorific value, moisture content, emissions (locally and over the entire supply chain), ash content and composition, volatile matter content, and abrasive quality. Below, these properties are explored per biomass type.

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[179] See McKendry (2002), p. 42.
[180] See Cremers (2009), p. 19.
[181] See Vroonhof/Bergsma (2005), p. 9-10.
[182] See Biomassa (2007), p. 11.
[183] See Cremers (2009), p. 21-22.
[184] See Cremers (2009), p. 19.
[185] See Cremers (2009), p. 15.

Dedicated energy crops

There are two types of dedicated energy crops: woody lignocellulosic energy and herbaceous lignocellulosic energy crops. Woody lignocellulosic energy crops consists of crops like eucalyptus, poplar and willow. As pellets, these crops have an NCV of approximately 18.4 GJ/t[186] and contain approximately 10% moisture and 2 to 3% ash. They are mainly sold from sources in China, Thailand, Vietnam, Brazil, Chile, Uruguay, South Africa, Belarus, the Ukraine, Portugal, Spain, and Turkey, priced at approximately 120 to 130 EUR/t FOB.[187] The designation FOB means 'free-on-board' (or 'freight-on-board'), and covers the costs of purchase, loading and shipment up to the port of destination; in this case Rotterdam.

Herbaceous lignocellulosic energy crops consists of crops like miscanthus, switchgrass and reed canary grass. As pellets, these crops have an NCV of approximately 17.8 GJ/t[188] and contain approximately 10% moisture and 1% ash. They are mainly sold from sources in China, Thailand, the United States, Canada, France and Lithuania, the Ukraine, and Poland, priced at approximately 90 to 110 EUR/t FOB.[189]

Residual wood

Residual wood consists of residues from the wood and forestry industries. Residual wood can be compressed in the forest into compressed-residue-bales (CRLs) with a length of 3 m and a diameter of 0.75 m. Their bulk density is 0.15 - 0.23 t_{dm}/m^3 at an initial moisture content of 50 %.[190] Afterwards, they may be compressed into pellets of typically 6 to 12 mm in diameter[191] with a moisture content of 6 to 10% and an ash content of 1 or 2%[192]. As an energy source, residual wood has an NCV of 15 to 17 GJ/t[193], or 16.7 GJ/t according to another source, and has far less negative effects on the air quality than coal does.[194] Of all residual wood, hardwood is nonabrasive, as it reduces the wear rate of straight coal. Due to soil and dirt contents of demolition wood, it is an abrasive type of biomass.[195] Residual wood is the most commonly sold form of biomass, and can be sourced from most

[186] See De Wit/Faaij (2010), p. 191.
[187] See Alibaba.com (2012), accessed 06/09/2012.
[188] See De Wit/Faaij (2010), p. 191.
[189] See Alibaba.com (2012) accessed 06/09/2012.
[190] See Glöde (2000); cited according to Suurs, (2002), p. 24.
[191] See Suurs (2002), p. 29.
[192] See Alibaba.com (2012) accessed 06/09/2012.
[193] See Alibaba.com (2012) accessed 06/09/2012.
[194] See Vroonhof/Bergsma (2005), p. 17.
[195] See Projectgroep "Duurzame productie van biomassa" (2007), p. 11.

forested areas. Largest suppliers are China, Cameroon, Vietnam, the Ukraine, Malaysia, the United States, Lithuania, Russia, Latvia, Poland, and Canada.[196] The total amount of forest felling residue (i.e. residual wood) in Europe is about 56 million dry tons of wood per year.[197] The largest reserves of forest felling residue can be found in Finland, Sweden, Germany and France. Poland and Spain also have substantial volumes available for energy production.[198]

The costs for obtaining residual wood as biomass are dominated by the costs of transporting residual wood from the site to an intermediate site (i.e. conversion plant). Research has been done into production costs in Poland, Finland, France and the Netherlands, in order to obtain the supply that can be harvested within a 100 km radius. These countries are assured to be (more or less) representative for the variety of forest felling residue (i.e. residual wood) found in all European countries. The cost outcomes are for Poland (35 EUR/t), Finland (45 EUR/t), France (66 EUR/t), and The Netherlands (67 EUR/t).[199] As local demand is greater than the supply, the Netherlands is an importer of these pellets. Their value at the plant gate lies around 100 EUR/t[200] and 130 EUR/t[201].

Agricultural residues

Corn, like wheat, rye, and triticale, is of the starch crop type. As pellets, these crops have an NCV of 15.8-17.5 GJ/t[202]. Their moisture content ranges between 8 and 11%, and ash around 7.5%. They are mainly sold from sources in China, Thailand, Vietnam, Australia, and the Ukraine, priced at approximately 130 to 140 EUR/t FOB.[203]

The NCV of rice chaff is 13.5 GJ/t after pelletization. Pelletization is required due to the low density of rice chaff. Although pelletization reduces the mass tenfold, the bulk density is still three times larger than pellet density. Other drawbacks are the high ash content

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[196] See Alibaba.com (2012) accessed 06/09/2012.
[197] See Karjalainen/Metsäntutkimuslaitos (2004), p. 34-36.
[198] See Karjalainen/Metsäntutkimuslaitos (2004), p. 27.
[199] See Karjalainen/Metsäntutkimuslaitos (2004), p. 34-36.
[200] See Junginger/Bolkesjo et al. (2008), p. 724.
[201] See Alibaba.com (2012) accessed 06/09/2012.
[202] See Alibaba.com (2012) accessed 06/09/2012.
[203] See Alibaba.com (2012) accessed 06/09/2012.

(18%) of the combustion, as well as the abrasive quality of rice husk.[204] However, the effect of rice chaff on the air quality is slightly better than that of coal.[205]

The NCV of palm oil is 37.5 GJ/t.[206] However, as of July 2006, co-firing bio-oil became forbidden by law in the Netherlands.[207] Soy oil has similar energy contents, is not forbidden by law, but costs 180 to 360 EUR/t. It can be sourced from China, Malaysia, the United States, Brazil, and the Ukraine.[208]

Industrial and municipal wastes

Relevant types of biomass in industrial and municipal wastes are residual vegetable oils, like tall oil pitch or used frying oil.

The NCV of tall oil pitch is 38.4 GJ/t. Using it as biomass feedstock has an overall better effect on the local air quality.[209] Its price ranges from 80 to 110 EUR/l and it can be sourced from Fujian (China), Los Angeles (the United States), and various ports in Brazil. Annual total supply respectively amounts to 2400, 400.000, and 6000 tons, deeming Los Angeles its largest source by far.[210]

The NCV of used frying oil is 39 GJ/t.[211] Using it as biomass feedstock has an overall better effect on the total air quality.[212] There is, however, no available conclusive data on the market price of used frying oil.

3.4 Chains

3.4.1 Identifying the supply chain properties of interest to the sourcing problem

As the supply chain exists to transport goods from a supplier located in one place, to a buyer located in another place, the first supply chain property of interest to the sourcing problem can easily be identified as distance. This directly relates to the locational sub-strategy of Arnold’s sourcing toolbox: an object is either sourced locally, domestically, or globally. For EBX, local would most certainly be the port of Rotterdam, as well as the rest

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[204] See Vroonhof et al. (2005), p. 12.
[205] See Vroonhof et al. (2005), p. 18.
[206] See Vroonhof et al. (2005), p. 30-31.
[207] See Cremers (2009), p. 37.
[208] See Alibaba.com (2012) accessed 06/09/2012.
[209] See Vroonhof/Bergsma (2005), p. 37-41.
[210] See Alibaba.com (2012) accessed 06/09/2012.
[211] See Vroonhof/Bergsma (2005), p. 23-24.
[212] See Vroonhof/Bergsma (2005), p. 26-27.

of the Netherlands due to its relatively small geographic area. The rest of Europe can roughly be termed domestic, due to the emergence of the European Common Market and the Euro currency which has made inter-European trade logistics less difficult[213]. And global sourcing implies sourcing from worldwide markets (i.e. other continents).

The mode of transportation is also related to distance, as well as to logistic capacity, speed, and of course the availability of necessary infrastructure (e.g. a port, railway, or road).[214] Longer distances within a chain will be tackled by train or by ship. A ship profits from the lowest variable costs possible. Their ports play an increasingly integrated role within supply chains, benefiting users with various value-adding services and, at higher prices, tailor-made services.[215] A general example would be advanced information technology, reducing turnaround times. A more specific example would be connecting a (coal and/or biomass) transfer dock to the power plant by conveyor belt, a service EBX uses at its Maasvlakte location. After transport by ship, rail transport profits from the lowest variable costs, as it too has the advantage of avoiding many cost increasing transfer points.[216] A disadvantage of rail transport within Europe can be the country-specific railways. The dominant track gauge (track width) in Europe is 1435mm. The Russian gauge of 1520mm is also used in Ukraine, Belarus, Latvia, and Lithuania. A final exception is the Iberian gauge of 1668mm, used by Spain and Portugal. Although there is some development towards a uniform railway system, differences in track width at some borders can still lead to time-consuming difficulties, such as switching wheels, locomotives, or even the entire train. It is therefore deemed "almost impossible to gain insight in the cost determining factors of [European] rail transport."[217]

The amount of ships, trains or trucks needed is naturally determined by the total biomass transport volume. This is determined by cargo capacity. Bulk carrier ships are segregated into different size categories ranging from handysize (which can hold 35.000 to 50.000 tons) to capsize (which typically hold 175.000 tons, although some hold more than 400.000 tons). With its 24 meter draft, the port of Rotterdam is equipped to accommodate the largest bulk carriers. Rail transport is commonly done by hopper cars, which have opening doors on the underside to discharge cargo. These cars are made for transporting bulk

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[213] See Essig (2000), p. 19.
[214] See Suurs (2002), p. 35.
[215] See Tongzon et al. (2009), p. 22.
[216] See Suurs (2002), p. 34.
[217] Suurs (2002), p. 33.

commodities like coal, ore, grain, or biomass and can typically carry 100 tons. In Europe, the maximum regulated train length is often 750m, which amount to a maximum total load of 6000 tons. A road truck transports a maximum load of 15 to 25 tons. In the Netherlands, transport infrastructure is well developed. The quality and availability of waterways, railways and roadways is good. Although road transport is deemed the most expensive form of transport, the relatively short transport distances within the Netherlands limit these costs, thereby making road transport the best method of transporting within the Netherlands.[218]

The numbers above imply that one train can transport 300 truckloads, and one ship can transport 30 trainloads, or almost 9000 truckloads. This will lead to logistical bottlenecks if insufficient storage facilities are available at on- and offloading points. Storage facilities in the chain are also necessary due to the seasonal supply of many types of biomass, while demand is constant.[219] In most supply chains for residual wood, seasonality of forest- and crop management results in large stocks of wood chips in the spring, when most wood is cut, and less in the summer, when these wood chips are shipped out.[220] The spruce tree is a large source for residual wood in Sweden and other European countries, and can be harvested during the whole year. However, harvesting during the winter can be advantageous as it enables the wood to dry over the summer.[221] On the demand side, biomass demand is constant. It is linked to energy demand, but also to the high capital investment costs of the Maasvlakte power plants, not to mention possible biomass supply chains. Accommodating the seasonal character of biomass may stress the transport chain to work in peaks, and tax the limits of storage facilities.[222]

Today, forests provide most of the biomass used for electricity and heat generation. A smaller but growing amount of biomass is grown on agricultural land as dedicated energy crops, though it is mostly used for biofuel in road transport.[223] Studies show that over the last five decades, the average production efficiency of food crop has increased and continues to increase. The average increase is however far greater in western countries than in less developed countries. Indeed, some western agricultural sectors even generate an

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[218] See Hamelinck et al. (2005).
[219] See Suurs (2002), p. 38.
[220] See Carlsson/Ronnqvist (2005), p. 595-596.
[221] See Suurs (2002), p. 23.
[222] See Suurs (2002), p. 38.
[223] See Fischer et al. (2010), p. 174.

overproduction. Western countries benefit from increasing use of fertilizers and pesticides, more efficient farm management, and up-scaling. In the future, the global trend is that of an increasing agricultural yield.[224] The growth potential for less developed areas, like for example Eastern Europe and Latin America, is large. This is due to their large land areas with good crop production potential, low population density, and growing agricultural practices. As these countries have the potential to become net suppliers of renewable energy[225], globally sourcing biomass from these regions distances is a strong possibility.

Although biomass is everything but a specific asset in itself, it is due to the bulk in which it is to be sourced that it is assumed to be a specific order. As can be learned from the paper industry, the planning involved in gathering and shipping different types of wood greatly complicate logistics. The problems that occurred led to a consolidation of wood types in the past years, so it is advisable to source biomass types that can be sourced together, or only source one type.[226]

Another problem to factor into the equation is the initial moisture content of biomass. Biomass containing moisture is in effect heavier as is necessary. Artificially drying biomass early in the transport chain reduces transport costs in the remaining transport chain.[227] Analogous to this, a larger conversion plant allows for longer supply distances.[228] This problem is solved by carefully weighing transport costs, transport duration, biomass weight, moisture content, and conditions like temperature.

Distance, volume, mode of transportation, the availability of necessary infrastructure (e.g. a port, railway, or road), and loading-, transport-, transfer-, and storage prices must be taken into account here. And finally, the CO_2 footprint is investigated to establish the sustainability of the supply chain.

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[224] See De Wit/Faaij (2010), p. 190.
[225] See Faaij (2001) cited according to Suurs, (2002), p. 11.
[226] See Carlsson/Ronnqvist (2005), p. 595.
[227] See Suurs (2002), p. 27.
[228] See Karjalainen/Metsäntutkimuslaitos (2004), p. 34-36.

Although it is too elaborate for this paper, *Figure 2, calculating energy consumption costs for long distance biomass transport* shows a method for calculating the specific costs and energy consumption for long distance biomass transport in the model below.

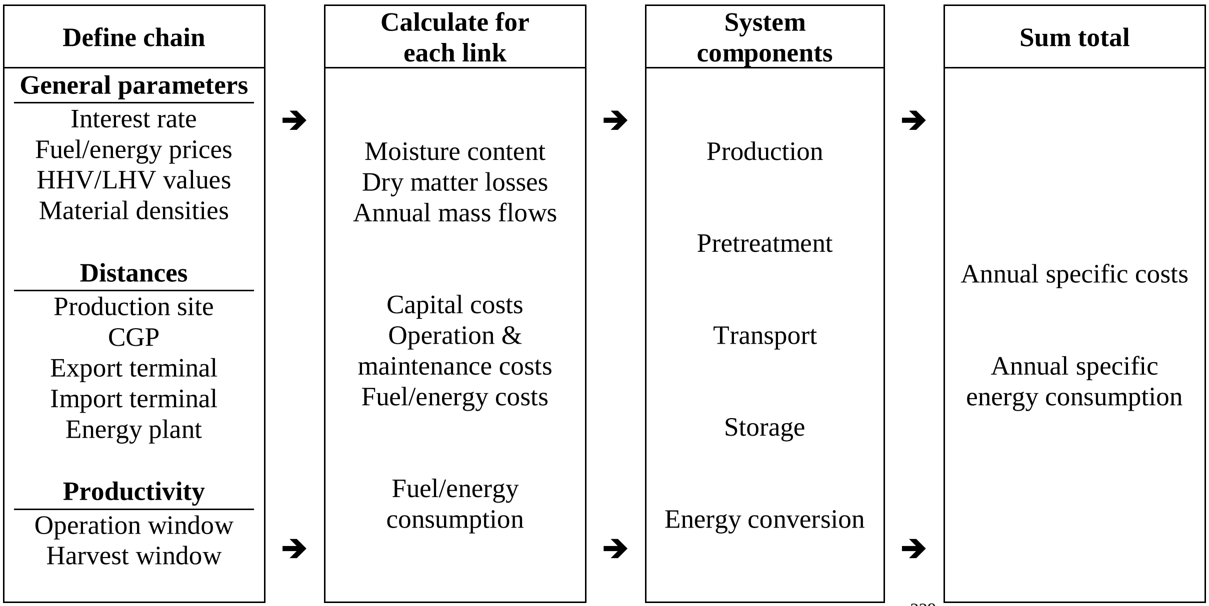

Figure 2, calculating energy consumption costs for long distance biomass transport [229]

3.4.2 *Describing the chains using the established chain properties*

In considering supply chain properties of interest to the sourcing problem, distance is the primary property. Distance determines to large extent the mode(s) of transportation (port, railway, or road). In turn, the mode of transportation directly influences cargo capacity and thus transport volume, as well as the necessity for storage facilities at certain points along the supply chain. Finally, the growth rate and/or the seasonality of forest- and crop management influence the annual supply (constant or seasonal). Below, these properties are explored per biomass type.

Dedicated energy crops

The costs for the production of dedicated bioenergy crops, such as miscanthus and eucalyptus, greatly differ between Western European countries and Central and Eastern European countries. Below, in *Table 3, Western European production costs of dedicated energy crops*, an overview is given of the Western European countries with the largest area of land.

[229] Source: Suurs (2002), p. 21.

Country	Wages € / hour	Fertilizer price € / 100 kg	Land costs € / hectare / year
Finland	16.73	54	164
France	9.52	56	137
Germany	14.13	45	267
Italy	14.38	57	309
The Netherlands	18.96	54	409
Norway	20.12	54	353
Spain	14.38	28	180
Sweden	12.66	54	110
United Kingdom	14.42	68	208
Average	15.10	52	246

Table 3, Western European production costs of dedicated energy crops[230]

The costs for the production of dedicated bioenergy crops are far lower in Central and Eastern European countries. Below, in *Table 4, Eastern European production costs of dedicated energy crops*, an overview is given of the Central and Eastern European countries with the largest area of land.

Country	Wages € / hour	Fertilizer price € / 100 kg	Land costs € / hectare / year
Poland	3,06	18	72
Romania	1,09	18	72
Ukraine	0.43	18	72
Average	2.92	27	50

Table 4, Eastern European production costs of dedicated energy crops[231]

Potentially available European arable land for growing dedicated bioenergy crops amounts to 360.000 km² (2010), 530.000 km² (2020), and 660.000 km² (2030). Potentially available European pastures and natural grassland amount to 50.000 km² (2010), 140.000 km² (2020), and 240.000 km² (2030).[232] For woody crops like eucalyptus, poplar, and willow, this amounts to 4.4 EJ per year (2010), 7.2 EJ per year (2020), and 9.5 EJ per year (2030). Additional production on pastures and natural grassland may total that amount to 5.9 EJ per year (2010), 9.7 EJ per year (2020), and 12.8 EJ per year (2030).[233] For herbaceous lignocellulose crops like miscanthus, switchgrass and reed canary grass, this amounts to 5.8 EJ per year (2010), 9.3 EJ per year (2020), and 12.2 EJ per year (2030). Additional production on pastures and natural grassland may total that amount to 7.4 EJ per year (2010), 12.1 EJ per year (2020), and 15.8 EJ per year (2030).[234] By 2030, some 44 – 72 million hectares could be freed up in the EU27 and Ukraine for growing bioenergy

[230] Source: De Wit/Faaij, (2010), p. 193.
[231] Source: De Wit/Faaij, (2010), p. 193.
[232] See De Wit/Faaij, (2010), p. 197.
[233] See De Wit/Faaij, (2010), p. 197.
[234] See De Wit/Faaij, (2010), p. 198.

feedstocks. Of this land, the Ukraine sums up 22 – 27 million hectares of the surplus land potential.[235]

Eucalyptus plantations are mainly found in Brazil, Chile, Thailand, Uruguay, and South Africa. In South Africa, they were originally planted more than a hundred years ago for the mining industry, and are now used for the production of paper. Eucalyptus grows much faster in tropic and sub-tropic climates. Also, wages and other costs are lower. The trees are harvested every seven years. It is estimated, that the annual amount of wood residue ranges from 200 kton to 1 Mton. Also, South Africa has many seaports.[236] An earlier study into the lifecycle analysis of importing eucalyptus from South Africa to the Netherlands has calculated a scenario where residual wood is transported by 30 to 40 ton truck to a pelletization plant, transported by truck over 20 to 200 km to a seaport, and transported in amounts of 35 to 40 kton by a Panamax bulk carrier to Rotterdam. This study concludes, that the environmental effects of co-combusting in the Netherlands is far better than burning it in South Africa.[237]

Residual wood

In Europe, up to 1.4 EJ of felling residue is available annually. Also, growing trees minus fellings and residues add 1.3 EJ per year. Another 2.7 EJ per year could be produced by harvested whole trees, although they are mainly intended for the timber sector.[238]

As can be learned from the timber sector, the transport of woody biomass from the forest to the local port is mainly carried out by trucking contractors. Different trucks are used for roundwood and for chips. From Sweden, distribution to Europe is mainly carried out by ship to different ports in the continent. After arriving in the port, trains are used for countries located in the interior of the continent such as Austria and Hungary.[239] Also, wood that is geographically located nearby another supplier's mills is sold to that supplier in exchange for wood located close to the firm's own mill, as this saves costs of relatively expensive inland truck transportation.[240]

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[235] See Fischer et al. (2010), p. 175.
[236] See Vroonhof et al. (2005), p. 19-20.
[237] See Vroonhof et al. (2005), p. 22-23.
[238] See De Wit/Faaij (2010), p. 199.
[239] See Carlsson/Ronnqvist (2005), p. 592.
[240] See Carlsson/Ronnqvist (2005), p. 599.

Agricultural residues

As agricultural yield increases over time, the residue-to-crop-ratio will decrease. This leads to a downward trend for the total supply potential of agricultural residues over time from 3.9 to 3.1 EJ per year between 2010 and 2030.[241]

Corn cobs can be pelletized, transported, and co-combusted. Corn is produced in a large amount of countries, among which is Thailand. According to an earlier study, in a scenario where these pellets are transported over a distance of approximately 300 km from the pelletization plant to the sea port in Bangkok with a pellet density of 0.5 ton per m^3, the environmental effects of co-combusting in the Netherlands is far better than using it as livestock fodder, as it is now used.[242]

Of harvested rice, 20% of its mass is chaff and 45% is straw. An estimated 50% of the chaff and straw is used for powering rice production, meaning that a large amount of residue is left unused. Worldwide, 38 to 57 Mton of rice chaff is annually available for use as biomass feedstock for the energy sector. A large amount of this comes from Thailand. As pelletization is best executed close to the source, larger rice mills are best suited.[243]

Palm oil is mainly sourced from Indonesia and Malaysia, where large plantations are dedicated to harvesting this vegetable oil.[244]

Industrial and municipal wastes

Tall oil pitch is a byproduct of paper/carton production and traded internationally as fuel.[245]

Used frying oil mainly comes from the food service industry and large kitchens.[246] Annual supply of used household frying oil in The Netherland amounts to 18.000 tons, while the food service industry can offer 28.000 tons. Through the initiative *Frituurvet, recycle het* [Frying oil, recycle it], approximately 30.000 tons is recycled.[247]

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[241] See De Wit/Faaij (2010), p. 199.
[242] See Vroonhof et al. (2005), p. 47-51.
[243] See Vroonhof et al. (2005), p. 9-10.
[244] See Vroonhof/Bergsma (2005), p. 30-31.
[245] See Vroonhof/Bergsma (2005), p. 3.
[246] See Vroonhof/Bergsma (2005), p. 23-24.
[247] See Voorlichtingsbureau Margarine, Vetten en Oliën (2010).

3.5 Competition

3.5.1 Identifying the competition properties of interest to the sourcing problem

In the context of the resource-based theory, resources are valued according to their contribution to the long-term competitive advantage of a firm. A sustained competitive advantage is obtained when a firm adopts a strategy that is "not simultaneously being implemented by any current or potential competitors and when these other firms are unable to duplicate the benefits of this strategy."[248] Consequently, it is stated that most biomass does not meet the first set of requirements for EBX to use it as a base contributor: although it is considered valuable in the quantity sourced, it is generally not rare, in-imitable, or non-substitutable. Biomass can however be defined as an industrial market resource, as its supply is generally specialized, immobile, and long-lasting. This results in EBX encountering "committed competition—rivalrous moves along incumbent producers that involve resource commitments that are irrevocable for non-trivial periods of time."[249] This then calls for a sustainable competitive advantage, as the resource demands a great deal of organizational commitment long before the resource can be economically utilized.[250]

Different markets currently compete for sources of biomass. A key issue is competition with food and feed production, mainly fodder for cattle, horses and sheep. It might occur, that an increase in energy demand increases demand of agricultural residues, thus creating a fodder products scarcity, leading to a price increase.[251] In a free market, prices for any form of biomass cannot compete with coal, which is roughly six times cheaper per GJ. Interestingly enough, current production costs in Brazil lie between one and two US dollars. It then seems that the high prices are caused by constraints on the supply side. [252]

3.5.2 Describing the competition using the established competition properties

Below, different markets currently competing for sources of biomass are explored per biomass type.

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[248] Barney (1991), p. 102.
[249] Caves (1984), p. 127-128.
[250] See Grant (1991), p. 124.
[251] See Faaij/Domac (2006), p. 13.
[252] See Faaij/Domac (2006), p. 12.

Dedicated energy crops

Agricultural land, freed up by a combination of increasing efficiency and constant food demand, can be used for growing biofuel feedstock for transport. Alternatively, this land can be used for growing dedicated energy crops for the heat and power sector. In this way, biofuel is a competitor for biomass, although this strongly depends on future regulatory frameworks and economic stakes.[253]

It is possible for the energy sector and the paper industry to share woody crops. For instance, although eucalyptus is used in the paper industry, its branches, leaves, bark and sawdust are not used. Therefore, these residues are a candidate for biomass feedstock. In South Africa and many other developing countries, the local price of wood residue is higher than coal. Therefore, this wood remains unused, or is largely burnt in piles.[254]

In the Netherlands, farmers generally receive low subsidies for cultivating energy crops. At 45 € per ha (in the year 2010), it is an unattractive business case to locally cultivate dedicated energy crops. There are, however, patches of land that are currently in use as pasture and too wet for arable crops. It is in these patches of land that high energy high rotation crops like miscanthus can be cultivated. A study into the potential of cultivating miscanthus in the northern provinces of Groningen, Friesland, and Drenthe, concluded the following: assuming that only those areas with the lowest production costs are likely to be dedicated to energy crops (miscanthus), this would yield 2.7 PJ, costing 5.4 – 5.9 € per GJ. When all land where miscanthus is competitive with current land use is taken into account within the named region, miscanthus would yield 71 PJ, costing 5.4 – 9.4 € per GJ. A similar business case for sugar beet generates less energy potential at higher costs.[255] A previous study concluded that "Miscanthus could be competitive with current land use in a relatively large area (given a level playing field in terms of subsidies)."[256]

Residual wood

The annual amount of residue wood in the Netherlands adds up to approximately 500 kton.[257] As in most industrialized countries, woody biomass is used in The Netherlands in

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[253] See Fischer et al. (2010), p. 175.
[254] See Vroonhof et al. (2005), p. 19-20.
[255] See Van der Hilst et al. (2010), p. 408-410.
[256] Van der Hilst et al. (2010), p. 414.
[257] See Vroonhof/Bergsma (2005), p. 57.

the construction of buildings[258] and for the production of pallets and particleboard. By substituting particleboard production for drywall production, residual wood can be used as an energy source.[259]

Agricultural residues

Although many large corn producing countries use corn cob pellets for other purposes, Thailand uses corn cobs as a raw cell additive in livestock fodder, which competes with the export for energy production.[260] Rice chaff can be used as a substitute for livestock fodder, enabling corn cob pellets to be pelletized, transported, and co-combusted. According to an earlier study, in a scenario where these pellets are transported over a distance of approximately 300 km from the pelletization plant to the sea port in Bangkok with a pellet density of 0.5 ton per m^3, the environmental effects of co-combusting in the Netherlands is far better than using it as livestock fodder.[261] Also in Thailand, rice chaff is used as a local energy source, or to enhance soil quality. However, large amounts remain unused.[262]

Palm oil is currently used as an energy-rich additive in livestock fodder. Also, as palm oil is globally the most popular vegetable oil, it is relatively expensive and there is no overproduction or residue available for use as energy feedstock. Soy oil may be used as a substitute, although it is even more expensive than palm oil.[263]

In the Netherlands, farmers generally receive subsidies for cultivating their agricultural crops. In accordance with CAP (Common Agricultural Policy), this amounts to 446 € per ha. This is ten times as much as is subsidized for cultivating energy crops.[264]

Industrial and municipal wastes

In its crude form, tall oil pitch is mostly used as low-grade fuel. Refined, tall oil pitch is a potentially valuable source of sterols. As sterols have medical value, it would be best to first extract this substance. However, there is not enough capacity for the refinement, so demands in these markets are not satisfied.[265]

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[258] See Hoogwijk et al. (2003), p. 128.
[259] See Vroonhof/Bergsma (2005), p. 19.
[260] See Vroonhof et al. (2005), p. 43-45.
[261] See Vroonhof et al. (2005), p. 47-51.
[262] See Vroonhof et al. (2005), p. 9-10.
[263] See Vroonhof/Bergsma (2005), p. 30-31.
[264] See Van der Hilst et al. (2010), p. 414.
[265] See Vroonhof/Bergsma (2005), p. 37-41.

Used frying oil is categorized as waste. Its annual supply is mainly used in the production of biodiesel[266], energy, and oleochemicals[267].

3.6 Conclusion

3.6.1 Which requirements must biomass meet in order to qualify as an option for co-combustion?

In order to qualify as an option for co-combustion, biomass must meet the requirements as stated in *Table 5, requirements for co-combustion*.

Requirement type	**Best case scenario**
Calorific value (NCV)	Higher
Moisture content	Lower
Emissions NO_X	Lower
Emissions SO_2	Lower
Emissions HCl	Lower
Emissions HF	Lower
Emissions PM_{10}	Lower
Ash content	Lower
Ash composition	If chlorine, then with sulfur
Volatile matter content	As long as the mix is known
Abrasive quality	Lower

Table 5, requirements for co-combustion

3.6.2 What types of biomass meet co-combustion requirements?

Biomass types suitable for co-combustion:

- Eucalyptus pellets
- Miscanthus pellets
- Residual wood pellets
- Corn husk pellets
- Soy oil
- Tall oil pitch
- Used frying oil

Biomass types unsuitable for co-combustion:

- Rice chaff pellets (high ash content, abrasive)
- Palm oil (forbidden by law)

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[266] See Vroonhof/Bergsma (2005), p. 23-24.
[267] See Voorlichtingsbureau Margarine, Vetten en Oliën, (2010).

3.6.3 What biomass properties directly influence sourcing strategy selection?

The previous research question has addressed the requirements that biomass must meet, in order to qualify as a potential feedstock for co-combustion. Therefore, this research question only focuses on biomass that meets such requirements.

Cheraghi et al.[268] respectively name quality, delivery, and price as the top three sourcing selection parameters. Following Dickinson, biomass can be identified as a standardized and simple product, typical of a low complexity and its use to manufacture an end product. Therefore, price can be considered the primary selection parameter (in €). Quality selection is determined by the NCV in gigajoules per ton (GJ/t). Delivery selection is determined by the transport distance (km). An interesting combination of these properties is the value for money, as expressed in price per NCV (GJ/€/t).

3.6.4 With which quantitative ranges are the biomass properties matched in order to adequately classify biomass types?

To facilitate the comparison of various sourcing strategies, the biomass properties price, quality, and distance are classified into three groups (i.e. *high*, *medium*, and *low*). Each group corresponds with a different quantitative range. These ranges stem from quantified biomass properties as documented prior in this chapter and summarized in *Table 6, quantified ranges of biomass proporties (1)*.

Property	**Low**	**Medium**	**High**
Price (€/t)	< 100	100 – 150	> 150
Quality (GJ/t)	< 15	15 – 25	> 25
Distance (km)	< 250	250 – 2500	> 2500

Table 6, quantified ranges of biomass proporties (1)

Price and quality can be translated into value for money as seen in *Table 7, quantified ranges of biomass proporties (2)*.

Property	**Low**	**Medium**	**High**
Value for money (GJ/€/t)	< 0.15	0.15 – 0.17	> 0.17
Distance (km)	< 250	250 – 2500	> 2500

Table 7, quantified ranges of biomass proporties (2)

3.6.5 Which biomass property combinations offer realistic options in respect to economic feasibility and sustainability?

[268] See Cheraghi et al. (2004), p. 97.

First, a list is made of all biomass offers suitable for co-combustion, and their supply quality and location as displayed in *Table 8, all biomass offers suitable for co-combustion*.

Biomass types	Value for money		Distance (km)	
	GJ/€/t	Range	Country	Range
Eucalyptus pellets	0.13 – 0.15	Med	BY, UA, PT, ES, TR	Med
Eucalyptus pellets	0.13 – 0.15	Med	CN, TH, VN, BR, CL, UY, ZA	High
Eucalyptus pellets	0.13 – 0.15	Low	BY, UA, PT, ES, TR	Med
Eucalyptus pellets	0.13 – 0.15	Low	CN, TH, VN, BR, CL, UY, ZA	High
Miscanthus pellets	0.16 – 0.20	High	FR, LT, UA, PL	Med
Miscanthus pellets	0.16 – 0.20	High	CN, TH, US, CA	High
Miscanthus pellets	0.16 – 0.20	Med	FR, LT, UA, PL	Med
Miscanthus pellets	0.16 – 0.20	Med	CN, TH, US, CA	High
Residual wood pellets	0.13 – 0.15	Med	All	Low
Residual wood pellets	0.13 – 0.15	Med	All	Med
Residual wood pellets	0.13 – 0.15	Med	All	High
Residual wood pellets	0.13 – 0.15	Low	All	Low
Residual wood pellets	0.13 – 0.15	Low	All	Med
Residual wood pellets	0.13 – 0.15	Low	All	High
Corn husk pellets	0.11 – 0.13	Low	UA	Med
Corn husk pellets	0.11 – 0.13	Low	CN, TH, VN, AU	High
Soy oil	0.10 – 0.21	High	CN, MY, US, BR	High
Soy oil	0.10 – 0.21	Low	CN, MY, US, BR	High
Tall oil pitch	0.35 – 0.48	High	CN, BR, US	High
Used frying oil			NL	Low

Table 8, all biomass offers suitable for co-combustion

Then, all combinations matching *low-quality-high-distance*, *low-quality-medium-distance*, and *medium-quality-high-distance* are deemed economically unattractive and unsustainable options. They are removed accordingly. As explored earlier in this chapter, the Dutch supply for residual wood pellets is not sufficient to meet EBX demands. Thus, Dutch residual wood is only realistic in combination with other options. Used frying oil is omitted from the list, as there is large competition for its annual supply, while its total annual amount fails to meet even 5% of EBX's demand. What remains, is the answer to RQ_5, as shown in *Table 9, selected biomass offers suitable for co-combustion*.

Biomass types	**Value for money**		**Distance (km)**	
	GJ/€/t	**Range**	**Country**	**Range**
Eucalyptus pellets	0.13 – 0.15	Med	BY, UA, PT, ES, TR	Med
Miscanthus pellets	0.16 – 0.20	High	FR, LT, UA, PL	Med
Miscanthus pellets	0.16 – 0.20	High	CN, TH, US, CA	High
Miscanthus pellets	0.16 – 0.20	Med	FR, LT, UA, PL	Med
Residual wood pellets	0.13 – 0.15	Med	All	Low
Soy oil	0.10 – 0.21	High	CN, MY, US, BR	High
Tall oil pitch	0.35 – 0.48	High	CN, BR, US	High

Table 9, selected biomass offers suitable for co-combustion

4 Sourcing strategy analysis

4.1 An introduction into the matching method

The biomass properties used in the analysis of the sourcing strategy are the value for money, and the sourcing distance. In order to generate a portfolio of the best sourcing strategies for each combination of value and distance, a biomass sourcing portfolio matrix is developed. This portfolio matrix uses value for money and sourcing distance as categorical axes, is paired to different sourcing sub-strategy configurations, and is populated with the realistic biomass sourcing options as identified in RQ_5.

As the location is included as a categorical axis on the portfolio matrix, it is not discussed as a sub-strategy. Also, the sub-strategy of the sourcing object will be excluded from the portfolio matrix, as for all relevant biomass it is clearly that of unit sourcing. Unit sourcing is typical of feedstock, identified by a low complexity and its use to manufacture an end product. The match between the remaining sub-strategies on one hand, and value and distance on the other, is discussed in the following paragraph.

4.2 Matching biomass property configurations to a sourcing strategy

4.2.1 Value creation model

Sourcing objects in unit form, such as biomass, are associated with external strategies as the associated supply risks are relatively low. Thus, an external strategy is used as the basis, with a few exceptions as follows.

Internal value creation is often used when supply is high in risk and/or value (high calorific value, in the case of EBX). Often, the higher supply risks of modular or system sourcing concepts, a just-in-time sourcing concept, or a limited supply, demand a closer buyer-supplier connection offered by an internal value creation concept. Also, as sourcing distances grow, their reliance on trust is increasingly replaced by legal agreements. Thus, internal value creation is a means for solving trust issues when sourcing globally.

4.2.2 Supply chain model

Stock sourcing helps avoid supply risks, but creates capital lockup for goods with high value. However, (high) value is not to be confused with (high) value for money, the biomass property used in the analysis of the sourcing strategy. Rather, the absolute value of biomass is inversely proportional to its value for money: biomass with a higher value for money (i.e. a higher calorific value for a lower price) has a lower absolute stock value. Therefore, biomass with a higher value for money is best matched with stock sourcing.

The complicated logistics and supply risks associated with just-in-time sourcing do not match the case of biomass sourcing, as its absolute value is too little and the transport distances are too great.

Demand-tailored sourcing reduces capital lockup but bears a certain amount of the logistic complexities and supply risks associated with a just-in-time strategy. Therefore, demand-tailored sourcing is a suitable strategy for biomass with a lower value for money that is to be transported over shorter distances.

4.2.3 Amount of suppliers

Single sourcing is best for situations that need a close relationship, as is the case with biomass with a high value for money, as well as with the complicated logistics and supply risks associated with global sourcing. Sourcing from multiple suppliers does add the possibility of substitution, lowering supply risks.

Sourcing all the necessary volume from one supplier can lead to a high value discount, while sourcing from multiple (competing) suppliers can lead to better contractual terms, such as lower prices. Multiple contracts do, however, add to transaction costs. Also, research has shown that using a greater number of suppliers can generate an unfavorable variation in incoming quality[269] or otherwise decrease the relative product quality[270]. Dual sourcing can act as a middle ground, forming a compromise between single and multiple sourcing.

4.2.4 Pooling concept

Individual sourcing can build up a strong individual demand position in supply markets, and also keeps things simple with reduced legal complexity, no coordination costs, and no risks related to member commitment or relationship tension. However due to the oligopolistic nature of the energy market, other market participants are expected to follow each other's strategies or even express interest in consortium sourcing opportunities.

[269] See Treleven (1988), p. 104-105.
[270] See Kekre et al. (1995), p. 394.

Consortium sourcing is of interest for biomass with a high value for money, mainly because it creates advantages of economies of scale and stronger negotiation positions.

4.3 Presenting the matches between sourcing object and sourcing strategy

In order to associate a sourcing object (i.e. biomass offers) with sourcing strategies, a model is presented (*Figure 3, model for associating sourcing objects with sourcing strategies*). The sourcing object can be made up of low, medium, and high biomass value, as well as low, medium, and high biomass transport distance. Ideally, biomass is of high quality and low transport distance, rendering the top left corner (number one) the best option. The least ideal option lies at the bottom right corner (number nine): biomass of low quality and high transport distance.

Defined along the scale of general-, industry-standard-, or special supplies, pretreated biomass (dried, chipped, milled, and/or thermally treated) fits best in the industry-standard supply category, where price is main cost driver. Biomass is then best sourced globally, competing on price and pooling demand. This theory is reflected by the results: box three is matched with price competition and demand pooling.

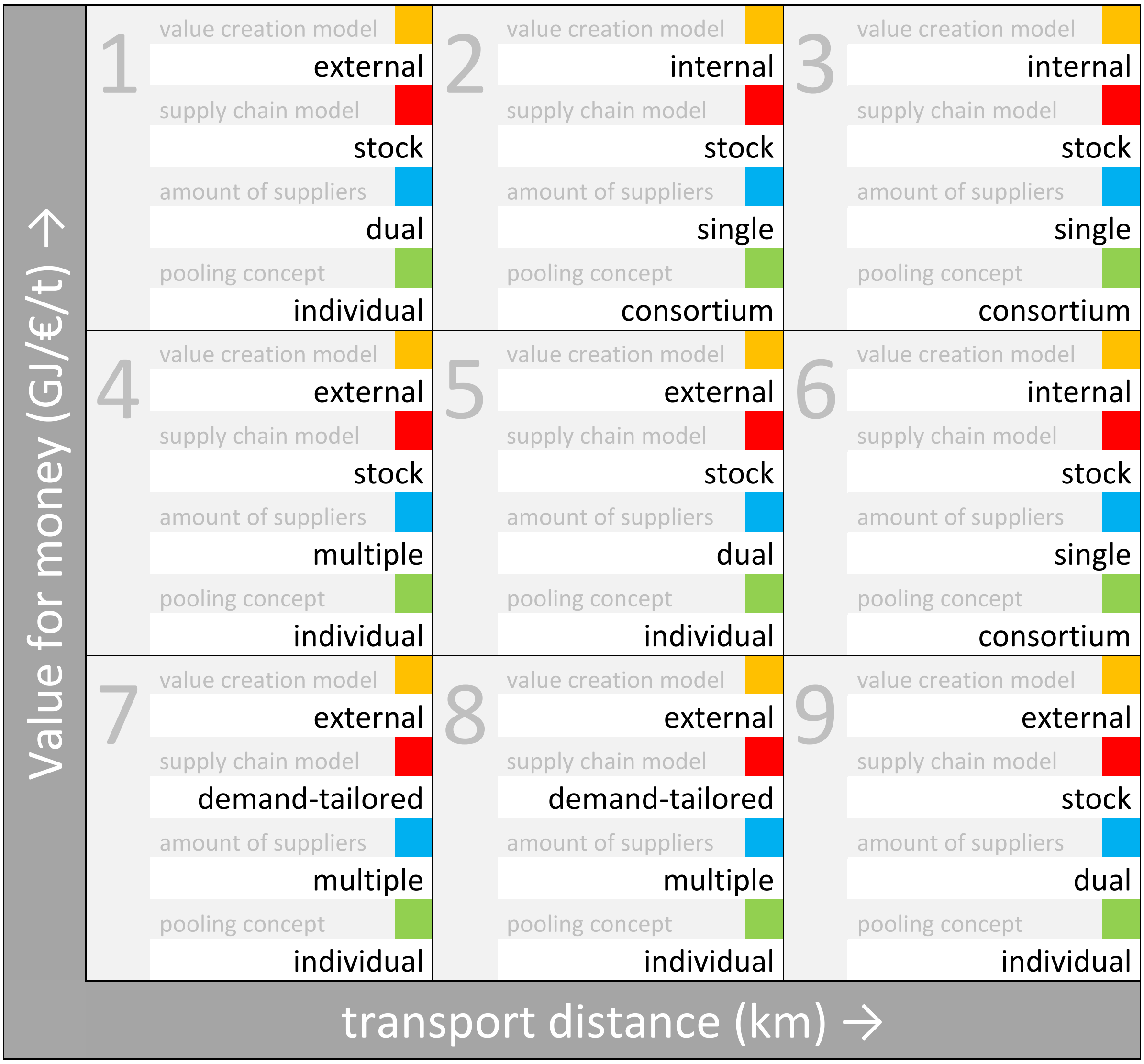

Figure 3, model for associating sourcing objects with sourcing strategies

RQ_5 has filtered all combinations of biomass properties that are realistically possible. In order to answer RQ_6 (With which sourcing strategy is each biomass property configuration best matched?) the preselected combinations of biomass properties from RQ_5 are matched to their respective sourcing strategies. Miscanthus pellets are categorized in boxes two, three, and five. Tall oil pitch and soy oil are categorized in box three. Eucalyptus pellets are categorized in box five. And finally, residual wood pellets are categorized in box four.

5 Sourcing strategy assessment

5.1 An introduction into the method of assessment

Up to here, the different sourcing strategies are associated with the three locational sub-strategies: local (the Netherlands), domestic (Europe), and global (overseas). As different supplier locations are known for each option, a loose assessment is made of the logistical implications of the different supplier locations, thereby identifying the best option(s). This assessment is based on logistical data gathered earlier in this thesis and common logic regarding transport routes, and aims to identify the best location, as well as the method of transportation from that location to EBX. As price and thus total cost is a large decision driver, this is also evaluated first for each option. EBX annually requires 26.5 PJ of energy from biomass feedstock. Given the NCV-values found for the different biomass options, a calculation is made of the annual requirement in kton, and the associated feedstock cost. Then, the practical execution of the attributed sourcing sub-strategies is explored and possible conflicts or other problems are identified.

5.2 Comparing the sourcing strategies amongst another

5.2.1 Miscanthus pellets from Europe

Sourcing miscanthus pellets can be done from France, Lithuania, the Ukraine, or Poland. It has been shown that production costs are lowest in Eastern Europe. The Ukraine is a promising option for the future, due to its 22 to 27 million hectares of surplus land. However, train transportation is a problem as the track gauge differs between the Ukraine and Poland, leading to additional transhipment costs. Shipping by sea requires a substantial detour, leading from the port of Odessa over the Black Sea, through the Bosphorus, around Greece, over the Mediterranean Sea, through the Straight of Gibraltar, over the North Atlantic Ocean to the port of Rotterdam. Therefore, train transport from Poland or sea transport from Lithuania are the best options. From Lodz, Poland, distance by rail is approximately 1.100 km. From the Klaipeda State Seaport in Lithuania, distance by sea is approximately 1.650 km.

In order to comply with co-combustion norms, 1.489 kton of miscanthus pellets is needed annually. With a price ranging between 90 and 110 EUR/t FOB, this leads to an annual feedstock cost ranging between 134 and 164 mln. EUR. It is assumed that the cost levels for Poland and Lithuania lie at the lower end of this range, as the Ukraine has higher transportation complexity, while France has higher production costs.

In order to secure a steady stream of high-value miscanthus pellets, EBX builds a strategic alliance with a pellet supplier based in Poland or Lithuania, acquiring a part of the plant through an upstream investment (*internal value creation*). This then leads to a situation where stock on both sides of the supply chain belongs to EBX, giving EBX some control over the supply, and enabling a certain amount of demand-tailored sourcing. This is however not crucial, as the high value for money of these pellets leads to low capital lockup risks anyway. Therefore, EBX is advised to maximize transport volume and benefit from an overall reduction in transport and transshipment costs by dedicating a part of its existing coal stockpiling infrastructure, located next to the power plant, to building up miscanthus pellet stock (*stock sourcing*). Due to the relatively high value for money, EBX is advised to engage in a close relationship (*single supplier*). As for the pooling concept: in order to create advantages of economies of scale and stronger negotiation positions, EBX should also seek to pool purchasing volumes with other members of industry (*consortium sourcing*). In that case, the upstream investment in the production plant should be done by all members of the consortium.

5.2.2 Eucalyptus pellets from Europe

Sourcing eucalyptus pellets can be done from Belarus, the Ukraine, Portugal, Spain, or Turkey. As production costs are lowest in Eastern Europe, Portugal and Spain are removed from the selection. As explained in the miscanthus strategy, the Ukraine is a promising option for the future whose transport options are currently more expensive than from options less distant. Belarus offers a similar scenario and is thus removed as well. By means of elimination, Turkey is the best option. Its track gauge matches that of most of Europe and its shipping port of Izmir offers easy access to the Mediterranean Sea. From Izmir, distance by rail is approximately 3.330 km, by sea 5.500 km.

EBX requires an annual supply of 1.472 to 1.559 kton of eucalyptus pellets. With a price ranging between 120 and 130 EUR/t FOB, this leads to an annual feedstock cost ranging between 177 and 203 mln. EUR. It is assumed that the cost levels for Turkey lie at the lower end of this range, as the Ukraine and Belarus have higher transportation complexity, while Portugal and Spain have higher production costs.

Thus, a supplying firm based in Turkey produces the eucalyptus pellets in a self-owned plant (*external value creation*). As in the case of miscanthus pellets, EBX should dedicate a part of its existing coal stockpiling infrastructure to building up eucalyptus pellet stock (*stock sourcing*). This maximizes transport volume and reduces transport and transshipment costs. Moreover, risks and complications in the supply chain are lowest when using a stock sourcing strategy, which fits the relatively long sourcing distance. Due to the moderate value for money, EBX is advised to invest in two supplier relationships, encouraging competition between suppliers while still benefiting from a certain amount of security of supply (*dual suppliers*). This is also the case when establishing a demand position: EBX can best build up a strong individual demand position in the supply market of eucalyptus pellets (*individual sourcing*).

5.2.3 Tall oil pitch from overseas

In order to meet co-combustion requirements, 690 kton of tall oil pitch is needed annually. However, supply is scarce and as soon as there is an attractive business case for refining tall oil pitch and extracting sterols, EBX may have to compete for supply with the medical field. From a marketing point of view: unless EBX can aid in extracting and supplying sterols to the medical field, while using the rest product as biomass, this is an undesirable option. From a sourcing point of view: Los Angeles offers an annual supply of 400 kton, while China and Brazil offer respectively 2.4 and 6 kton. If EBX succeeds in acquiring the entire supply, it would only satify 59% of its annual demand. With a price ranging between 80 and 110 EUR/t FOB, this leads to an annual feedstock cost ranging between 33 and 45 mln. EUR. Due to the large level of competition in the market for tall oil pitch, it is assumed that the cost levels lie at the high end of this range. If EBX chooses tall oil pitch as a feedstock, an minimal annual biomass demand of 10.8 PJ will have to be acquired from another type of feedstock. As the planning involved in gathering and shipping different types of biomass greatly complicates logistics, it is advisable to source biomass types that can be sourced together, or only source one type. While this would render tall oil pitch an undesirable option from a sourcing point of view, its high value for money renders it an exception.

Sourcing tall oil pitch is mainly done from the port of Los Angeles. From the port of Los Angeles, distance by sea is approximately 14.000 km, traveling through the Panama Canal and across the North Atlantic Ocean. China and Brazil also offer small amounts. From the ports of both Xiamen and Quanzhou, China, distance by sea is approximately 18.500 km, traveling from the South China Sea across the Arabian Sea, the Gulf of Aden, the Red Sea, through the Suez Canal, over the Mediterranean Sea, around Gibraltar to the port of Rotterdam. From the port of Itaqui, Brazil, distance by sea is approximately 7.600 km, crossing the North Atlantic Ocean.

For the supply security of high-value tall oil pitch, EBX builds a strategic alliance with the Los Angeles based supplier, acquiring a part of the plant through an upstream investment (*internal value creation*). Due to the large sourcing distance and the high value for money of tall oil pitch, it is important to attain a high level of supply security (*stock sourcing*). In this case, EBX should build a bulk liquid storage facility adjacent to its power plant. Though, due to the upstream investment, the stock on both sides of the supply chain would belong to EBX, enabling a certain amount of demand-tailored sourcing. The large sourcing distance and high value for money also argue in favor of a single supplier. This would also be the logical choice, given the upstream investment in the Los Angeles based supplier. However, as the total demand cannot be met by the Los Angeles supplier, China and Brazil will also supply tall oil pitch to EBX (*multiple suppliers, by necessity not by choice*). Due to the shortage of tall oil pitch, it would be best for EBX to secure a maximum supply amount for itself. However, as described earlier in this thesis: if A wants a resource which B owns, and there are limited alternative sources for this valued resource, A's dependence on B is high. Therefore, as EBX would have a substantial dependence on the Los Angeles supplier, it would lead to an unbalanced relationship in which the supplier holds the power. Thus, EBX may be forced to create advantages of economies of scale and stronger negotiation positions by pooling purchasing volumes with other members of industry (*consortium sourcing*). In that case, the upstream investment in the Los Angeles plant should be done by all members of the consortium (e.g. Essent, NUON, and Electrabel).

5.2.4 Residual wood pellets from the Netherlands and Europe

Sourcing residual wood pellets can be done partly from the Netherlands. When Dutch supply runs out, pellets from other European countries can be used. Most likely exporters would be the Ukraine, Lithuania, Latvia, or Poland, as they offer the largest supply. Analog to the sourcing strategy of miscanthus pellets, train transport from Poland or sea transport from Lithuania are better options than coping with the large transport distance from the Ukraine. From Lodz, Poland, distance by rail is approximately 1.100 km. From the Klaipeda State Seaport in Lithuania, distance by sea is approximately 1.650 km.

Sourcing by sea from Latvia is also an interesting option. From the Freeport of Riga, distance by sea is approximately 1.900 km.

In order to meet the annual demand, 1.559 to 1.767 kton of residual wood pellets is needed. With a price ranging between 100 and 130 EUR/t FOB, this leads to an annual feedstock cost ranging between 177 and 212 mln. EUR. It is assumed that the cost levels for the Netherlands lie at the lower end of this range, as the other options have higher transportation complexity. The cost levels for Poland, Lithuania, and Latvia also lie at the lower end of this range, as they have a relatively low transportation complexity and low production costs.

Both the Dutch and European options fit roughly the same sourcing strategy. Thus, supplying firms based in the Netherlands, Poland, Lithuania, or Latvia, produce the residual wood pellets in a self-owned plant (*external value creation*). Sourcing over relatively small sourcing distances, as is the case when sourcing from the Netherlands, is associated with relatively low supply chain risks and complications. Even so, due to the sourcing object value, EBX is advised to build up residual wood pellet stock (*stock sourcing*), thus securing as much of the Dutch supply as possible while reducing transport and transshipment costs. This is also advised when sourcing the remaining amount of residual wood pellets from Poland, Lithuania, or Latvia. As for the amount of suppliers: as the sourcing value and distance are relatively low, EBX can best seek an advantage in negotiating price and other contractual terms by encouraging competition between suppliers (*multiple suppliers*). However, when sourcing from other European countries, EBX is advised to invest in only two supplier relationships, encouraging competition between suppliers while still benefiting from a certain amount of security of supply (*dual suppliers*). EBX can then best build up a strong individual demand position in the supply market of residual wood pellets and keep coordination in the supply chain simple (*individual sourcing*).

5.3 Presenting the best sourcing object and sourcing strategy combinations for EBX

Below, *Figure 4, top ranking sourcing object and sourcing strategiy combinations* matches these objects and locations with their associated sourcing strategies. This answers RQ_6: "With which sourcing strategy is each biomass property configuration best matched?"

Miscanthus pellets
Sourced from Lodz, Poland or Klaipeda, Lithuania

value creation model	supply chain model	amount of suppliers	pooling concept
internal	stock	single	consortium

Eucalyptus pellets
Sourced from Izmir, Turkey

value creation model	supply chain model	amount of suppliers	pooling concept
external	stock	dual	individual

Tall oil pitch (while supply lasts)
Sourced from Los Angeles, and Xiamen / Quanzhou, China and Itaqui, Brazil

value creation model	supply chain model	amount of suppliers	pooling concept
internal	stock	*multiple (in practice)*	consortium

Miscanthus pellets (remaining demand)
Sourced from Lodz, Poland or Klaipeda, Lithuania

value creation model	supply chain model	amount of suppliers	pooling concept
internal	stock	single	consortium

Residual wood pellets (while supply lasts)
Sourced from the Netherlands as well as from Lodz, Poland or Klaipeda, Lithuania or Riga, Latvia

value creation model	supply chain model	amount of suppliers	pooling concept
external	stock	multiple	individual

Residual wood pellets (remaining demand)
Sourced from Lodz, Poland or Klaipeda, Lithuania

value creation model	supply chain model	amount of suppliers	pooling concept
external	stock	dual	individual

Figure 4, top ranking sourcing object and sourcing strategiy combinations

When only considering total annual costs, the best sourcing strategy would revolve around a combination of tall oil pitch while its supply lasts, and miscanthus pellets for the remaining annual demand. Together, the annual costs for this combined option are lowest at 74 to 94 mln. EUR, as is shown in *Table 10, top ranking sourcing strategies according to total annual costs*.

Type	Supplier location	Annual cost indication
Miscanthus pellets	Lodz, Poland Klaipeda, Lithuania	134-164 mln., lower end
Eucalyptus pellets	Izmir, Turkey	177-203 mln., lower end
Tall oil pitch (59%) + miscanthus pellets (41%)	Los Angeles + Lodz, Poland Los Angeles + Klaipeda, Lithuania	33-45 mln., higher end (59%) + 134-164 mln., lower end (41%) = 74-94 mln.
Residual wood pellets	Netherlands + Lodz, Poland Netherlands + Klaipeda, Lithuania Netherlands + Riga, Latvia	177-212 mln., lower end

Table 10, top ranking sourcing strategies according to total annual costs

However, there is not enough tall oil pitch supply to meet demand, and competing for supply with the medical field may negatively impact EBX's reputation. Therefore, when other factors than only price are taken into account, tall oil pitch is an undesirable option. The annual costs for residual wood pellets and eucalyptus pellets, both starting at 177 mln. EUR, are far greater than the annual costs of miscanthus pellets. It is then miscanthus that proves to be the best option. Although it is more expensive than tall oil pitch, its supply is sufficient to easily meet demands. Also, it can be sourced from one location: either Lodz, Poland or Klaipeda, Lithuania. This answers RQ_7: “Which combination of sourcing object and sourcing strategy is best for EBX?”

6 Conclusion

6.1 Answering the research problem

RQ_1: Which requirements must biomass meet in order to qualify as an option for co-combustion?

It must have a high calorific value (NCV), low emissions, and low contents of moisture, ash, and abrasive matter. Volatile matter is not a problem, as long as the mix is known.

RQ_2: What types of biomass meet co-combustion requirements?

Eucalyptus pellets, miscanthus pellets, residual wood pellets, corn husk pellets, soy oil, tall oil pitch, and used frying oil.

RQ_3: What biomass properties directly influence sourcing strategy selection?

Price (in €) and quality (in GJ/t), taken together as value for money (GJ/€/t). Distance (in km) is also of influence.

RQ_4: With which quantitative ranges are the biomass properties matched in order to adequately classify biomass types?

Value for money is low under 0.15 GJ/€/t, high above 0.17 GJ/€/t, and medium in between. Distance is low under 250 km, high above 2500 km, and medium in between.

RQ_5: Which biomass property combinations offer realistic options in respect to economic feasibility and sustainability?

Eucalyptus pellets (medium value, medium distance), three configurations of miscanthus pellets (high value, medium distance; high value, high distance; medium value, medium distance), residual wood pellets (medium value, low distance), soy oil (high value, high distance), and tall oil pitch (high value, high distance).

RQ_6: With which sourcing strategy is each biomass property configuration best matched?

Sourcing miscanthus pellets from Lodz, Poland or Klaipeda, Lithuania, is best matched with a strategy of internal value creation, stock supply chain, single supplier, and consortium sourcing.

Sourcing eucalyptus pellets from Izmir, Turkey, is best matched with a strategy of external value creation, stock supply chain, dual supplier, and individual sourcing.

Sourcing tall oil pitch from Los Angeles, Xiamen or Quanzhou, China, and Itaqui, Brazil, is best matched with a strategy of internal value creation, stock supply chain, multiplie supplier (not by theory, but due to a further shortage of supply otherwise), and consortium sourcing.

Sourcing residual wood pellets from the Netherlands, together with Lodz, Poland or Klaipeda, Lithuania, is best matched with a strategy of external value creation, stock supply chain, multiple (in the Netherlands) or dual (in Poland or Lithuania) supplier, and individual sourcing.

RQ_7: Which combination of sourcing object and sourcing strategy is best for EBX?

Sourcing miscanthus pellets from Lodz, Poland or Klaipeda, Lithuania with a strategy of internal value creation, stock supply chain, single supplier, and consortium sourcing.

Main research problem: which types of biomass are feasible for co-combustion and with which sourcing strategy are they best associated in anticipation of a growing demand?

In summarizing the answers to research questions one to seven, the main research problem addressed within this thesis is answered. The types of biomass feasible for co-combustion are miscanthus pellets (from Lodz, Poland or Klaipeda, Lithuania), eucalyptus pellets (from Izmir, Turkey), and residual wood pellets (from the Netherlands, together with Lodz, Poland or Klaipeda, Lithuania). Their best associated sourcing strategies are shown in *Figure 4, top ranking sourcing object and sourcing strategiy combinations*.

6.2 Alternative sourcing strategy recommendations

EBX is advised to consider the following when further formulating and excecuting a biomass sourcing strategy:

- Opportunistic behavior can occur in any relationship, and all companies are vulnerable to it. If a supplier indulges in opportunistic behavior, it will damage EBX; if EBX indulges in opportunistic behavior itself, it may also do damage itself in the long run. It would therefore be advisable to prevent both scenarios. This can be done by a combination of trust and control or, in other words, control-based behavioral transparency and social bonds.
- It is best to seek the right members of industry as partners with whom to pool the sourcing miscanthus, in order to create advantages of economies of scale and stronger negotiation positions. Candidates for pooling an upstream investment in the production plant are Essent, NUON, and Electrabel, as they all own coal-fired power plants in the Netherlands and are faced with the same sustainability requirements as EBX.
- EBX may offer more than just the contract price when making an upstream investment (i.e. knowledge of new technologies or markets, services such as helping to improve the product or helping the supplier penetrate new markets, etc.).[271]
- Take into account the management difficulties associated with global supply chains,[272] such as an increase in transport costs, supply chain lead-time, inventory cost tradeoffs, complexity of demand forecasting, problems due to cultural and developmental differences, language barriers, different practices, transportation deficiencies, underdeveloped telecommunications, inadequate worker skills, and disadvantages in supplier quality, equipment, and technology. Altogether, these factors may harm the competitive advantage of the supply chain.[273] Country-specific uncertainties are found in fluctuating currency exchange rates, tariffs,

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[271] See Christiansen/Maltz, (2002)., Ellegaard, et al., (2003). cited according to Schiele/Steinle, (2008), p. 12.
[272] See Dornier, et al., (1998).; Wood, (2002).; MacCarthy/Atthirawong, (2003). cited according to Meixell/Gargeya, (2005), p. 533.
[273] See Meixell/Gargeya, (2005), p. 533.

quotas, economic and political instability, and changes in the regulatory environment.[274]

- Consider the operation window, which is the timeframe wherein all transport operations must be fulfilled. Factors that influence the operation window are logistic limitations in the supply chain, such as the capacity of a storage facility, or supply restrictions such as difficulties encountered in setting up distribution systems or the unavailability of the product due to harvesting.[275]
- Consider the future of biomass supply in the Netherlands. In 2050, the Netherlands may be able to supply about 200 PJ of biomass for the energy market, but it will probably not be enough to meet demand. As the Netherlands is a net importer of biomass, what amount of the global supply of 150 EJ to 400 EJ can be imported in 2050? Equally sharing amongst the world's population will lead to an annual supply of 300 to 750 PJ. Sharing according to gross national product will more than double this amount. However, countries with a lot of biomass will also be a relatively large consumer. Approximations of the annual Dutch biomass supply in 2050 for primary energy range from 0 and 1000 PJ (excluding losses as a result of conversion).[276]
- Protect against effects of long-term uncertainty. As global energy markets increasingly rely on biomass as a feedstock, global supply shortages and increasing biomass prices will follow. This could partly be compensated by efficiency improvements in agriculture, which lowers the price. On the whole, it is unclear what supply will be available at what price.[277]

6.3 Discussion, limitations, and implications for further research

6.3.1 Discussion

The theoretical contribution of this thesis is made in the context of sourcing as a strategic tool. As stated earlier in this thesis, the broad categorical nature of biomass uncovers a knowledge gap in the application of normal sourcing literature to such a sourcing problem. By addressing the issue of such a gap, this thesis aims to generate an academic discussion

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[274] See Dornier, et al., (1998)., cited according to Meixell/Gargeya, (2005), p. 533.; Kaufmann/Hedderich, (2005), p. 135.
[275] See Suurs, (2002), p. 35.
[276] See Ros, (2011), p. 25.
[277] See Ros, (2011), p. 26.

regarding the implications of ‘unknown’ sourcing objects for the creation of sourcing strategies. This thesis also contributes to academic sourcing literature by presenting a model for creating sourcing strategies for sourcing objects with a broad categorical nature.

In parallell to its theoretical contribution, this theory is aimed at the practical case of EBX, answering the research problem: which types of biomass are feasible for co-combustion and with which sourcing strategy are they best associated in anticipation of a growing demand? In having answered this question, this thesis offers a practical contribution to EBX. What remains is the question whether the practical contribution of this thesis is transferable to sourcing problems other than the specific problem expressed by EBX. In order to do so, the research questions must first be generalized:

1. Which requirements must the object meet in order to qualify as an option for sourcing?
2. What types of objects meet sourcing requirements?
3. What object properties directly influence sourcing strategy selection?
4. With which quantitative ranges are the object properties matched in order to adequately classify object types?
5. Which object property combinations offer realistic options in respect to economic feasibility and [if applicable] sustainability?
6. With which sourcing strategy is each object property configuration best matched?
7. Which combination of sourcing object and sourcing strategy is best?

On one hand, the model formulated within this thesis is largely based on strategic purchasing portfolio models in general and Kraljic’s portfolio approach for strategic sourcing in particular. Kraljic’s approach assesses a company’s purchasing portfolio and, like all purchasing portfolio models, can be used to organize a complete purchasing mix. Through Arnold’s sourcing toolbox, six sub-strategies are designated which can be used to determine an appropriate sourcing strategy, depending on the organization and the situation at hand. This approach offers a broad starting point. On a side note, the particular case of biomass sourcing omitted two of the six sub-strategies: location (which was included as a categorical axis on the portfolio matrix) and the sourcing object (all relevant biomass and other feedstocks matches unit sourcing). For each sourcing problem, a new selection of relevant sub-strategies can be made.

On the other hand, while sourcing strategies usually revolve around sourcing a particular object, the research method presented within this thesis is aimed at sourcing objects with a broad categorical nature (i.e. an object that can be one of many different things), as the holistic approach offered by the research questions is suitable for a large variety of sourcing problems such as sourcing fertilizer, building materials such as isolation, or even sourcing food to aid third world countries. However, when dealing with 'simple' sourcing problems (e.g. where price is the only issue), requirements and properties of influence to sourcing strategy selection are far more limited.

In conclusion, the practical contribution of this thesis is transferable to a situation of any power company seeking biomass feedstocks for co-combustion. It is also transferable to a situation seeking specific feedstocks for power generation such as coal, or a situation of any industrial company seeking feedstocks, or even a situation such as an office seeking pencils. However, such sourcing problems can be expected to be 'simple' sourcing problems. While the research questions are able to tackle 'simple' sourcing problems, their holistic approach may render them an over-elaborate, even cumbersome, solution. Finally, is it not transferable to a situation where services are sought, as Arnold's six sourcing sub-strategies are aimed at physical objects.

6.3.2 Limitations

It remains important to consider decision models as used in this thesis as instruments that support sourcing decisions by scrutinizing them, and not confuse this for a rigid replacement of one's personal and professional judgment.[278] In the case of portfolio models, it is recommended to use portfolio models "with an understanding of their limitations and perhaps in combination with other tools"[279]. First there is the difficulty regarding the complexity of dimensions: if they are too complex they may distract from the ultimate goal[280], and if they are too simple important variables may be overlooked[281]. Then there are the resulting strategies, relating to categorizing competitors, customers, and suppliers, but possibly missing certain important interdependencies[282]. "It is important to focus on the concept that a company is an interdependent group of products and services,

[278] See Boer et al. (2001), p. 76.
[279] Olsen/Ellram (1997), p. 102.
[280] See Haspeslagh (2003), p. 58.
[281] See McNamee (1984), p. 109.
[282] See Coate (1983), p. 54.

each playing a distinctive and supportive role."[283] Finally, portfolio models categorize issues into groups, often four or nine, within a matrix. Most do not provide guidelines to categorize different issues within the same group[284], although evidence has been published that in using the matrix, professional purchasers also distinguish between different strategies within each quadrant[285]. Considering their popularity and their small dimensions, it is recommended to take the above into consideration when using models such as the Kraljic matrix. This use should not only concentrate on the portfolio model itself, but rather should be a combination of this normative model and open discussion. Only then can creative and differentiated solutions be reached.[286]

A number of simplifications have been made for reasons of practicality. For instance in identifying variables of influence to the sourcing strategy selection, growth rate and seasonality of annual supply are excluded. In considering different supply chain scenarios, mode of transportation, cargo capacity, transport volume, storage facility capacity, transshipment times, and other logistical variables are used or quanified based on general information or assumptions.

[283] Olsen/Ellram (1997), p. 102.
[284] See Derkinderen/Crum (1984), p. 135.
[285] See Gelderman/Van Weele (2003), p. 213.
[286] See Lilliecreutz (2001), p. 79.

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