The Wood Pellet Value Chain

An economic analysis of the wood pellet supply chain from the Southeast United States to European Consumers.

Yifei Qian
Will McDow

March 2013

U.S. Endowment for Forestry and Communities

ACKNOWLEDGEMENTS

The authors would like to thank The USDA Forest Service and The US Endowment for Forestry and Communities for its support, which made possible this report as well as these related publications, which are available at edf.org/bioenergy:

- "European Power From US Forests: How Evolving EU Policy is Shaping the Transatlantic Trade in Wood Biomass," Jamie Joudrey, Will McDow, Tat Smith, and Ben Larson. EDF, 2012.

- "Pathways to Sustainability: An Evaluation of Forestry Programs to Meet European Biomass Supply Chain Requirements," Brian Kittler, Will Price, Will McDow and Ben Larson. EDF and Pinchot Institute for Conservation, 2012.

In addition, the authors also wish to thank the following for their input, suggestions and comments related to the development of this report:

- Tat Smith, University of Toronto
- Robert Prinz, METLA
- Elizabeth Woodworth, Enviva
- Robert Simpson, Green Wood Consulting
- Ben Larson, Larson Consulting
- Nathanael Greene, NRDC
- Danna Smith, Dogwood Alliance
- Frederick W. Cubbage, NC State University

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Chapter 1 Introduction to the Wood Pellet Value Chain

Wood pellet manufacturing and export is a young but fast growing industry in the United States. The production and export of wood pellet have proliferated over the past five years, particularly in the southeastern US. (See Appendix 1 for map of existing and announced large wood pellet facilities). Additional large-scale plants are expected to come on line and continue to expand the market landscape in the coming years. Growth in wood pellet capacity has been driven by the high demand for biomass from European countries in response to their renewable energy policies and financial incentives. (See Appendix 2 for map of wood pellet flow between the U.S. and Europe). Several factors will determine whether the wood pellet industry will continue to grow, including the continuation of EU renewable energy policy drivers and requirements for sustainable management.

The value chain analysis in this report covers wood pellet production and consumption, from biomass feedstock supply to pellet consumption as an industrial fuel. The geographical terminals of this value chain mainly focus on landowners in the southeastern U.S and energy utilities companies in the European Union (EU), the United Kingdom, the Netherlands and Belgium in particular. Figure 1.1 provides a graphical overview of the four cost centers of the value chain: 1) feedstock supply, 2) pellet production, 3) distribution and 4) consumption. Figure 1.1 also identifies the main actors, links, activities and material flows within each of the four major cost centers. Each cost center is briefly described below.

DEFINITIONS:

Supply Chain: A complex network of buyers and sellers associated with the movement of raw materials through production processes to end users. In this report, the wood pellet supply chain begins with forests in the Southeast U.S. and ends with electricity production in Europe.

Value Chain: The set of processes and activities undertaken within a a sector that add value to a product or products. The value chain considers both primary and secondary processes of production, distribution and use of a good.

Supply - cost center #1: Biomass feedstock used in wood pellet production comes from a variety of forest resources each with differing costs. Feedstock supply represents the beginning of the wood pellet value chain. To the extent government policy or social pressure demands sustainable biomass procurement policies and programs, the activities and economics of this cost center could change significantly. Chapter 2 of the report focuses on the biomass feedstock portion of the value chain.

Production – cost center #2: The pellet production cost center focuses on large pellet producers since they represent the major industrial bulk pellet exporters. Whether it is viable for them to supply sustainable and qualified wood pellets to overseas client is a focal research topic in this report. Their business viability is evaluated through exploration of biomass supply, production costs, distribution of pellets and incremental costs of sustainability practices. Chapter 3 outlines the wood pellet manufacturing section of the value chain.

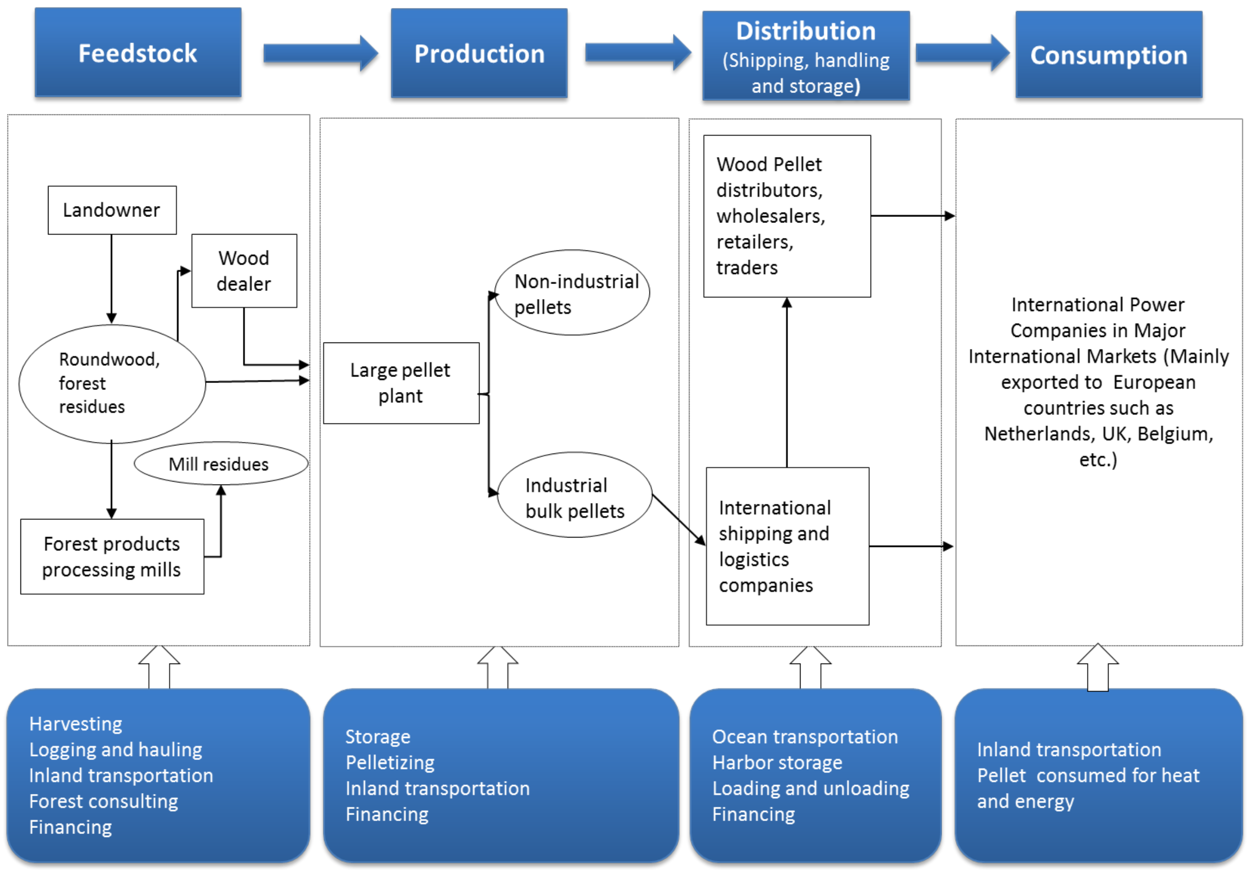
Distribution – cost center #3: The pellet distribution cost center plays an important role in wood pellet global trade. The market of various shipping companies, brokers and traders is highly fragmented and complex. In addition, biomass shipping has its specific characteristics that determine only certain routes and ports are cost-effective and capable of handling large amounts of pellets. Chapter 4 details the various considerations and economic factors affecting wood pellet distribution to EU markets.

Consumption – cost center #4: The final cost center covered in this report is pellet consumption by EU electric utility plants. Today, the European power market is the engine of global wood pellet business. Renewable energy policies, financial incentives and market and sustainability requirements are critical external factors which will determine the future of wood pellet consumption in Europe. Currently, the primary destinations of exported U.S wood pellets are Netherlands, United Kingdom and Belgium. Chapter 5 provides an overview of the role of renewable energy policies and incentives in these countries within the wood pellet value chain, and also a comparison of fuel economy between wood pellet and traditional coal fuel under policy incentives.

This report examines the wood pellet value chain in order to develop a deep and thorough understanding of an emerging industry. The report seeks to answer the following questions:

1) What are the major cost centers throughout the value chain and how do they interact with each other?
2) How is value created through major cost centers along the value chain?
3) Which sectors in the value chain could best be leveraged to implement policies or initiatives to advance sustainability goals?

Figure 1.1 The wood pellet value chain



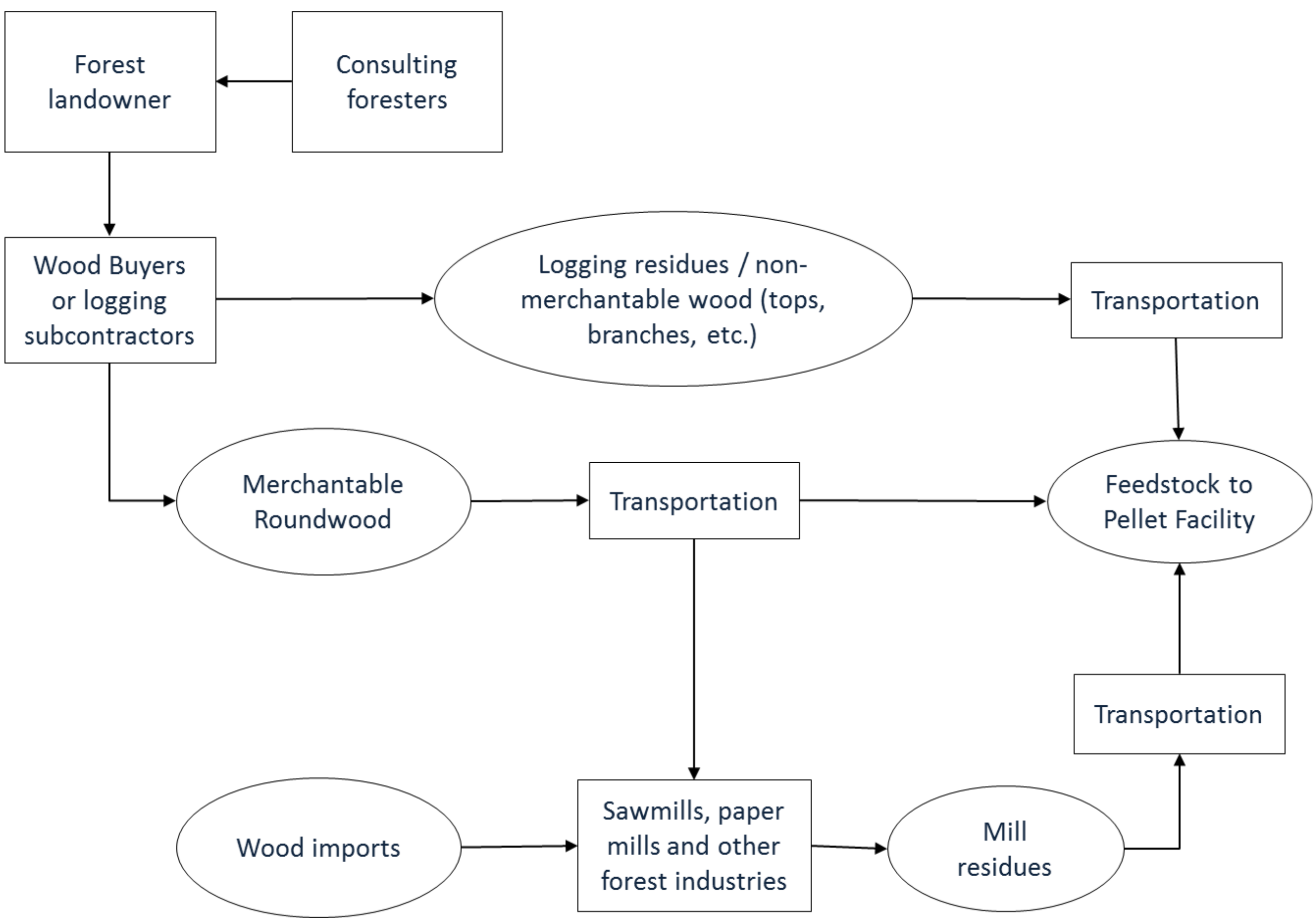
Chapter 2 Biomass Supply

Wood biomass supply system

Woody biomass can come from a variety of sources – roundwood, mill waste, harvest residuals, urban clearing, etc. Estimates of available woody biomass production vary widely under different assumptions. By one estimate, the total woody biomass available in the US may approach 167 million tonnes per year(Milbrandt & National Renewable Energy Laboratory, 2005).

The wood pellet value chain begins with a forest landowner and a harvesting operation. This chapter explores the biomass supply cost center associated with Southeast landowners and the logging / transportation industry, wood fiber supply and other important factors that influence the cost of biomass delivered to a biomass facility. Figure 2.1 illustrates the supply chain of woody biomass from landowner to pellet facility.

Figure 2.1 Biomass supply chain from landowners to pellet facility



Woody biomass providers can be divided into roundwood suppliers and residuals suppliers, though in reality this distinction is often blurred when a single provider supplies multiple product categories simultaneously. Roundwood is the bole of the tree that has been cut into suitable length, but is otherwise unprocessed. All remaining woody material after a forest harvest is considered logging residuals, including tops, limbs, branches and other traditionally non-merchantable wood.

Wood pellet manufacturers can either procure wood biomass from wood dealers or from private landowners directly through loggers. Pellet manufacturers can also obtain wood fiber from mill residuals, the byproducts of other forest industries such as sawmills and paper mills. Mill residuals and wood wastes often can be procured at lower cost compared to pulpwood and roundwood, and thus transportation expenses are generally the primary cost for mill residuals in the supply model. However, residuals are not likely to be sufficient in quantity to supply a large-capacity pellet facility or quality to meet pellet standards requirements. Most of those residuals serve as supplementary biomass feedstock, energy source for drying process at pellet plants or for use in other products.

In the case of roundwood, it is originally sold from forest landowners through stumpage sales. Once buyers sign contracts with owners, they are allowed to harvest a specific amount of timber over a certain time period. Landowners can be classified as industrial and non-industrial owners and further classified by size of forest ownership. A pellet exporter with 500,000 tons of production capacity may need 50,000 acres of forestland to support production. Meeting that supply will require many landowners and many wood buyers participating in the supply chain. Both smaller family forest owners, who account for a significant amount of all forest landowners in Southeast, and large industrial landowners will likely be a necessary part of the wood fiber supply chain for bioenergy.

Whether sourcing wood directly from landowners or through wood dealers, biomass procurement systems seek a low price, regular delivery and biomass feedstock with minimum moisture and ash content. Conversely, landowners seek a stable market, premium price and flexibility to sell at market highs. A contract agreement could marry interests of both parties by setting standard provisions in term, unit of measure, sales quantity, biomass specifications, compensation, sustainability standards, termination, etc. However, long-term contracts are not a normal operating practice today.

Feedstock cost break-down

Feedstock procurement cost to pellet producers is based on delivery price and volumes of each biomass type. The delivery price is the compensation paid to a supplier for a specified type of biomass received at the pellet facility and at a specified volumetric unit. As mentioned earlier, the greatest cost of mill residuals derives from transportation. The pricing for roundwood, however, depends on stumpage price, harvesting and processing costs, and diesel fuel for transportation. The value-adding process from forest stumpage to delivery price received at gate is illustrated as Figure 2.2. The percentage of delivered price is indicated for each step.

Figure 2.2 Value-adding process of roundwood feedstock

Stumpage price

Stumpage price is the value of standing wood paid by loggers or wood brokers to forest landowners. Pine pulpwood stumpage price in the US South generally trended upwards during the past 10 years with significant price swings from year to year. The stumpage price fluctuation have generally diminished in recent years and stabilized around $9/green ton. (TMS News Quarterly 4Q 2012)

Since pellet producers can utilize many unmarketable low-grade trees, the stumpage price paid might be lower and has been estimated around $4~5/green ton (Texas Forest Service, December 2005). The stumpage price represents the value of whole trees standing in the forest. The volatility of industry-wide prices can result from changes of timber consumption in housing markets and the volume of wood imports (First Research, July 16, 2012). Local prices vary according to proximity to mills, accessibility, logging conditions, tree size, quality and species, and the amount of timber per acre. While pellet facilities might wish to mitigate the risk of upward pricing trends by fixing the contract price, landowners or wood dealers are reluctant to agree to a fixed market price in contracts (BioReseource Management Inc. & Dougherty & Dougherty Forestry Services, May 2012). To date, long-term contracts are not an industry standard in the wood pellet supply chain.

Harvesting cost

The greatest cost in the biomass supply cost center includes the costs associated with harvesting (See Figure 2.2). Forest biomass is harvested by loggers, who in almost all cases are not the employees of pellet companies. Harvesting methods can vary from site to site, but major activities may include delimbing, skidding, hauling to roadside, etc. Standard practice generally includes cutting the harvested material into roundwood, and sorting or merchandizing the roundwood for the highest value. In-woods chipping or other processing may also be employed for low-grade material. Inputs related to harvesting are primarily labor, machines and diesel fuel.

Cost data available on harvesting are usually based on estimates without auditing and verification. Table 2.1 summarizes a case study conducted in East Texas, focusing on whole-tree logging of small diameter trees of pine stands, which cannot meet the minimum size for pulpwood or sawlog standards (Texas Forest Service, December 2005). The annual production of biomass was assumed to be 48,000 green tons. It should be noted that diesel cost in the original case is based on $2.2/gallon. For this report, the diesel costs have been revised upward to $3.5/gallon, which provides more accurate assessment of current costs.

Deloitte & Touche LLP has conducted a survey in Northeastern Ontario, Canada, which focused on the public forestland (Deloitte & Touche LLP, August 26, 2008). Their case study also includes renewal fees, stumpage fees and administration fees charged by the Canadian government (Ministry of Natural Resource), which accounts for 20% of the delivery price. Not considering these costs, the average harvesting cost is around $23/ m^3, which is slightly higher than the number calculated in the East Texas case study. According to industrial estimate, the average net profit margin of the logging industry is around 2.5% (First Research, July 16, 2012), which can be roughly translated to a profit of $0.4/green ton.

Table 2.1 Case study for a biomass logging operation in East Texas

Item	Cost ($)	Unit cost ($/green ton)	Unit cost ($/m3)	%
Annual capital cost (depreciation from equipment and truck, assuming purchased new)	**128,601**	**2.68**	**3.22**	**17%**
Total annual operating cost	**624,221**	**13.00**	**15.61**	**83%**
Repair and maintenance	113,250	2.36	2.83	15%
Diesel Fuel (0.03g/hp-hr, $3.5/g off-highway diesel)	224,380	4.67	5.61	30%
Lube	56,416	1.18	1.41	7%
Large parts (Tires, etc.)	16,200	0.34	0.41	2%
Insurance Premium	33,975	0.71	0.85	5%
Wages	168,000	3.50	4.20	22%
Other costs	12,000	0.25	0.30	2%
Total annual cost	**752,822**	**15.68**	**18.82**	**100%**

(Conversion from cubic meter to green ton: 1 m^3 of southeast pine species = 1.2 green ton)[1]

Source: Texas Forest Service, December 2005

[1] Conversion factor is referenced from http://www.rayonier.com/Businesses/Forest-Resources/FAQ.aspx

Transportation Cost

Transportation has been identified as a major or even predominant component of the overall production costs of biomass from logging site to mills depending on distance to mill. In this report onsite hauling (from logging place to roadside) is classified as harvesting activity and is not included in this section. Previous research indicates that transportation costs could account for as much as 50% of the total biomass production and supply costs (Han, 2011; McDonald, Taylor, & Valenzuela, 2001; Pan, Han, Johnson, & Elliot, 2008). In the woody biomass supply chain, the primary transportation mode to move biomass from forest to mill and from mill to port is by truck. Although overall costs will vary by truck configuration, road conditions, travel routes, truck utilization rate and fuel price, prevailing trucking rate is around $0.15/GT•mile (Han, 2011; Texas Forest Service, December 2005). Table 2.2 provides an overview of the cost components related to transportation, based on the BIOTRANS model developed by Terrain Tamers(Han, 2011).

Table 2.2 Cost components of transportation

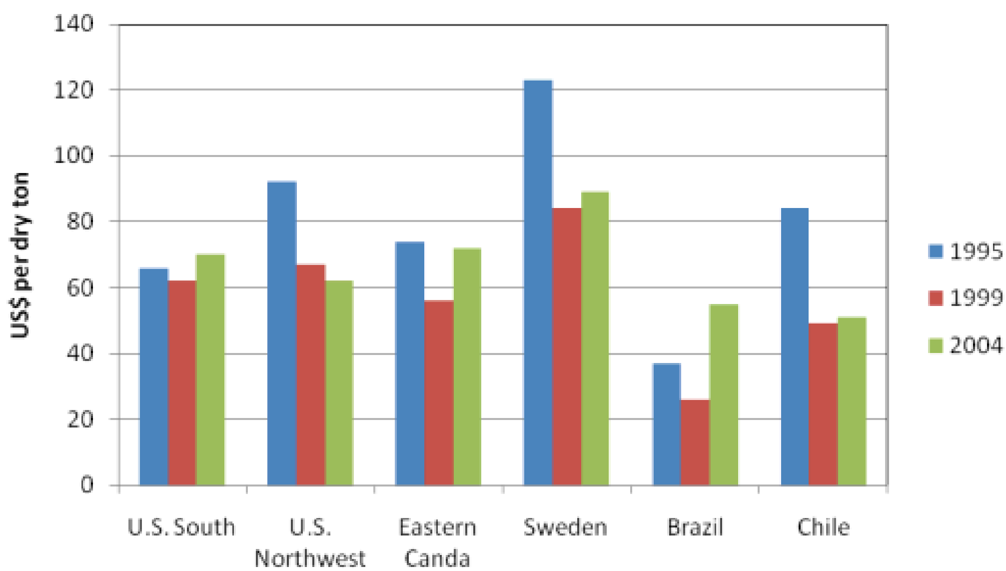
Cost Item	Cost Percentage
Fuel	28%
Labor	27%
Tires	8%
Maintenance & Repair	7%
Overhead	8%
Interest	6%
Depreciation	6%
Oil & Lubricants	3%
Insurance	2%
Others	5%
Total	100%

Source: (Han, 2011)

Delivery price of roundwood

The delivery price paid to wood fiber suppliers should reflect the stumpage price, harvest cost and transportation cost. In most long-term agreements (usually longer than one year), contract price can be adjusted with market trend under certain mechanisms. Similarly, adjustment of fuel price can address wide swings in diesel cost. Third parties may generate reliable and unbiased public information for such adjustment reference, such as governmental agency reporting and forest product price reporting services. Figure 2.3 shows roundwood delivered prices in major markets. In U.S South market, this price has fluctuated around \$30/green ton (1\$/green ton ≈ 2\$/dry ton). In recent years, there has been a downward pressure on the delivery price, which may be attributed to the decreased demand for pulp and paper, decreased demand for fuel wood resulting from natural gas price decline, and the modest drop in diesel prices.

Figure 2.3 Roundwood Delivered Prices



Source: (David N. Wear, 2011)

Risk and Mitigation

In the process of sourcing biomass, a pellet manufacturer has two central concerns: 1) the availability of sufficient amount of biomass to support production; and 2) an acceptable price level of delivered biomass to sustain business. This section discusses the major risk factors associated with the these concerns.

Cost uncertainty due to price volatility

The contribution of each cost factor to the final delivery price provides some estimate of the risk associated with biomass harvest and delivery. To estimate the costs, Table 2.3 uses the Texas case study for harvest data, assumes stumpage price to be \$9/green ton, and average sourcing distance to be 50 miles, with a trucking rate at $0.15/GT • mile. Table 2.3 sums the biomass supply cost at each stage from the previous analysis.

Table 2.3 Delivery price breakdown at each stage

Stage	Item	Unit cost ($/green ton)	Percentage of contribution
Stumpage	**Pine pulpwood**	***9.00***	***28%***
Harvest and processing	**Annual capital cost (depreciation from equipment and truck, assuming purchased new)**	**2.68**	**8%**
	Total annual operating cost	**13.00**	**40%**
	Repair and maintenance	2.36	7%
	Diesel Fuel (0.03g/hp-hr, $3.5/g off-highway diesel)	4.67	15%
	Lube	1.18	4%
	Large parts (Tires, etc.)	0.34	1%
	Insurance Premium	0.71	2%
	Wages	3.50	11%
	Other costs	0.25	1%
	Total annual cost	***15.68***	***49%***
Transportation	trucking rate (gt•mile)	0.15	N/A
	transportation distance (miles)	50	N/A
	Transportation cost	***7.50***	***23%***
	Diesel Fuel	2.10	7%
	Labor	2.03	6%
	Tires	0.60	2%
	Maintenance & repair	0.53	2%
	Interest	0.45	1%
	Depreciation	0.45	1%
	Overhead	0.60	2%
	Others	0.75	2%
Delivery price of roundwood		***32.18***	***100%***

Stumpage price, harvesting cost and transportation accounts for 28%, 49% and 23% of the delivery price. The single biggest cost elements are stumpage (28%), diesel (22%) and labor (17%). This table is based on very rough estimates, though the estimated delivery price matches the roundwood delivery price reported in the literature. In reality, the stumpage price may be lower because pellet manufacturers are likely to mix some low-value wood as well in pellet production. In addition, pellet manufacturers are likely to transport biomass for longer distance, and increase the percentage of diesel fuel in overall costs. Fluctuation in diesel price will not only affect pellet facilities, but also other actors along the suppler chain such as loggers or hauling companies. Hence, the price volatility risk may be amplified inasmuch that pellet facilities may have large dependence on these actors. At all events, actors along the supply chain need to be aware of price change and take measures to minimize the business risk due to price volatility.

Biomass supply and demand

In the short-run, the total wood supply is relatively fixed because timber takes many years to regenerate. The amount available for sale is based on the offered stumpage price and the harvesting and forest management activities of the previous period. Wood demand is highly affected by macroeconomic conditions. In 2010, a 15% jump of production in paper industry partly explained the high price for pulpwood stumpage during that period (First Research, June 2012). Change in wood demand also affects the logging industry. When the wood demand is high, there may be a shortage for logging crew, and in turn increase the labor cost in this supply chain system. Prolonged periods of low wood harvest demand may result in contraction of logging crews, potentially impacting future harvest activity. Finally, the market equilibrium is dependent on the availability of wood, logging crews, landowners' willingness-to-sell at market price, and other factors such as weather.

Regulatory uncertainty and counterparty risk

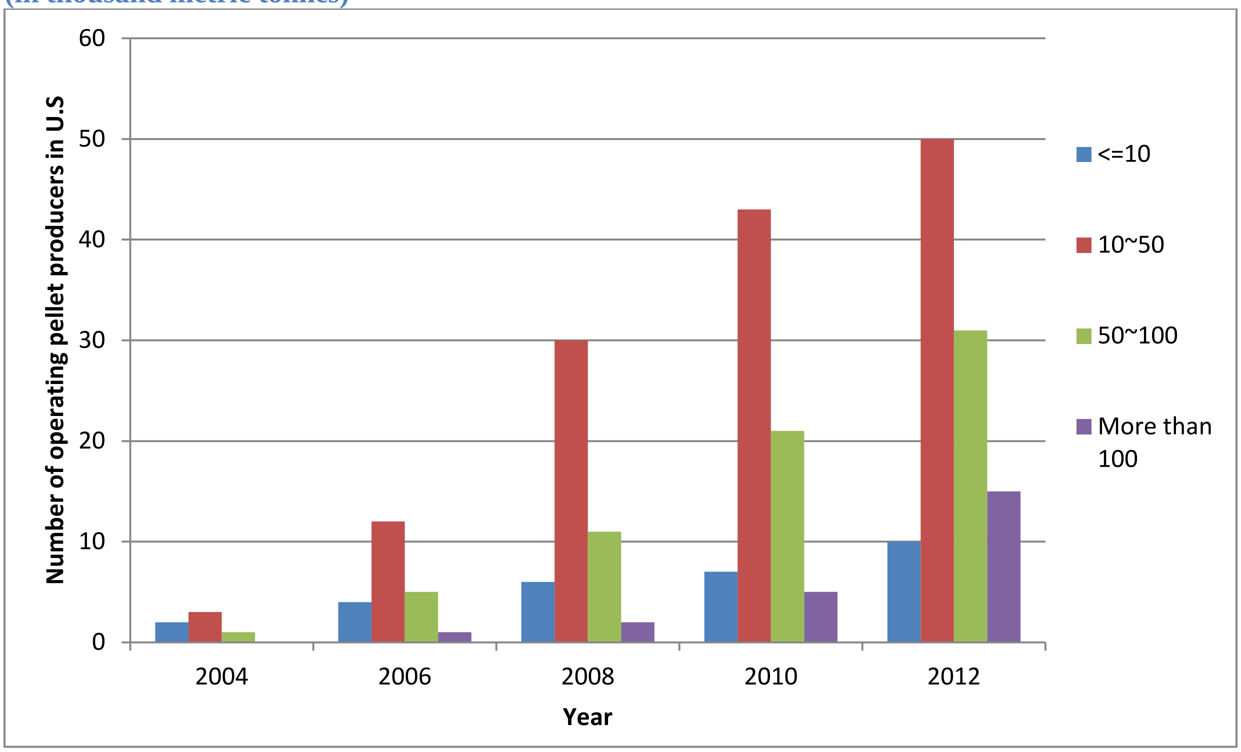
The European Union is likely to enforce stricter sustainability criteria on biomass in the coming years. Although there is uncertainty about the future standards, forest management costs could increase due increased certification requirements, logger training and monitoring. Some large landowners have integrated forest management into their businesses and set sustainable goals as their long-term strategies. For small landowners, per acre forestland cost of sustainable management may be higher. Furthermore, counterparty risk exists if pellet producers procure wood from wood dealers, who may not record where the biomass comes from. If the wood cannot be recognized as meeting the sustainable standards for renewable energy, it could lose its competitive advantage to export.

Chapter 3 Pellet Production

Background

This chapter centers on large capacity wood pellet manufacturers who target the export markets. The pellet manufacturing industry has grown rapidly during the past decade. Recent growth in this industry has been focused on medium and large manufacturers whose annual production capacity is larger than 100,000 metric tonnes. In 2006, only one U.S. pellet manufacturer was capable of producing more than 100,000 metric tonnes of pellets per year. By 2012, the number had increased to 15. Between 2010 and 2012, the number of manufacturers with a capacity over 100,000 tonnes of production increased three-fold. Figure 3.1 depicts the growth in the number of pellet manufacturers by production capacity.

Figure 3.1 Growth trend in the number of pellet manufacturers by production capacity (in thousand metric tonnes)



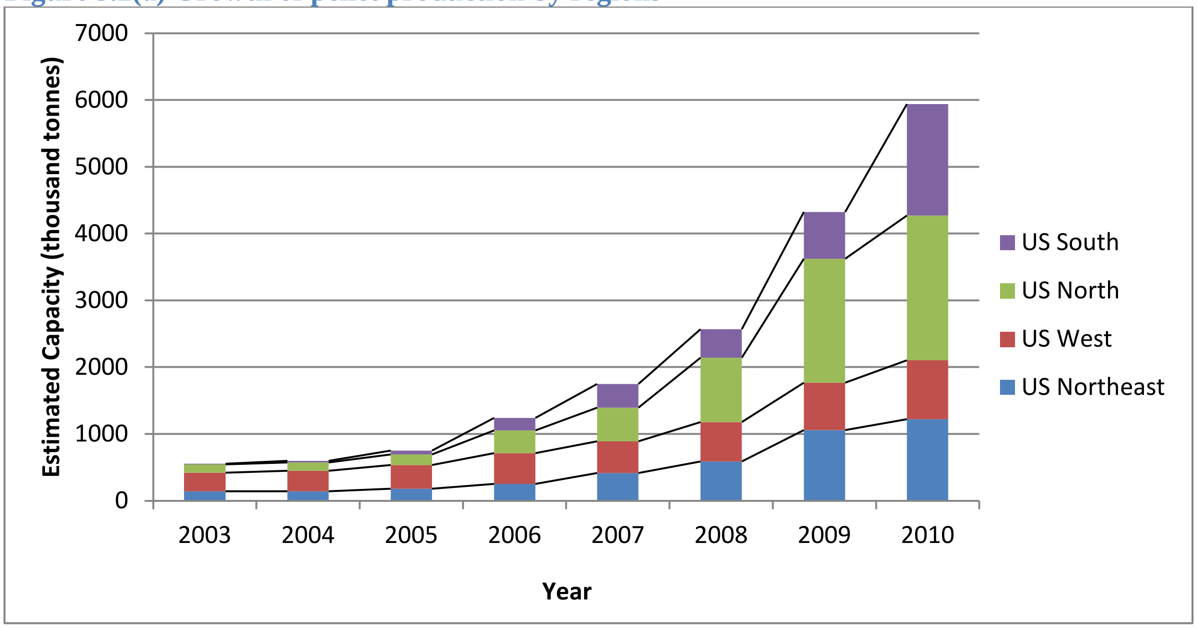
*note: Operating producers are referred to those who are purchasing feedstock and producing pellets, not including projects that are under constructions or on-hold.

Source: Wood Bioenergy US Database, Forisk Consulting LLC (June 25, 2012)

The greatest pellet production remains in the northern U.S for residential heating, as shown in Figure 3.2 (a). However, the industry landscape has changed dramatically with the recent pellet production expansion in the Southern region. Figure 3.3 (b) shows that the southern region has added most of the new capacity of pellet production since 2010. In addition, the southern U.S also accounts for around 60%

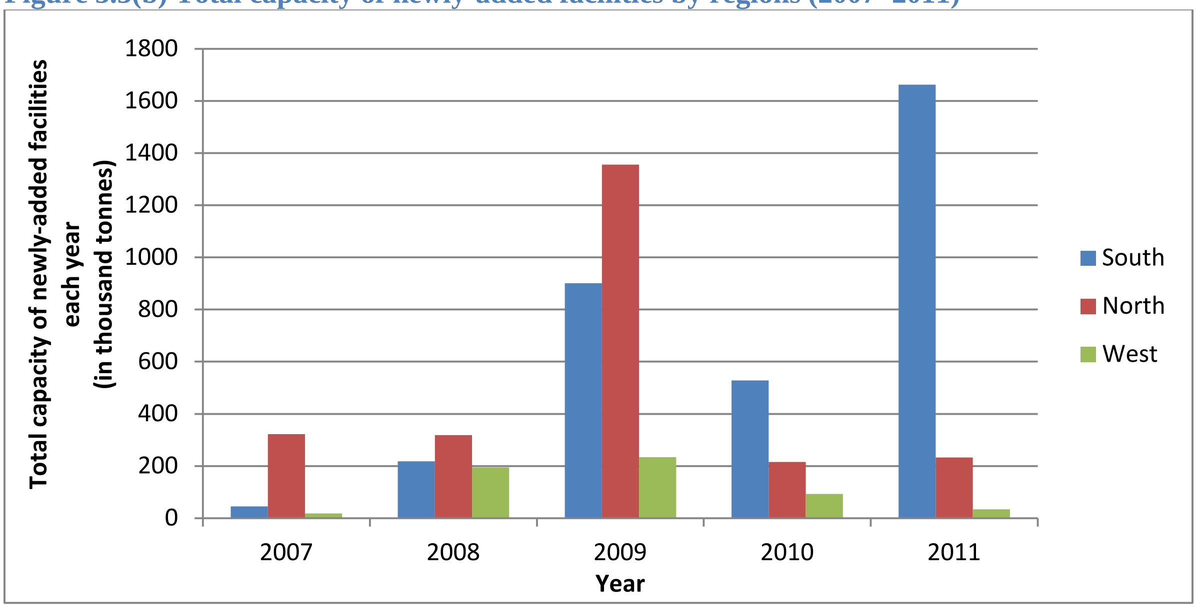
of the projects which are under construction or in the permitting stage (including applying for and receiving permits or contracts to construct a facility) between 2012 and 2020 (WBUS database). Among the newly-added facilities in the Southern U.S are some of the largest pellet plants in the world – Georgia Biomass, Green Circle Bio Energy and Enviva Ahoskie.

Figure 3.2(a) Growth of pellet production by regions



Source: (Cocchi & al., 2011)

Figure 3.3(b) Total capacity of newly-added facilities by regions (2007~2011)

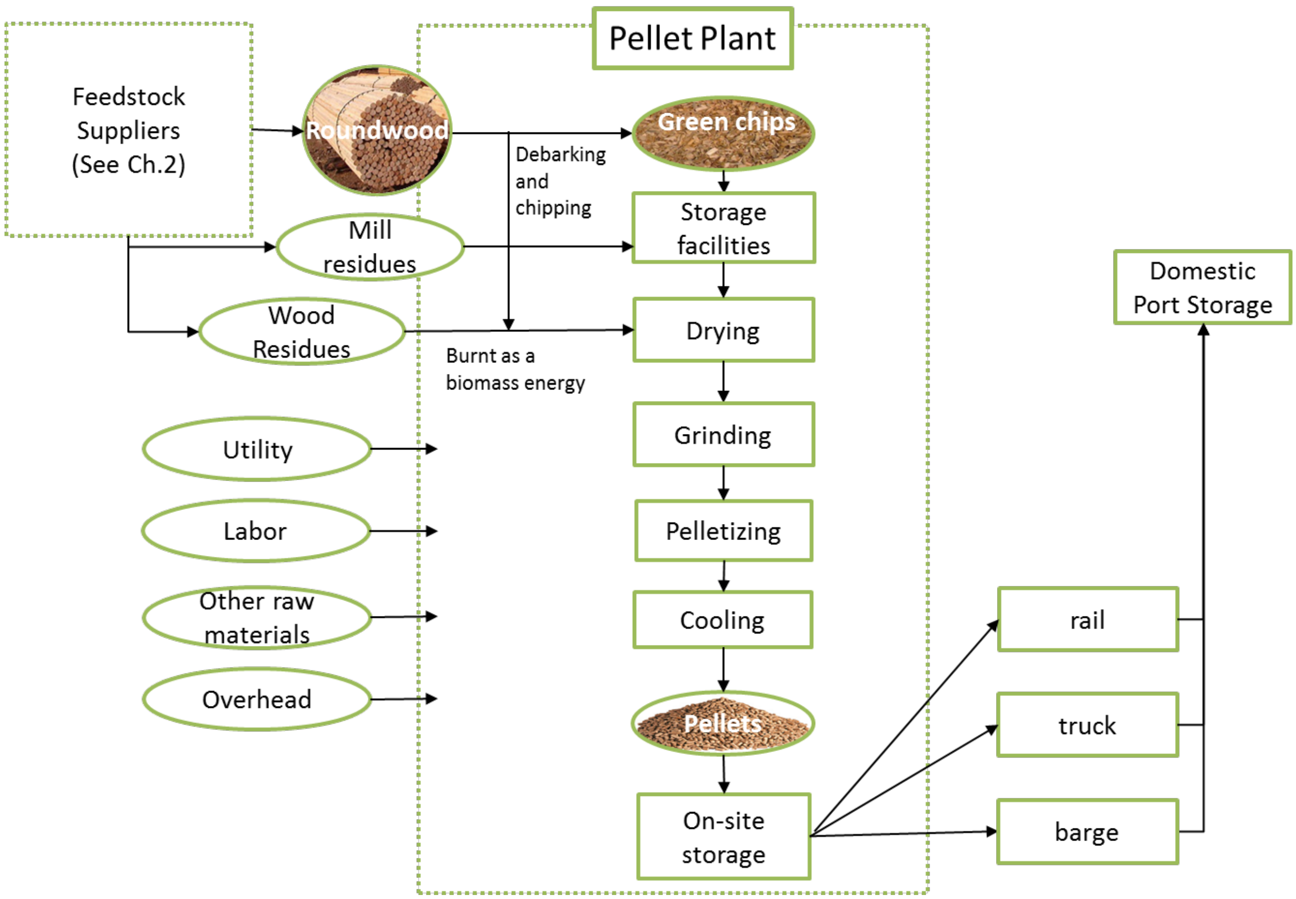


Source: Wood Bioenergy US Database, Forisk Consulting LLC (June 25, 2012)

Overview of wood pellet production

Developing a wood pellet project requires multiple stages including site selection, feasibility study, financing, obtaining permits or contracts, construction and initiating operations. This analysis focuses on the value-adding process of an operating facility, and only discusses briefly the stages before operation. Figure 3.4 illustrates the production process of a typical operating pellet plant.

Figure 3.4 the production process of a wood pellet exporter



Feedstock used in pellet production can be roundwood, unprocessed forestry residuals and processed mill residuals. Most of the pellet exporters use roundwood in their production to meet European consumers' stringent quality requirements. Besides feedstock, other major inputs for pellet production include chemical agents and other raw materials, labor, and energy.

Roundwood has to be pre-processed to reduce size and moisture content, steps include debarking, chipping, drying and hammering. At this stage, moisture content is critical and must be controlled around 10% (Pellets@las, 2009a), since wet raw material is difficult to pelletize. Bark and other residuals left in the debarking and chipping processes can be burned as a source of supplementary energy for drying. After drying, the raw material will be sorted by size and oversized ones sent to hammer mill for grinding so that at delivery the size will be homogenous.

Following the pre-processing stage is the pelletizing process – raw material is compressed with a rolling press through a die block. Before pressing, steam conditioning may be used to soften lignin and facilitate chemical binding processes with some agents. Softened lignin and wood dust is then transported to the die. The rolling press provides the required pressure in the pelletizing process, and the pressure level is determined by different types of raw material.

Since the temperature of raw material has been increased in the pelletizing stage, a cooling process is needed so that pellets have better durability, which reduces the formation of dust in the transportation and handling. The cool pellets will then be conveyed to the storage facility after dust removal, while residuals will be recycled back into production.

Pellets can either be stored at the manufacturing plant or at the harbor after in-land transportation. Ideal storage facilities could be closed halls or silos that can protect against moisture and maintain pellet quality. The three principal ways to transport pellets from plant to port are by truck, rail or barge (Pellets@las, 2009b).

Cost Analysis

The value-adding process at the pellet production center begins with the procurement of feedstock, and ends with delivery of wood pellets to buyers or traders, as shown in Figure 3.5. This section discusses each cost portion in detail.

Figure 3.5 Value-adding process at pellet production center

Feedstock cost

As discussed in Chapter 2, feedstock cost is determined by the delivery prices of different types of woody biomass and their volumes. To calculate the feedstock cost on a per ton of pellets unit basis, a conversion factor is needed because raw material has higher moisture content than pellets and not all raw materials are used directly in production. Some raw material is utilized as a drying fuel, and some is lost in storage and handling. An examination of existing pellet projects in the U.S. shows that on average one ton of wood pellets are generated from two green tons of wood fiber (Forisk Consulting LLC, June 25, 2012). Based on a delivered roundwood price of $25 to $35 per green ton, the cost of per tonne pellet feedstock is estimated at the range from $50 to $70. Some researchers estimated the delivered costs of forest-based feedstock to be around $70/dry ton by supply chain and economic modeling, which could also serve as a reference for per tonne pellet feedstock cost (Gonzalez et al., 2011).

Plant Operation Cost

Plant operation costs include fixed and variable cost that directly relate to the manufacturing of wood pellet, but does not include financial cost, selling or management expenses.

a. Fixed cost

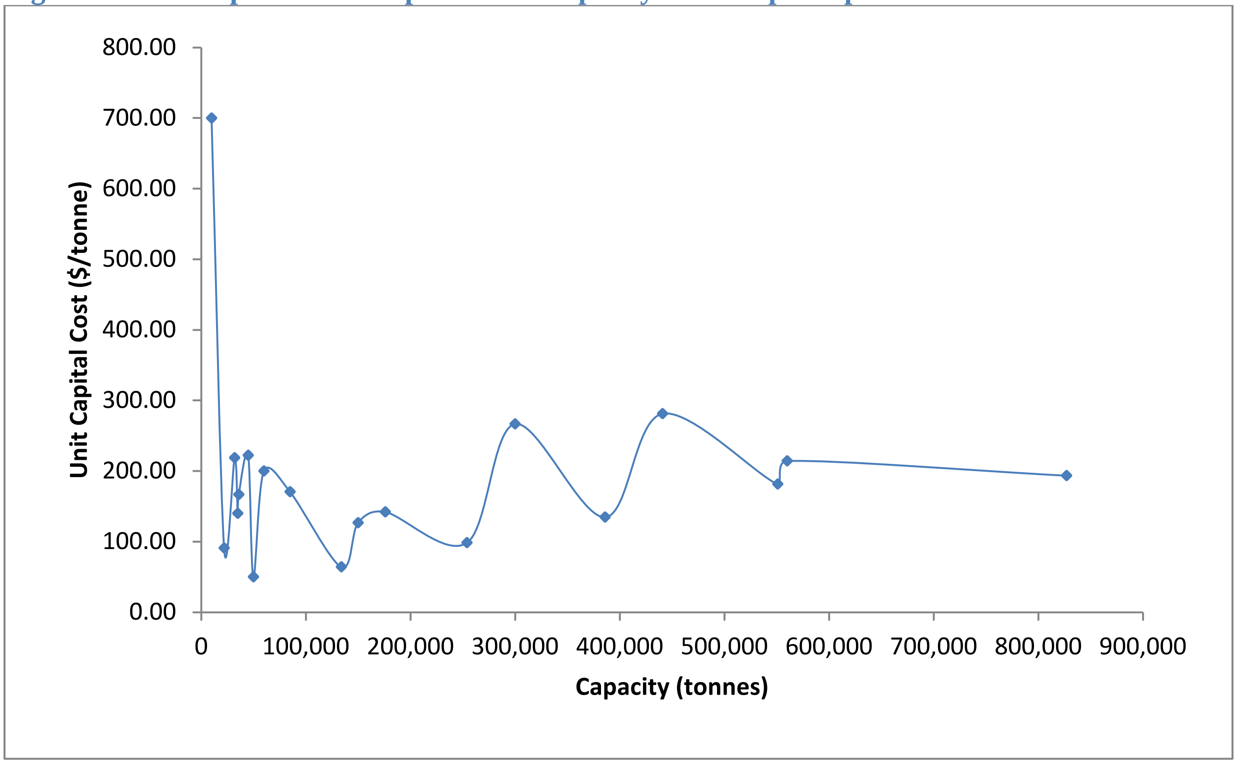
Two fixed costs are considered in this analysis: 1) annual depreciation of plant assets, and 2) fixed operational and maintenance costs. Depreciation is estimated by amortizing initial project capital cost under a fixed discount rate. Capital expenditure for plant and equipment varies by plant size, location and production process. Major capital investment in a base scenario includes dryer and fueling system, hammer mill, pellet mill, cooler, storage and handling facilities, peripheral equipment, office buildings, and miscellaneous equipment. Additional capital cost may include on-site grinding facilities, enhanced emission control system, etc.

Generally, large-scale pellet producers can achieve competitive costs by economy of scale. However, they may invest in other enhanced facilities to achieve better pellet quality or additional facilities for export purposes (i.e. storage silos at harbor, loading and unloading facilities, etc.), which may result in a higher capital cost per unit of pellet production. Figure 3.6 shows the relationship between facility annual production capacity and unit capital cost. It seems that plants whose capacities are around100,000~200,000 tonnes have the lowest unit capital cost.

Assuming that for each wood pellet project, all of the capital is used to construct plant facilities and purchase equipment, also assuming a ten-year project life, capital cost for per tonne pellet ranges from $6.48 to $36.42 under a 5% discount rate and from $8.14 to $45.77 under a 10% discount rate, with an average cost at $21.31 and $26.78, respectively. Pirraglia et al. used a techno-economic model to determine pellet production cost and estimated the depreciation cost to be $22.41/tonne, which is close to the average capital cost calculated by this study (Pirraglia, Gonzalez, & Saloni, 2010). Capital costs estimated by other case studies are at the lower end, from $6/tonne in a U.S pellet mill economic analysis (Mani, Sokhansanj, Bi, & Turhollow, 2006), to $12.28/tonne and $15.13/tonne in Austria and Swedish case studies (the number has been adjusted from 2004 Euro-US Dollar exchange rate) (Thek & Obernberger, 2004).

Costs for maintenance purposes include replacement of parts, shutdowns, and overhaul to extend useful life of major equipment. Maintenance costs for most facilities and equipment are around 2~3% of the capital costs except pellet and hammer mills, which can be as high as 10% due to more wear and tear (Mani et al., 2006). Total repairs and maintenance costs are estimated around $5~6/tonne pellet (KPMG LLP, 2008; Urbanowski, 2005).

Figure 3.6 Unit capital cost and production capacity of wood pellet plants in U.S



Source: Wood Bioenergy US Database, Forisk Consulting LLC (June 25, 2012)

b. Variable Cost

Following the logic of value-adding process, variable cost associated with plant operation excludes the cost of wood fiber from which the pellet product is derived. This section involves major costs of energy, personnel and other raw materials.

1) Utility Cost

Energy is a major plant operation cost due to the large amount of heat and electricity required throughout the manufacturing process of drying, hammer milling, pelletizing and cooling. Drying consumes almost 70% of the total energy (Pirraglia et al., 2010), and many pellet producers achieve cost reduction in overall production by energy co-generation from biomass raw materials, such as barks, tops, branches, and residuals. This report assumes that pellet producers adopt an energy co-generation strategy, and that the fuel cost for drying is counted in the feedstock cost. Previous research suggest that per tonne pellet production requires approximately 400~600 Kwh of energy in total (Di Giacomo & Taglieri, 2009; Pirraglia et al., 2010). Assuming that 30% of the energy is supplied by utilities, using the average retail price of electricity 6.2 cents/Kwh in Southern states (EIA, 2011), the energy cost from utilities is around $10/tonne pellet. This cost may change according to pellet producers' utility suppliers and the type of energy resource they use. Since retail price of electricity range from ₵4.07/Kwh to ₵21.97/Kwh, the energy cost would be $5.64 to $39.42 per tonne pellet under the same calculation method. Some producers may contract renewable energy suppliers to cut the carbon footprint in pellet production. For example, Green Circle Bio Energy only purchases renewable electricity from hydropower and methane operations[2].

Other utility costs are associated with water, sewer and waste management facilities. These costs are negligible compared with other major cost components, and thus this report will use a $10/tonne pellet as a rough estimate for total utility cost in the base case scenario.

2) Personnel

Generally, pellet plants require skilled labor, and the cost could be significant. Direct labor includes production workers, maintenance technicians, forklift operators and supervisors. The cost is determined by the structure of labor and hourly rate. Hourly rate of labor can vary by the unemployment rate and other demographics in different geographic locations. Under different assumptions, direct labor costs can vary from $4 to $40 per tonne pellet (Pirraglia et al., 2010; Urbanowski, 2005). Based on the assumption of 7 workers per shift and an hourly rate of $20~30, and the assumption of operating 8400 hours per year, the cost of labor would be $7.35/tonne pellet for a 200,000 tonne mill.

[2] Kotrba, R. Closing the Energy Circle, from http://biomassmagazine.com/articles/1331/closing-the-energy-circle

Transportation cost to port

Logistics supporting the transportation from plant to port is critical to meet the expanding wood pellet export demand. For a pellet exporter, the distance from plant location to port and logistics infrastructure may have the same strategic importance as proximity to biomass sources. A combination of availability of wood sources and existing infrastructure of ports, rail and roads is a main factor for Southern US pellet producers to achieve competitive price (Norris, April 2011). See Appendix 1 highlighting the importance of coastal biomass resource proximity to Southern ports in recent sittings of new pellet facilities.

There are three principal ways to deliver wood pellets from a plant to a port: truck, rail and barge. Road transportation is a very common method to deliver wood products. However, considering the truck's larger greenhouse gas and community impacts as well as cost compared to other two alternatives, wood pellet producers shift transportation modes to reduce the carbon footprint. From an economic standpoint, pellet transportation might become unprofitable when exceeding a trucking distance of 60~100 km (Pellets@las, 2009b). Due to the cost and environmental concerns, several large pellet producers use rails and barge instead. For example, Green Circle uses trains to deliver pellet from plant (Cottondale, FL) to the Panama City Port at a contract rail rate as low as $7/tonne (Norris, April 2011). Georgia Biomass is also shipping the wood pellets by rail car to the Savannah port (Ferre', March 2012). If situated along major inland waterway, transporting by barge is easy, efficient and environmental friendly. Wood pellets from Enviva's Amory facilities are shipped by barge through the Tombigbee River and stored in barge until they are loaded to maritime shipping vessel[3]. Under the scenario of transporting by truck, the delivery cost would range from $7.5~$15/tonne pellet when the distance of transportation changes from 50~100 miles.

Other Costs

Aside from direct costs associated with pellet production, a pellet facility also incurs indirect costs such as SG&A (selling, general and administration expenses), and financial costs. These costs vary across firms, and it's difficult to obtain reliable numbers. Thus, this report does not make assumptions for these costs and only estimate gross margin for pellet producers, which does not subtract these indirect costs. However, these costs need to be considered by pellet producers.

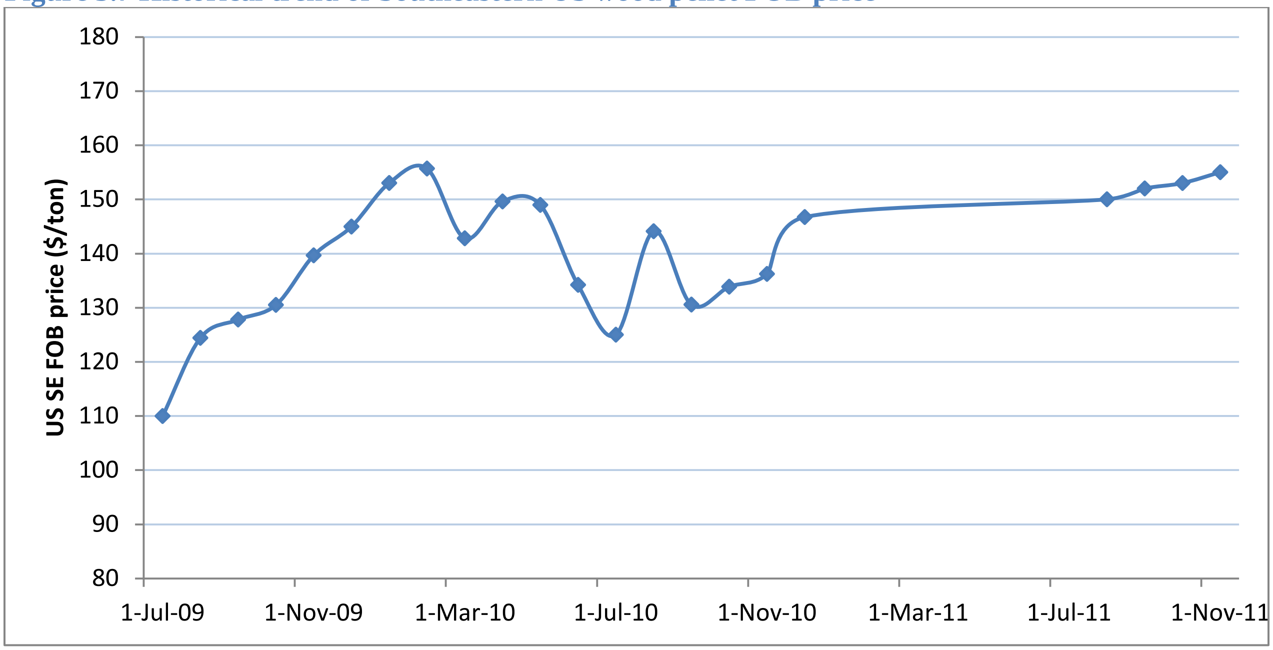
Delivery price at domestic port

FOB (Free On Board) export price can serve as a reference for the delivery price of wood pellet to traders or European utility buyers at US domestic ports. Under the Incoterms Rules, which are developed by the

[3] Enviva LP. Port Operations, from http://www.envivabiomass.com/manufacturing-operations/port-operations/

International Chamber of Commerce, FOB is usually followed by a port name, indicating that sellers only pay for the transportation to the port of shipment and loading costs, whereas the buyers pay for freight, insurance, unloading and the transportation from import port to final destination[4].Title and risk pass to buyers once delivered on board the ship by the seller (Sikkema et al., 2011). Argus Media updates weekly report on Biomass Market that includes wood pellet price indexes and forward price assessment. Based on Argus' market data, Figure 3.7 shows the historical price trend of Southeastern US FOB prices for wood pellets (the data from Jan 2011 to July 2011 was not available). The FOB price rose sharply from $110/ton in July 2009 to around $155/ton at the beginning of 2010, fell back to $125/ton in the first two quarters in 2010, and then trended upward again.

Figure 3.7 Historical trend of Southeastern US wood pellet FOB price



Source: (Argusmedia, January - December 2010, May - December 2009, November 2011; Sikkema et al., 2011)

Pellet Production Cost Center Summary

Based on the previous analysis, Table 3.1 presents the percentage of each major cost at the production cost center under an assumed scenario. In the base scenario, the delivery price of roundwood in Chapter 2 is multiplied by a conversion factor of 2 to calculate feedstock cost; plant operation costs uses Pirraglia's work as the estimation for capital cost, or in other words, depreciation of assets. The fixed O&M cost, personnel and utility cost are assured to be $5.5/tonne, $10/tonne and $10/tonne respectively, which were

[4] http://en.wikipedia.org/wiki/FOB_Price#cite_note-iccfobpreamble-0

often quoted by other researchers. For the transportation cost from plant to port the assumed scenario uses a middle point of cost range as the estimate. In addition, Table 3.1 also summarizes the range of each cost from the above analysis and literature review. Under the assumed scenario, feedstock cost accounts for about 52% of the total cost, while plant operation cost and delivery cost to ports are around 39% and 9% respectively. If pellet producers deliver their goods at $155/tonne, they can achieve a gross margin of 20.7%. This profit margin is lower than the average of manufacturing industry, which is around 30% (First Research, May 2012), but higher than many other forest industry profit margins.

Table 3.1 Cost Break-down at pellet production center

		Assumed Scenario	Percentage of Total Cost	low	high
Feedstock Cost		**64**	**52.1%**	**50**	**70**
Plant operation cost	**Total cost**	**47.91**	**39.0%**	**21.12**	**131.19**
	Fixed cost	27.91	22.7%	11.48	51.77
	Depreciation of assets	22.41	18.2%	6.48	45.77
	Fixed O&M cost	5.5	4.5%	5	6
	Variable cost	20	16.3%	9.64	79.42
	Energy	10	8.1%	5.64	39.42
	Personnel	10	8.1%	4	40
Delivery cost to ports		**11**	**8.9%**	**7**	**15**
Direct Production Costs		**122.91**	**100.0%**	**78.12**	**216.19**
FOB wood pellet prices		**155**		**130**	**160**
Gross margin		**20.7%**			

Sensitivity Analysis

To examine how each major cost factor affects the profitability of pellet manufacturers, sensitivity analysis is conducted by modifying each within its cost range. Figure 3.8 shows the sensitivity analysis results by changing multiple cost inputs. Feedstock cost is the most sensitive factor influencing the profitability of pellet producers. A 22% decrease in biomass feedstock cost can increase the gross margin from 20.7% to nearly 30%. To achieve the same growth, capital cost has to be decreased by around 70%, while personnel or energy or transportation costs have to be reduced by more than half.

Furthermore, a sensitivity analysis is also conducted to evaluate how the volatility of FOB price would affect pellet producers' businesses. Figure 3.9 illustrates how pellet exporters' profitability changes with FOB prices from $130/tonne to $160/tonne. Figure 3.9 shows that fluctuation of FOB price within the current range would result in gross profit margins ranging from 10% to 30%, holding other costs at the assumed scenario. The pellet production industry should remain a fairly attractive investment when the FOB price remains $160/tonne or more.

Figure 3.8 SensitivityAnalysis of Major Cost Factors (holding other costs constant)

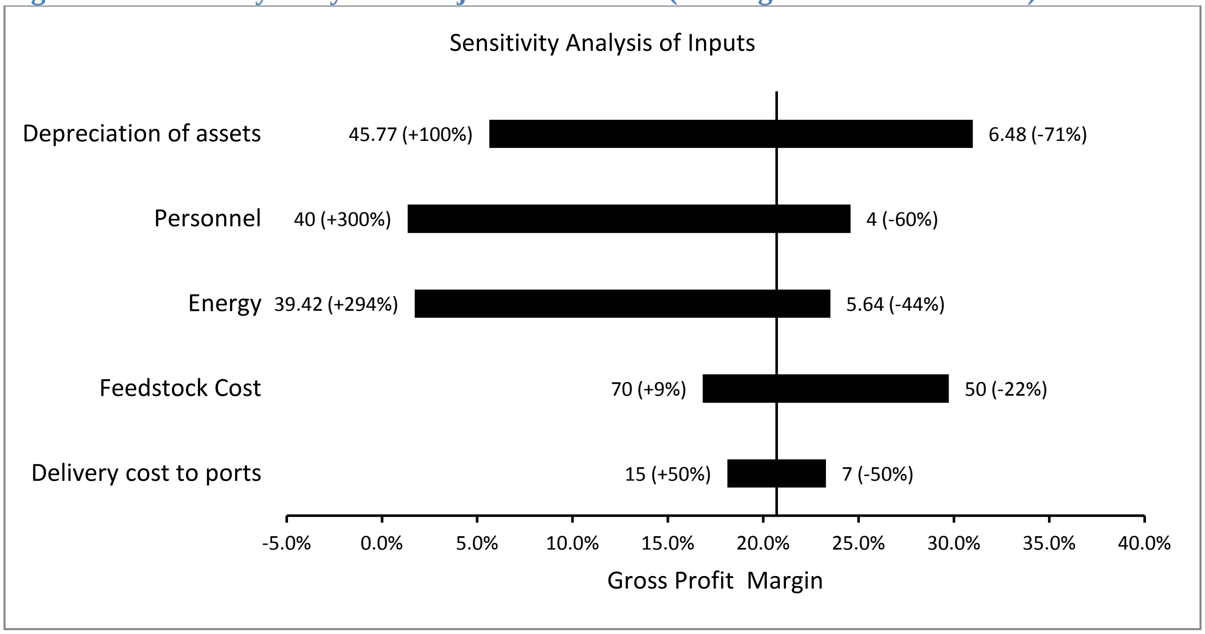
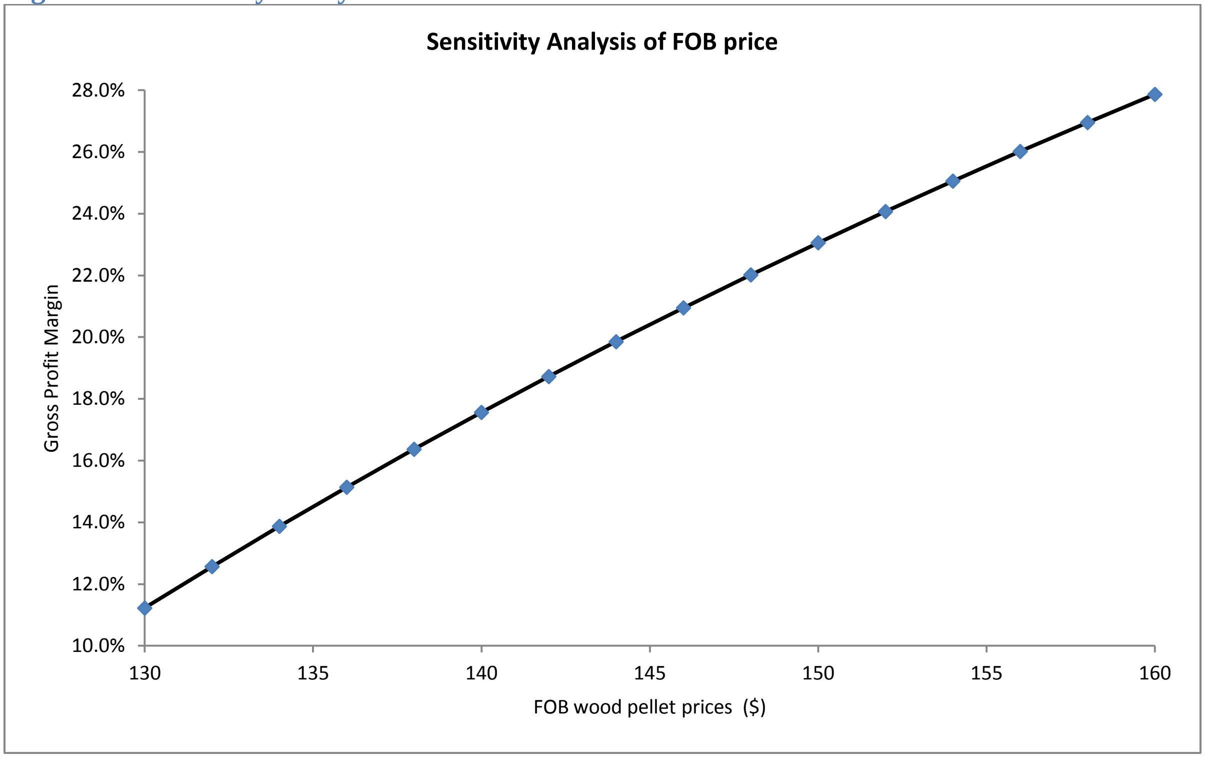


Figure 3.9 Sensitivity Analysis of FOB Price

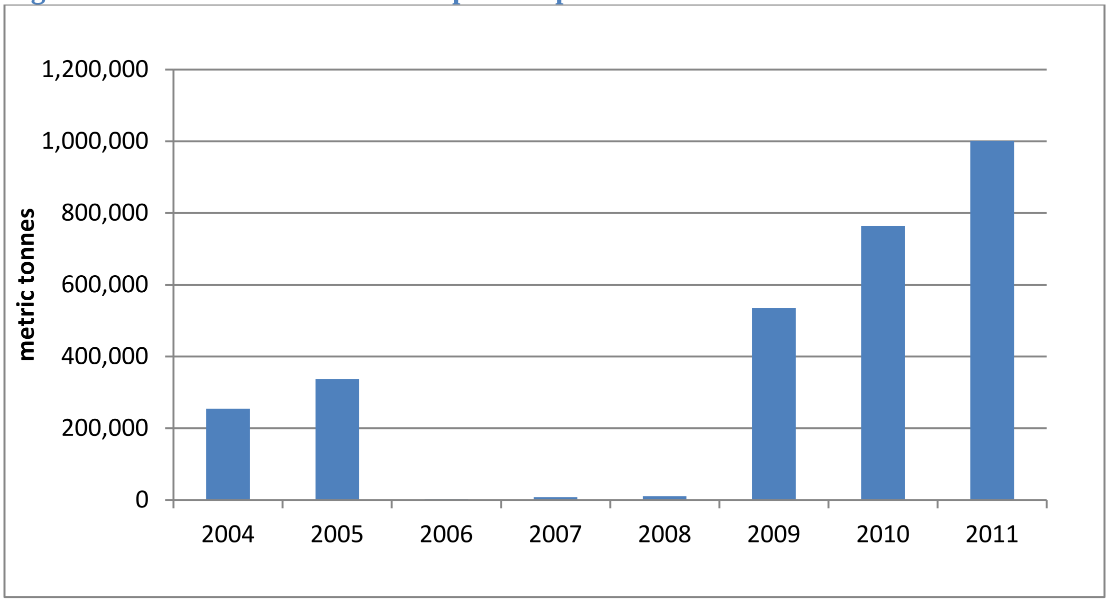


Chapter 4 Pellet Export

Background

Driven by European countries demand for biomass fuel, the United States has seen a sharp growth in wood pellet export in the past three to four years, as shown in Figure 4.1. In 2011, the total export amount reached one million metric tonnes. Wood pellet exports became viable due to the comparatively higher energy density compared to other biomass fuels, European renewable energy policies, and also to more efficient international logistics. This chapter focuses on the logistics and distribution of wood pellet export business, from domestic US ports to destination ports in Europe.

Figure 4.1 Historical trend of wood pellet export from US to EU27 countries

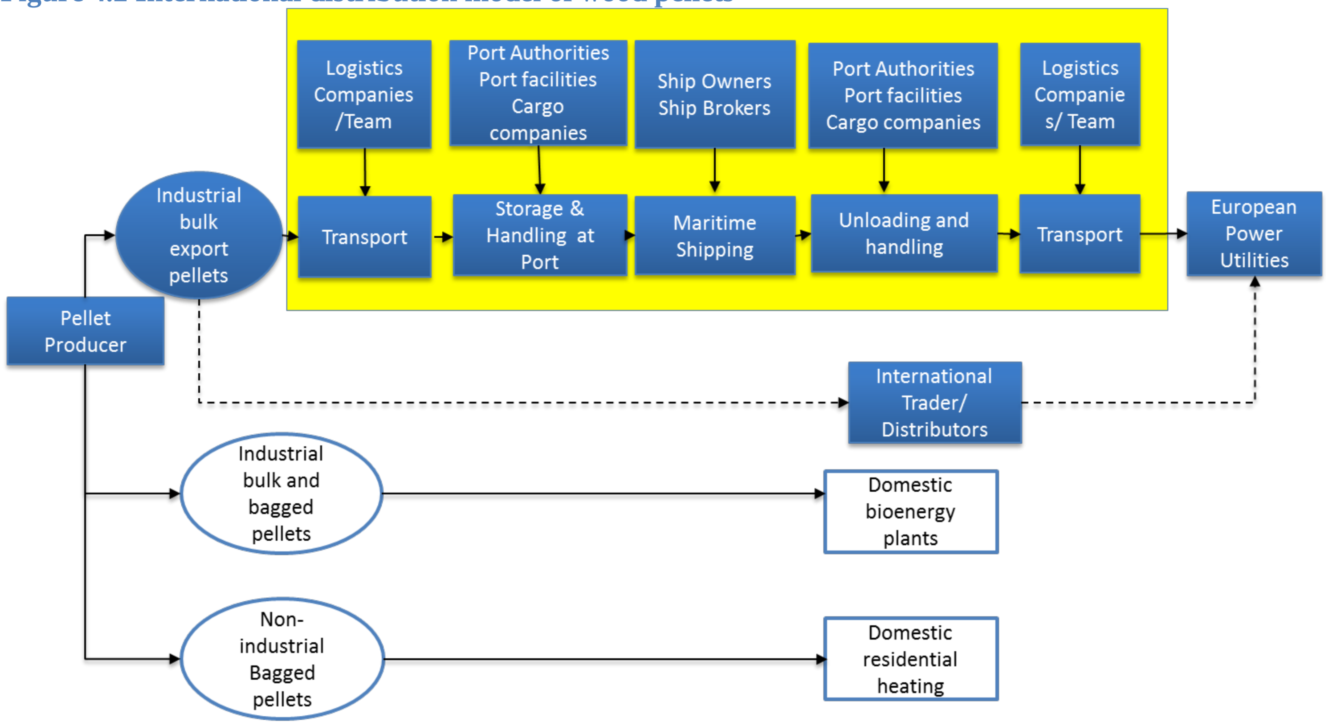


Source: (Eurostat, 2012)

Supply Chain of International Distribution

Figure 3.2 illustrates the international distribution model of wood pellet exports, with the highlighted area to be the focus of this Chapter. The three potential pellet consumers are international users, primarily European power utilities, domestic industrial users and domestic residential heating. In domestic markets, pellets can be either delivered in bulk directly to power facilities or sold in bags through wholesalers and retailers. Sales to overseas consumers are industrial bulk pellets, and have a minimum volume requirement of 5,000 tonnes (Sikkema et al., 2011). This chapter focuses on the value chain associated with export for industrial users in Europe.

Figure 4.2 International distribution model of wood pellets



So far, pellet exporters can only supply a few large-scale European consumers, inferred by their production capacity and contract shipping amount. For example, Enviva's operating facilities represent 750,000 tonnes of production capacity, while they signed a 480,000 tonnes/year contract with Electrabel and a 240,000 tonnes/year contract with E.ON (Bloomberg, August 2010; Enviva LP, February 2012). A European power utility, however, may have multiple domestic and international biomass suppliers, within or outside Europe.

European industrial wood pellet users import pellets from Canada, the U.S and Russia among other smaller pellet export countries (Cocchi & al., 2011). Two wood pellet import models have emerged: 1) diversified supply chain with separate wood pellet producers and buyers; and 2) vertically integrated pellet supply with European utility subsidiary created to supply pellets. The current largest U.S. pellet facility, Georgia Biomass, is the bioenergy subsidiary of German utility RWE Innogy. RWE, with the merger of Dutch utility Essent, invested in their own pellet plant in the U.S, not only because of the abundant sustainable forest resource, but also to ensure reliable supply and good quality (Gibson, April, 2011). Between the pellet producer and European consumers, international traders can also be involved to link the business and organize movement of wood pellets. Traders can play an important role in helping biomass suppliers to access to a larger marketplace, ensuring they meet sustainability criteria and quality standards, and mediating the terms of shipping.

At the top of Figure 4.2 describes the physical movement of wood pellets in international trading. The export facility serves as the interface between inland logistics and maritime shipping. After the dispatch from factories, pellets have to be stored at ports before loading onboard. Storage and handling of huge amounts of pellet could pose a great challenge due to the characteristics of pellets. Although wood pellets are upgraded from wood, they still have the drawback of tendency to crumble when exposed to moisture, which will increase the amount of dust and fines. The high level of wood dust, together with a detected methane-rich storage environment and the occurrence of microbial and chemical oxidation caused by fungi and bacteria, will pose fire risk if no measure is taken. Green Circle Bio Energy has reported two fires at the port of Panama City during the past four years – one in the conveyer system and the other in the storage barge. Some pellet producers built their own storage silos at port, which ensures safety and product quality by monitoring temperature, moisture and other indicators, like Enviva's Chesapeake port[5]. Such well-facilitated ports surely require heavy upfront investment and may also increase operational costs, but they can prevent major accidents and save millions of dollars of loss.

The focal discussion area of this chapter, maritime shipping, is at the center of wood pellet flow chain. It covers the value chain from FOB or loading pellets onto a cargo ship until the pellets are delivered to a European biomass facility. Seaborne shipping accounts for more than 80% of total world merchandise trade by volume (United Nations, 2008), supporting international trade as the backbone. The three major types of maritime shipping cargos are dry bulk, oil and containers. Forest products constitute an important part of minor dry bulk cargos and account for the largest growth by volume within this group (The UNCTAD Secretariat, 2011). International shipping rises and falls with global economic conditions, and thus wood pellet businesses would be exposed to this macroeconomic risk through this link. The freight cost of shipping pellets largely depends on the global shipping demand and supply capacity, bunker fuel prices and other factors. The sections below discuss the freight costs and major challenges of wood pellet shipping.

Strategic Importance of Ports

In Chapter 3, we have pointed out the critical link of ports in the transportation chain, and we would continue to elaborate on this point in this section. Ports are of strategic significance to pellet export business. Two major factors make some ports more favorable than others: FOB price and port efficiencies.

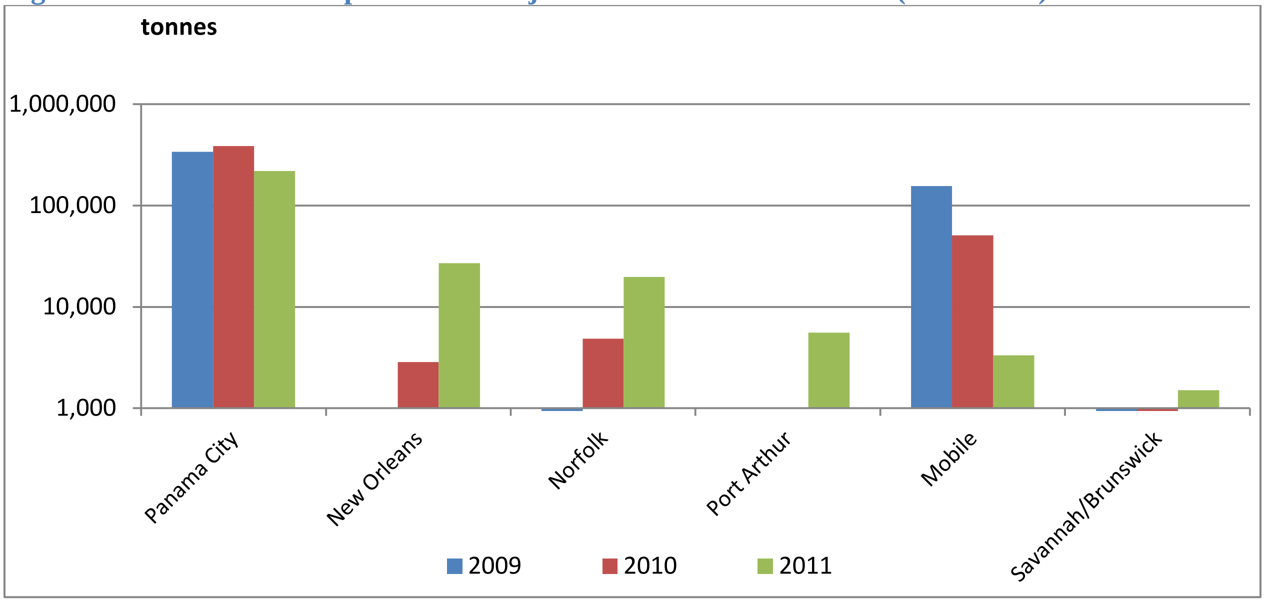
[5] Enviva LP. Port Operations, from http://www.envivabiomass.com/manufacturing-operations/port-operations/

FOB price has been discussed as an average export delivery price in Chapter 3. In reality, however, FOB price can vary widely across ports. Major pellet producers such as Green Circle, Enviva, and Georgia Biomass are all situated close to ports with competitive FOB prices.

Different ports also have wide variation in their efficiencies, which can be reflected by dock facilities, connections to inland transportation lines, harbor characteristics (channel depth and tidal movements), congestion level, etc. Port efficiency could be an important determinant of shipping costs as some research indicates (Clark, Dollar, & Micco, 2004). As the pellet industry form clusters in the Southern U.S region, new pellet producers can benefit from existing distribution and dock infrastructures, and thus lower their costs.

Therefore, during the site selection period for a pellet mill, proximity to cheap FOB ports and along existing transportation lines should be taken into consideration, as well as availability of suitable biomass resources. Appendix 1 maps out the most important wood pellet export ports in the U.S Southeast and major wood pellet producers. Figure 4.3 shows the export amount of wood pellets from major ports. Since Green Circle Bio Energy has been the largest wood pellet exporter in the past few years, the port of Panama City to which Green Circle deliver its products has kept the number one position in terms of the export amount of wood pellets. With the completion of several heavily-invested pellet projects and their production coming on line, sharp increase from Norfolk (VA), Savannah (GA) and Brunswick (GA) are anticipated.

Figure 4.3 Wood Pellets Exports from Major Ports in Southeastern US (2009~2011)



Source: (USITC, 2012)

Value-adding Process

Figure 4.4 depicts the value-adding process of wood pellets from export port to destination plant in Europe. The beginning value of this value chain could be represented by FOB price, while the terminal monetary value is the purchase price at European power plants. Between the two points include port charges, loading and unloading costs, shipping freight costs and inland transportation costs within the European boundary. Since there is no consistent data on various miscellaneous costs, this chapter will not give a specific number or data range for these costs.

Figure 4.4 The Value-adding process of wood pellets from export ports to terminal power plants

Loading and unloading costs

Wood pellets can be difficult to handle because of their tendency to break up. Aside from their fragile characteristic, they would swell and fall apart after absorbing water. This process also generates large amounts of dust, which is very flammable. Therefore, well-designed equipment and measurements should be adopted to minimize the impact of handling on wood pellets. For example, pneumatic loading and unloading have been widely used in dry bulk cargo, but they appear to be too hard on wood pellets. Belt conveyors are a more gentle handling method, but they have to be equipped with heat, smoke and flame sensors to reduce explosion risk. Pellet producers may invest in the equipment for handling, loading and unloading on their own, or pay cargo companies for handling services. If pellet producers make their own investment, they may require additional capital costs or seek public funding, as discussed in Chapter 3. As for contract cargo companies, charges for handling, loading and unloading services vary across companies, by weight of cargo, the vehicles from which pellets are removed, and different types of facilities.

Port Charges

Port charges are paid to port authorities, or other entities, with the objective of covering the costs of provision of port facilities and services. Since port is critical in connecting domestic and overseas distribution system, cargo owners add value to its products simply by sending their cargo to the right ports. The benefit of value creation may be shared and tapped by port authorities through the price for port. In return, port charges could be used to improve the efficiencies of port to satisfy the main port users – cargo owners and ship owners.

For pellet exporters and importers, port charges are based on the weight, nature (ore, oil, general cargo, etc.) and time cargo spends in port (The UNCTAD Secretariat, 1975). Major types of charges include: 1) port dues, for utilization of port facilities and services; 2) Cargo handling on board, for all operations from quay to ship's hold and vice versa; 3) storage charges, for the use of transit shed. Depending on weather conditions, the duration of cargo at harbor can vary greatly. An exporter who is at the end of a long queue may increase his port charges significantly due to delays waiting for harbor space

Freight Costs

The two largest cost components of freight costs are chartering rates of vessels and bunker fuel costs. The overall costs depend on the charging rate of vessels and fuel prices, which change with macroeconomic conditions, as well as the shipping distance and routes.

1) Chartering rate of vessels

Industrial wood pellets are shipped by dry bulk carriers, vessels that are specially designed for dry cargos in bulk. Pellet exporters can either own shipping fleets or lease vessels from charter markets. Major players in this charter market include charterer with cargo to export, professional ship owners and ship brokers (Bradley, Diesenreiter, & Tromborg, 2009). Vessels are chartered out through three different options: 1) Bareboat charter – the charterer can use the vessel for a couple of years and has to pay all voyage related costs (including bunker costs, port dues, etc.) and vessel operating expenses (including crew wages, maintenance, insurance, etc.); 2) Time charter – the charterer uses the vessel usually over months or years, but only pays for voyage-related costs; 3) Spot charter – the owner of the vessel undertakes both costs and the charterer is responsible to pay freight rate based on agreement. Most spot charters only associate with a single voyage, whereas time charter is more common in round-trips[6]. In the time charter market, chartering rates primarily depend on the length of chartering period and the characteristics of vessels. In the spot charter market, rates vary by a number of factors such as fuel prices, cargo size, commodity, port dues and canal tolls. Dry bulk carriers seldom operate on round-trips, but normally on a port-to-port liner service.

The chartering rate primarily depends on the type of vessel and its supply-demand balance. There are four different-sized dry bulk carriers: Handysize (20,000~35,000 DWT[7]), Handymax (35,000~50,000 DWT), Panama (50,000~80,000 DWT) and Capesize (100,000~300,000 DWT) (Bradley et al., 2009). Economy

[6] http://www.excelmaritime.com/the-market

[7] DWT: Dead weight tonnes, which is the difference between the weight of water displacement when the vessel is submerged to load line and when it displaces light. This term expresses the total tonnes a vessel can carry, including cargo, crew, fuel, water and stores.

of scale in bulk shipping is very critical in cost reduction. Vessels with larger capacities will significantly reduce unit cost on voyage-related expenditure and operating costs. An increase from 40,000 DWT to 120,000 DWT in ship size can reduce cost per DWT by 50% (Stopford, 2009). However, the number of ports and routes that can handle large vessels is limited.

Wood pellet products are usually counted as minor bulk cargos. Due to their light weight, they are mostly shipped together with other cargos on Handysize and Handymax vessels. Handysize vessel charter rates are relatively steady fluctuating from high $20/tonnes range to mid-$30/tonnes range from the US east coast to ARA (Antwerp-Rotterdam-Amsterdam) ports (Argusmedia, November 2011). The Baltic Dry Index, which is based on the daily-updated expertise view of freight cost on time charter market from a panel of international shipbrokers, is also an important price reference in maritime shipping. This index is a weighted average of various vessel sizes and routes (not restricting to Baltic regions), and serves as a measure of global demand for shipping capacity versus supply of dry bulk carriers.

2) Bunker fuel cost

Bunker fuel is a derivative of crude oil – the remaining petroleum product after refineries process the more valuable fuels from crude oil. It is think and heavy, and thus difficult to transport. Usually, it is stored at or close to ports, and mainly transacted via physical contracts. The bunker fuel prices vary across ports and the market is pretty fragmented. Bunker fuel prices are important to overall freight costs. Study shows that the freight rate will increase by 27% as the bunker fuel price doubled (Bradley et al., 2009). Thus, the long-term growth trend as well as the volatility in fuel price poses a potential risk to the wood pellet export business.

3) Shipping routes

The freight cost also relies on whether a route is common or not. The cost of transporting a large amount of wood pellet in an existing route such as Vancouver to ARA (Antwerp-Rotterdam-Amsterdam) may be similar to that of transporting a much smaller amount in a route out of the way. Development of new cost-effective shipping routes has to be supported by large and modern port facilities, sufficient and guaranteed wood pellet supply, and other critical actions (Bradley et al., 2009).

CIF Prices

Similar to FOB price, CIF price (cost, insurance and freight price) has been frequently quoted in international trading. The CIF price indicates the value of a good at the import port, including freight cost and any insurance incurred to that point, exceptthe import duties and taxes. The major difference between

CIF and FOB lies in the duties bound to sellers and buyers. Under the CIF contract, the seller is responsible for paying for shipping and insurance, but risk would be transferred to buyers once the freight is loaded onboard. . Figure 4.5 gives a full illustration of who takes the responsibility at each stage.

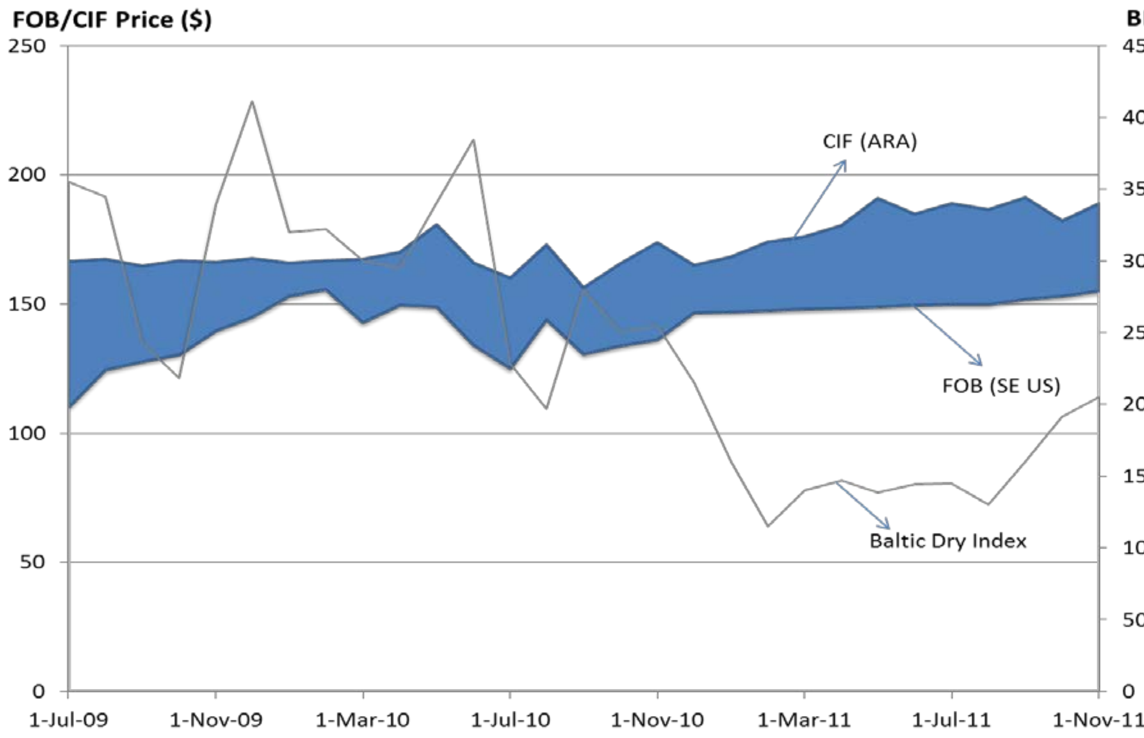
Figure 4.5 Duties of buyer/seller according to Incoterms 2010

Incoterms	FOB	CIF
Loading on truck (carrier)	Seller	Seller
Export-Customs declaration	Seller	Seller
Carriage to port of export	Seller	Seller
Unloading of truck in port of export	Seller	Seller
Loading charges in port of export	Seller	Seller
Carriage to port of import	Buyer	Seller
Unloading charges in port of import	Buyer	Buyer
Loading on truck in port of import	Buyer	Buyer
Carriage to place of destination	Buyer	Buyer
Insurance	Buyer	Seller
Import customs clearance	Buyer	Buyer
Import taxes	Buyer	Buyer

In 2008, the industrial wood pellets price index was launched at the Rotterdam's exchange platform APX-Endex. CIF ARA (Amsterdam-Rotterdam-Antwerp) Index not only reflects the price of pellet traded in the ports of Amsterdam, but also becomes the most important measuring stick for international trading of industrial pellets. As shown in Figure 4.6, the CIF ARA ranges from $160 to $190 per metric tonne.

Figure 4.6 also draws the historical trend of Baltic Dry Index (BDI) during the same period as CIF/FOB prices. As mentioned earlier, BDI could reflect the freight cost in global shipping. It appears that freight cost is not correlated with the gap between CIF (ARA) and FOB (SE US) prices. In other words, the gap between CIF and FOB prices does not merely reflect the freight cost, but contains other risks such as uncertain changes of currency exchange rates and price lags as well. If pellet exporters sign CIF contracts, they would not be able to pass those risks to the downstream buyers.

Figure 4.6 Southeastern US FOB price, CIF (ARA) price and BDI



Source: FOB price & CIF price (Argusmedia, January - December 2010, May - December 2009, November 2011; Sikkema et al., 2011); BDI (wikinvest)

European inland transportation

Roadway transportation is the most developed mode in Europe. However, the high cost and price volatility of diesel fuel makes transporting by truck less favorable. Additionally, increasing carbon costs on transport fuels will likely further undermine truck transport. Instead, waterway and rail transportation are promising ways in terms of reducing environment impact as well as business risks. Water transportation is the most environmentally friendly way of transportation, producing only 20% of the GHG that trucks do. In addition, waterway transport could also be more efficient in labor use and transportation time. It is estimated that the charging rate by barge would be around £3/tonne ($4.8/tonne)[8] in the United Kingdom. With regard to the controversial issue of carbon neutrality from burning biomass, developing a low-carbon inland transportation system for woody biomass should be taken into serious consideration.

[8] Assume £1 = $1.6 in this report.

Chapter 5 Pellet Consumption

European Market

Most U.S wood pellets exports are destined for European countries. The top three import countries are the Netherlands, Belgium and the United Kingdom. These countries account for more than 90% of the total wood pellet trade from the U.S to Europe as depicted in Appendix 2. While the Netherlands are the largest importer over the past several years, the UK market has been growing the fastest. The Netherlands, Belgium and UK have the highest industrial wood pellets demand due in large part to supporting country policies regarding biomass energy. In addition, these countries have adequate port infrastructure that ensures efficient wood pellet supply chain and in a sense makes them a primary trading hub of wood pellets among European countries (Verhoest & Ryckmans, March 2012).

Table 5.1 identifies the major utilities in Europe that consume wood pellets for electricity or heat generation. U.S pellet producers have become important suppliers to these utilities. For example, RWE-ESSENT sources a large proportion of its wood pellet feedstock from its U.S subsidiary Georgia Biomass (Gibson, April, 2011); Enviva LP is one of the main wood pellet suppliers to GDF-SUEZ and E.ON (Bloomberg, August 2010; Enviva LP, February 2012); FRAM Renewable Fuels mainly exports pellets to Danish and Swedish markets (National Association of Conservation Districts). In addition, many of these European utilities have ambitious plans to increase the number of co-firing plants or expand installed capacities.

Table 5.1 Wood pellet use for each Utility in Europe (2010)

Utilities (kt)	Belgium	Denmark	Netherlands	Sweden	UK	Total (utility)
RWE-ESSENT			1,000		2,500	**3,500**
GDF-SUEZ	1,200		500			**1,700**
DRAX					1,000	**1,000**
Goteborg Heating				700		**700**
DONG ENERGY		600				**600**
VATTENFALL		300				**300**
E.ON					240	**240**
Total (country)	**1,200**	**900**	**1,500**	**700**	**3,740**	**8,040**

Source: (Verhoest & Ryckmans, March 2012)

Pellet Combustion and Value Conversion

At the consumption stage of the value chain, value is increased through the conversion of wood pellets into useable energy most often in the form of either heat or electricity. The value added at this stage drives the entire wood pellet supply chain from its beginning in the U.S. South's forests.

The value of wood pellets is determined by moisture and ash content. Roughly estimated, if moisture is controlled at 7%, wood pellet would have a heating value (an indicator of the energy stored in a type of fuel) of 17.5MJ/kg (4.9Kwh/kg) (Pellets@las, 2009a). For direct thermal conversion, efficiency is roughly 80%~90% (Pellet Fuels Institute). But pellets are more commonly combusted for electricity generation at much lower efficiency, generally 35~40% (European Climate Foundation, 2010). Pellets have been widely used in Northern European countries for domestic or central heating. Co-firing pellets with coal in power plants has been successful and gained widespread adoption since the 1990s. Co-firing refers to burning two or more fuels simultaneously with different commingling methods. Wood pellets are well-suited for co-firing with coal because of its physical properties and economic benefits, largely driven by government incentives. It has advantages over other co-firing material in terms of energy density, low moisture, uniformity and similarity to coal characteristics. Different technologies exist to convert pellets into electricity. Pellets can either be burned to produce steam or produce gas to turn electricity turbines. The most efficient, though still emerging conversion technology is gasification of wood pellets to drive a gas combined-cycle turbine (GCC) (D'Ovidio & Pagano, 2009).

The value conversion process of wood pellets in a power plant is illustrated in Figure 5.1. The wood pellet value chain gains its terminal value as energy output, avoided carbon payments and other renewable energy incentives. Waste heat and wood ash residuals are two potential products that are not currently valued in the marketplace. The value of energy output is most often represented by electricity price. On average, the efficiency of converting wood pellets to electricity is only about one-third of energy content (Badger, Rahmani, Pullammanuppallil, Hodges, & McDonell). Since the average industrial electricity price in EU 27 countries is around €0.1/kwh (European's Energy Portal, May 2012), we can estimate the wood pellet's energy value to be €160/tonne ($208/tonne)[9].

Wood pellet's economic value also lies in its avoided carbon tax. According to European carbon policy, woody biomass is considered to be carbon-neutral as long as being sourced from sustainable forests as defined in European Renewable Energy Directive 2009/28/EC. A vigorous debate about the actual carbon accounting of wood pellet based bioenergy is emerging in Europe and other countries that supply wood pellets. Ensuring the correct carbon accounting of wood pellets remains a significant obstacle to full public support. This report recognizes the critical importance of this debate while also using the existing EU policy incentives to complete the value chain.

[9] Assume €1 = $1.3 in the report.

Table 5.2 provides the carbon emissions data of burning different types of fossil fuels (US EPA, May 2008). Assuming the carbon price in the European trading market is €7.8/ton CO_2 as indicated by the European Energy Portal, the avoided carbon tax from replacing fossil fuels with wood pellets is calculated in the table. In addition to the above economic values, biomass as a renewable energy resource has obtained sufficient policy incentives and subsidies in certain European countries, which enable wood pellets to compete with traditional fossil fuels in industrial use. We will elaborate those supportive policies in the UK, the Netherlands and Belgium in the next section.

Figure 5.1 the value conversion process of wood pellets

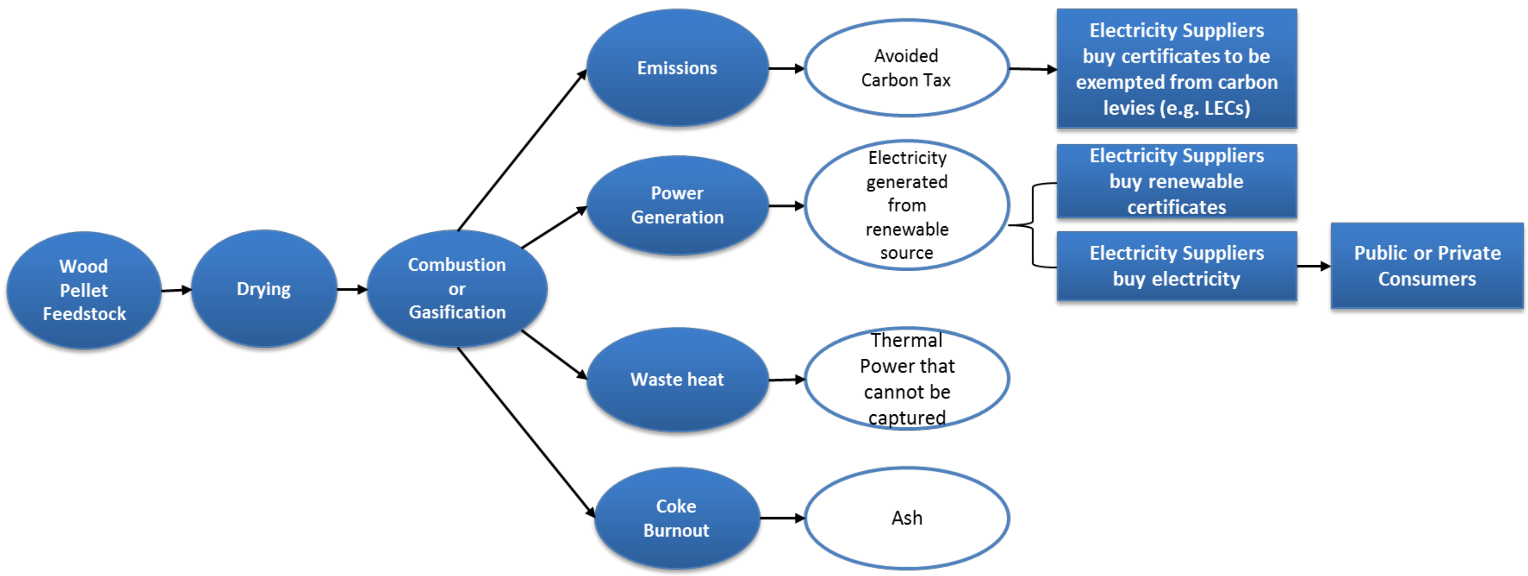


Table 5.2 Carbon emissions of various type of fuel and avoided carbon tax using wood pellets

Fossil Fuel	Heat Content	CO2 Content Coefficient	Carbon Emissions	Carbon Tax Price	Avoided Carbon Tax	
Coal	(mmBtu /ton)	(kg CO2 /mmBtu)	(ton CO2 /ton fuel)	€/ton	€/ton	$/ton
Anthracite Coal	25.09	103.62	2.60	7.80	20.28	26.36
Bituminous Coal	24.93	93.46	2.33	7.80	18.17	23.63
Sub-bituminous Coal	17.25	97.09	1.67	7.80	13.06	16.98
Lignite	14.21	96.43	1.37	7.80	10.69	13.89
Natural Gas	(Btu/scf)	(kg CO2 /mmBtu)	(ton CO2 /scf fuel)	€/ton	€/scf	$/scf
Natural Gas	1029	53.06	0.05	7.80	0.43	0.55
Petroleum	(mmBtu /barrel)	(kg CO2 /mmBtu)	(ton CO2 /barrel)	€/ton	€/barrel	$/barrel
LPG	3.85	63.16	0.24	7.80	1.90	2.47
Propane	3.82	63.07	0.24	7.80	1.88	2.44

Source: Carbon emissions factor, (US EPA, May 2008); Carbon Tax Price, (Europe's Energy Portal)

Policy Incentives

European Union

The EU has several important policy incentives that directly impact the wood pellet value chain. The most important pieces of legislation include (Joudredy, Mcdow, Smith, & Larson, 2011):

1) Renewable Energy Directive (RED) of 2009 – RED (2009) set a 20/20/20 target for the EU and corresponding member country targets. Specifically RED calls for 20% total energy consumption from renewable energy sources, 20% reduction in energy consumption and 20% reduction in GHG emissions by 2020.
2) Report COM (2010) 11 – The Report COM (2010) 11 addresses the sustainability issue remaining to be solved in RED (2009), with a conclusion that binding sustainability criteria were not necessary for solid biomass at the time when the report was released.
3) Energy Efficiency Directive of 2011 (also known as COM (2011) 370) – The aim of COM (2011) is to guarantee that the EU meets the 20% reduction goal in energy consumption. One of its many initiatives is to encourage the development of CHP plants in member countries, which is likely to increase the demand for pellets throughout EU.

Under the overall EU Renewable Energy (RE) objective, each member state must develop its own National Renewable Energy Action Plans (NREAPs), and their target may vary. Besides these three pieces of legislation, the Emission Trading System (ETS) also plays a crucial role in stimulating biomass demand, by establishing the economic value of avoided carbon. The sections below examine the renewable energy policies in the three largest importers of wood pellets, the UK, the Netherlands and Belgium. Then using the UK renewable energy incentive system, the economic competitiveness of wood pellets and coal are analyzed.

The United Kingdom

The UK has committed to produce 15% of energy from renewable sources. Biomass electricity and heat have been identified in the UK Renewables Roadmap as the key technologies that have the greatest potential to meet the country's renewable energy goals in a cost-effective way (DECC, July 2011). Two primary incentives exist to promote electricity generation from biomass.

1) Renewables Obligation Certificates (ROCs)

The Renewables Obligation Certificates (ROCs) are tradable certificates demonstrating a companies' compliance with the renewables obligation. ROCs are issued by Ofgem, the administration organization of ROCs, to electricity generators according to the amount of eligible renewable energy produced. Generators then sell the acquired ROCs to the electricity suppliers. Each electricity supplier in the UK must specify and annually increase the proportion from eligible renewable energy or pay a penalty known as the index-linked buy-out price (DECC, 2013). Those who fail to meet the targets for supplying renewable energy pay a sum (multiplying the number of ROCs by the buy-out price) into the buy-out fund. The fund then pays renewable energy generators in proportion to the ROCs generated by them. This is known as the Recycle Buy-out Fund (RBF) premium, which is an additional but variable income to electricity generators. Table 5.3 summarizes ROC data since the programs introduction in 2002.

Table 5.3 Statistics for RO in the UK (for England and Wales only)

	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11
ROCs/MWh	0.030	0.043	0.049	0.055	0.067	0.079	0.091	0.097	0.111
% of ROCs issued for biomass	10.9%	10.7%	7.6%	6.5%	7.0%	7.7%	8.5%	10.2%	7.9%
Buyout price(£)	30.00	30.51	31.39	32.33	33.24	34.3	35.76	37.19	36.99
RBF premium (£)	15.94	22.92	13.66	10.21	16.04	18.65	18.61	15.17	14.35
Total Nominal Value of ROC(£)	45.94	53.43	45.05	42.54	49.28	52.95	54.37	52.36	51.34

Data Source: (DECC, April 23, 2012)

With the introduction of banding in April 2009, the ROC system has been reformed from a mechanism that provides single level support for all renewable technologies to one which offers multi-level supports based on the renewable technology. Banding levels are reviewed on a four-year basis so that appropriate levels of support for different technologies can be ensured. Recently, the UK's Department of Energy and Climate Change (DECC) has confirmed the proposed bandings for biomass support during 2013 to 2017, giving biomass developers certainty that the government will maintain its subsidies for the next four years. Under the new banding proposal, the support level for conversion of coal-fired power plant to biomass will be reduced from 1.5 ROCs/MWh to 1 ROC/MWh, and support level for dedicated biomass will be reduced to 1.4 ROCs/MWh from 1.5 ROCs/MWh from April 2016, representing a 7% decrease. Many large biomass power plant developers such as E.ON are reviewing their projects now in light of this subsidy cut[10]. The new banding levels will take effect on 1 April 2013.

2) Levy Exemption Certificates (LECs)

LECs offer evidence of electricity generation from qualifying renewable sources for suppliers so that they can be exempted from paying Climate Change Levy (CCL), an index-linked tax on energy use in industry, commerce and the public sector. Under the existing UK policy, energy generated from eligible biomass plant or CHP plant can apply for CCL exemptions. The CCL rate is £0.509p/Kwh from April 2012 to April 2013, and £0.524p/kwh beginning in April 2013 (HM Revenue & Customs). Similar to ROCs, LECs are also issued to generators and monitored by Ofgem. LECs are traded to electricity suppliers and redeemed by suppliers for the amount of electricity that can be exempted from CCL. If not being exempted, the levy would be charged on consumers. Therefore, LECs provide additional economic values to biomass electricity generators as electricity suppliers purchase the certificates through contracts.

The Netherlands

The Netherlands has a target of sourcing 14% of electricity from renewables by 2020. Today, around one-third of the total green energy is produced from biomass (Verhoest & Ryckmans, March 2012). This growth has been driven primarily by the MEP premium, a feed-in premium for electricity generated from renewables. The MEP was initiated in 2002 (Cocchi & al., 2011) and the incentive last 10 years for eligible facilities. But since 2006 no new projects have been able to apply for this feed-in tariff. Instead, the SDE and SDE+ schemes replaced the existing MEP ones in 2007, and exclude the large-scale power plants for financial support. Most of the co-firing plants will lose their subsidies under MEP schemes

[10] http://epoverviews.com/articles/visitor.php?keyword=E.ON

between 2012 and 2015 (Verhoest & Ryckmans, March 2012). In 2008, the premium for biomass combustion was €67/MWh ($87/MWh); this premium has been adjusted to a range of €115~156/MWh ($150~203/MWh) and a weighted average of €123/MWh ($160/MWh) in 2009 (EREC, 2009). To avoid discontinuation of co-firing due to decreasing financial support, the Dutch government stated in the "green deal" that all coal-fired power plants should commit to co-firing biomass at least 10% (Goh, Junginger, Jonker, & Faajj, 2011).

The Netherlands have limited land resources to produce sufficient amount of woody biomass, and thus, more than 90% of wood pellets for co-firing were imported in 2009 (Goh et al., 2011). It is a major challenge now in international trading to develop uniform standards in technical specifics, contract and foremost sustainability. Currently, sustainability certificate or criteria for biomass is voluntary for industrial consumers. However, the Dutch government is likely to link future subsidy schemes with the existing certificate such as the NTA 8080/8081 (Cocchi & al., 2011). RWE ESSENT, the largest consumer of wood pellets in the Netherlands, also took the leading role in solid biomass sustainability certification development. The Green Gold Label (GGL) initiated by them has been formally recognized by the EU as a valid certification scheme. For other smaller CHP plants, sourcing a higher percentage of certified biomass might be the industrial trend they have to follow.

Belgium

Following the EU target, Belgium has an objective of 13% renewable energy share in energy portfolio by 2020. In Belgium, the most important incentive for renewable power generation is the Green Certificate (GC). Very similar to how ROCs work in the UK, power suppliers have to meet a growing obligation or quota of renewable power production, and penalties will be applied to suppliers who lack sufficient GCs. GCs are tradable in the market, with a minimum value being the financial gap of extra cost in electricity production compared to the use of fossil fuels. The GC schemes vary by regions across Belgium, but they share many commonalities and are all based on the same principles. For example, in Flanders Region, one certificate is granted for each NET MWh of green electricity which subtracts the fossil energy used in power generation; in Wallonia, a GC is granted for every 456 kg CO2 emission avoided (ADEME & Barel, 2009).

Different renewable technologies usually vary in grant levels of GC due to the relative contributions to carbon emission reductions, indicated by the CO_2 saving rate τ. For example, for a 100% pellets-fueled power plant, the τ is 0.84. The Belgium utility Electrabel converted one of its plants in Wallonia into a 100% pellets fired plant, with an efficiency of 34%. However, considering that most of the wood pellets were imported from a number of countries, the CO_2 saving rate τ was adjusted to 0.65. With an installed capacity of 80.3 MWe and a production potential of 562,100 MWhe per year, the Electrabel plant can receive 343,489 Green Certificates per year (Van Stappen, Marchal, Ryckmans, Crehay, & Schenkel, 2003). In 2011, the average profits of GC generated from biomass are listed in Table 5.4.

In Belgium a sustainability certification of biomass fuel is required to obtain the green certificates. For each power plant in Belgium, their global supply chain has to be examined and approved by the certification body SGS Belgium in the Laborelec Certification System.

In addition, Belgium has implemented total tax exemption for renewable energy investment. At the federal level, CHP is eligible for a 13.5% first-year capital allowance on investment (i.e. the facility is able to write off 13.5% of their CHP investment against taxable income (COGENchallenge, 2007)).

Table 5.4 Average value of Green Certificate for biomass power generation in Belgium

Channels	Average grant level	Average produce price		Average support level	
	GC/MWh)	(€/GC)	($/GC)	(€/MWh)	($/MWh)
Biomass for power plant	0.798	86.95	113.04	69.38	90.19

Source: (CWaPE, 2011)

Comparative Economics: Wood Pellets versus Coal

This section examines the fuel competitiveness of wood pellet compared with coal. Previously, we have discussed different country policies that support generating electricity from biomass. Among them, the UK has a complex subsidy system to stimulate the development of renewable energies. The existing UK policies and incentives provide a useful study of the wood pellet fuel economy in Europe. Table 5.5 (next page) presents our calculations for the economics of wood pellets compared to coal under a 2013~2014 policy scenario. It shows that combusting wood pellet is economical across almost all technologies, including in a co-firing plant, a conversion plant or a dedicated biomass power plant, except when co-firing percentage is less than 50%.

Table 5.5 UK biomass power plants generation economics 2013~2014

		New Co-firing plant support level			Conversion to biomass	New Dedicated biomass power plant
		<50% 0.3 Roc	(50 ~85%) 0.6 Roc	(85~100%) 0.7 Roc	1 Roc	1.5 Roc
Electricity	Wholesale Electricity price (£/MWh)[1]	73.2	73.2	73.2	73.2	73.2
	ROC price (£/MWh)	15.6	31.2	36.4	52	78
	LECs (£/MWh)	5.24	5.24	5.24	5.24	5.24
	Renewable Energy price (£/MWh)	94.04	109.64	114.84	130.44	156.44
	Renewable Energy price in US Dollar ($/MWh)	122.25	142.53	149.29	169.57	203.37
Wood pellet fuel economics	Wood Pellet price CIF ARA (€/tonne)	132	132	132	132	132
	Exchange rate (£/€)	0.8	0.8	0.8	0.8	0.8
	Wood pellet energy content (MWh/tonne)	4.9	4.9	4.9	4.9	4.9
	Wood pellets costs (£/MWh)	21.55	21.55	21.55	21.55	21.55
	Electricity efficiency	34%	34%	34%	34%	34%
	Efficiency-adjusted cost of wood pellets fuel (£/MWh)	63.39	63.39	63.39	63.39	63.39
	Pellet spark spread (£/MWh)	30.65	46.25	51.45	67.05	93.05
	Pellet spark spread in US dollars ($/MWh)	39.85	60.13	66.89	87.17	120.97
Coal Fuel Economics	Coal fuel cost (£/MWh)	11.45	11.45	11.45	11.45	11.45
	Electricity efficiency	34%	34%	34%	34%	34%
	Electricity-efficiency adjusted coal fuel cost (£/MWh)	33.68	33.68	33.68	33.68	33.68
	Carbon price of coal fuel (€/tonne)	20.28	20.28	20.28	20.28	20.28
	Energy content of coal (MWh/tonne)	6.9	6.9	6.9	6.9	6.9
	Exchange rate (£/€)	0.8	0.8	0.8	0.8	0.8
	carbon price at efficiency (£/MWh)	6.9	6.9	6.9	6.9	6.9
	Clean dark spread (£/MWh)	32.6	32.6	32.6	32.6	32.6
	Clean dark spread v. pellet spark spread (£/MWh)	1.95	-13.65	-18.85	-34.45	-60.45
Wood pellet v. Coal	**Clean dark spread v. pellet spark spread (£/MWh)**	**1.95**	**-13.65**	**-18.85**	**-34.45**	**-60.45**
	Clean dark spread v. pellet spark spread in US dollars ($/MWh)	2.54	-17.74	-24.50	-44.78	-78.58

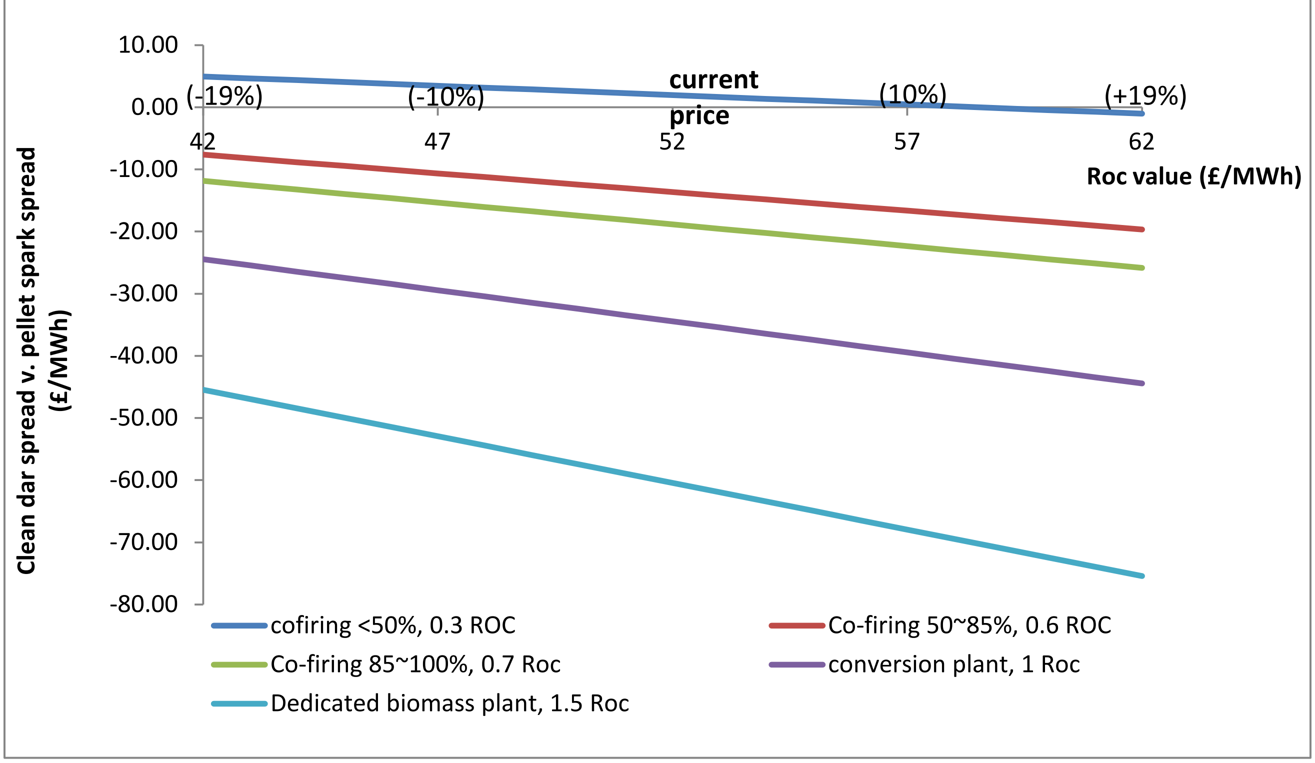
[1] DECC. Electricity wholesale prices.

Scenario Analysis

1) ROC value

As mentioned in the policy incentive section, the current value of ROC in the UK is around £52~53/MWh. Generally, the ROCs price trends upwards, since the government tightens the cap of certificates each year under the pressure to meet the 2020 goals. The decrease of ROCs value during 2008~2010 was primarily due to the migration of micro-generating stations to the Feed-in-Tariff scheme – which was introduced in 2010 and specially designed for small-scale low-carbon electricity plants (<5 MW) (DECC, April 23, 2012). In the near term, it is unlikely that ROCs value will undergo big changes, for example, rise to £57/MWh. Therefore, plants that co-fire biomass less than 50% probably would not consider wood pellets as cost-effective fuels even if ROCs value slightly increases. All other technologies would remain competitive across the likely range of ROC prices.

Figure 5.2 the ROC price impact on wood pellet fuel economy

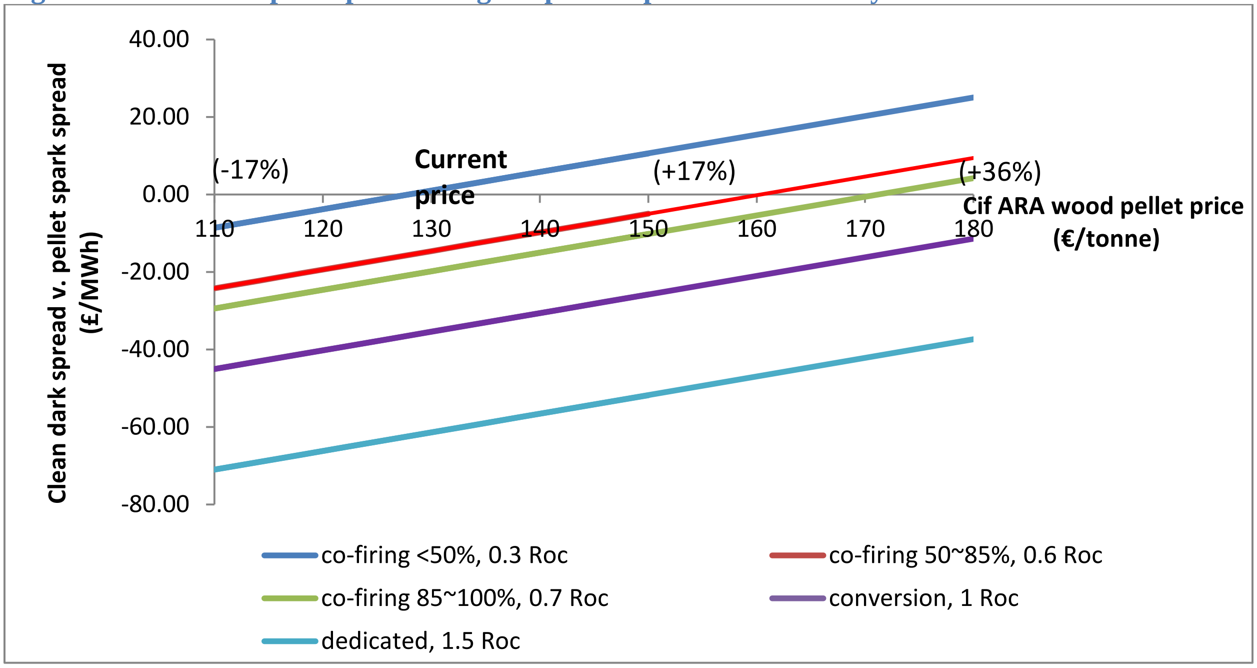


2) Wood pellet price

Since it is very difficult to find the average purchase price of wood pellets for major UK plants, the Cif (ARA) price is used as an approximate value. The most probable Cif (ARA) price range of wood pellets is from €130~140 /tonne, in which a facility co-firing at less than 50% may still prefer coal to wood pellets. In addition, if a major shift occurs in the cost of wood pellets that drives the price beyond

€160/tonne, even a support level of 0.6 ROC may be insufficient, and any co-firing plant will find pellet fuel uneconomical when the price rises to €170/tonne. However, we need to keep in mind that Cif (ARA) prices may not capture the real contract prices between pellet suppliers and utilities consumers. To avoid the price volatility and ensure supply, utilities consumers are likely to sign long-term contracts with their international suppliers, and the information of these prices is confidential.

Figure 5.3 The wood pellet price change impact on pellet fuel economy



3) Coal price

Coal price is both a driving force for growth in wood pellet demand and also a risk factor for biomass power plant developers. The coal price has almost doubled during the past five years, and currently, the price is at historical high as shown in Figure 5.5. Similarly, prices of other fossil fuels increased sharply in recent years, and the change in oil price is particularly dramatic. If following this trend, wood pellet would become more and more competitive because the price of coal seems to be rising faster than the pellet price. In addition, assuming the price of wood pellet remains the same, all biomass power plants, either dedicated or co-firing, would gain cost advantage if the coal price continues to increase by 5%, reaching €12/MWh.

However, the price of coal could be highly volatile. Although currently the fuel cost of coal is less competitive than wood pellets, it would be favorable again if it falls back below €7~8/MWh. Figure 5.5 indicates that if the coal price goes under £6 or 7/MWh, any co-firing plant would be uneconomical, although converted or dedicated biomass plants may still run well under the current subsidy scenario. This volatility of coal price could be the riskiest factor for co-firing plants.

Figure 5.4 Impact of coal price change on wood pellet economy

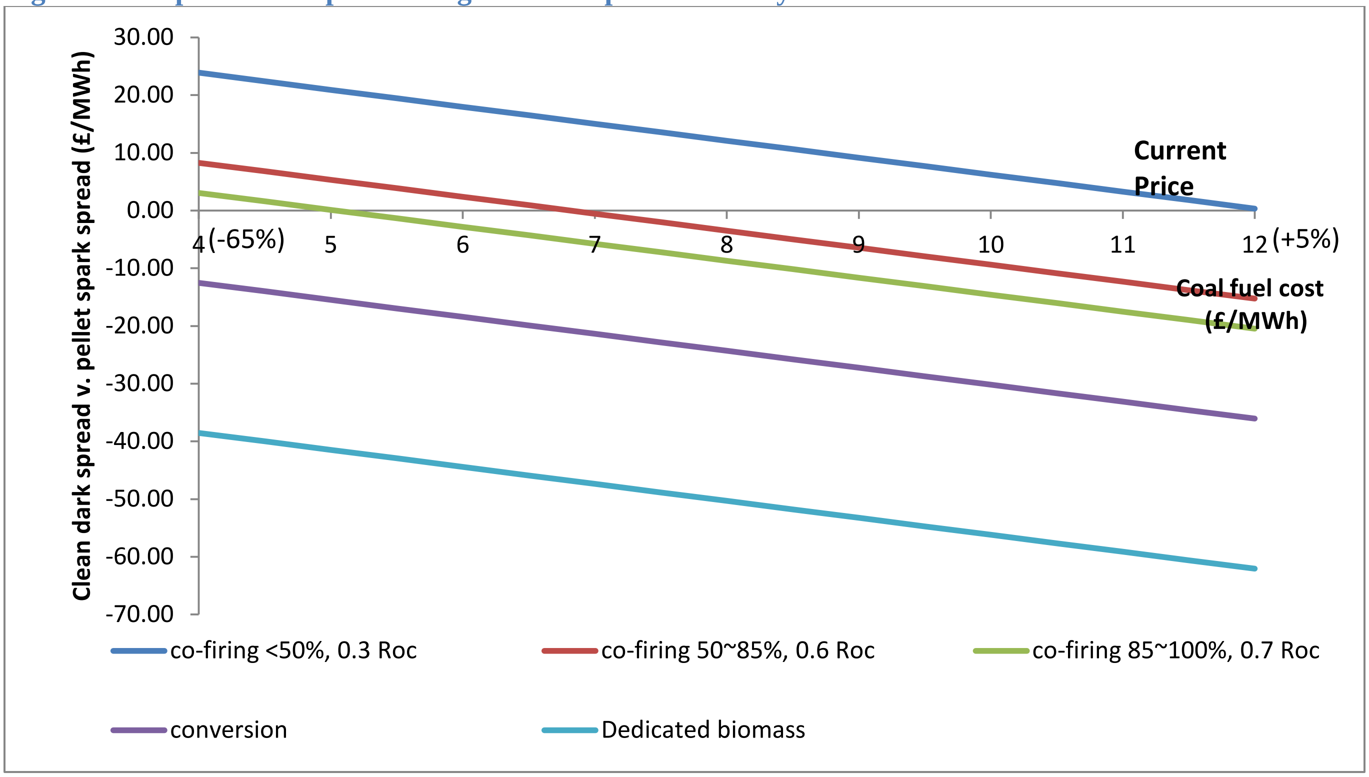
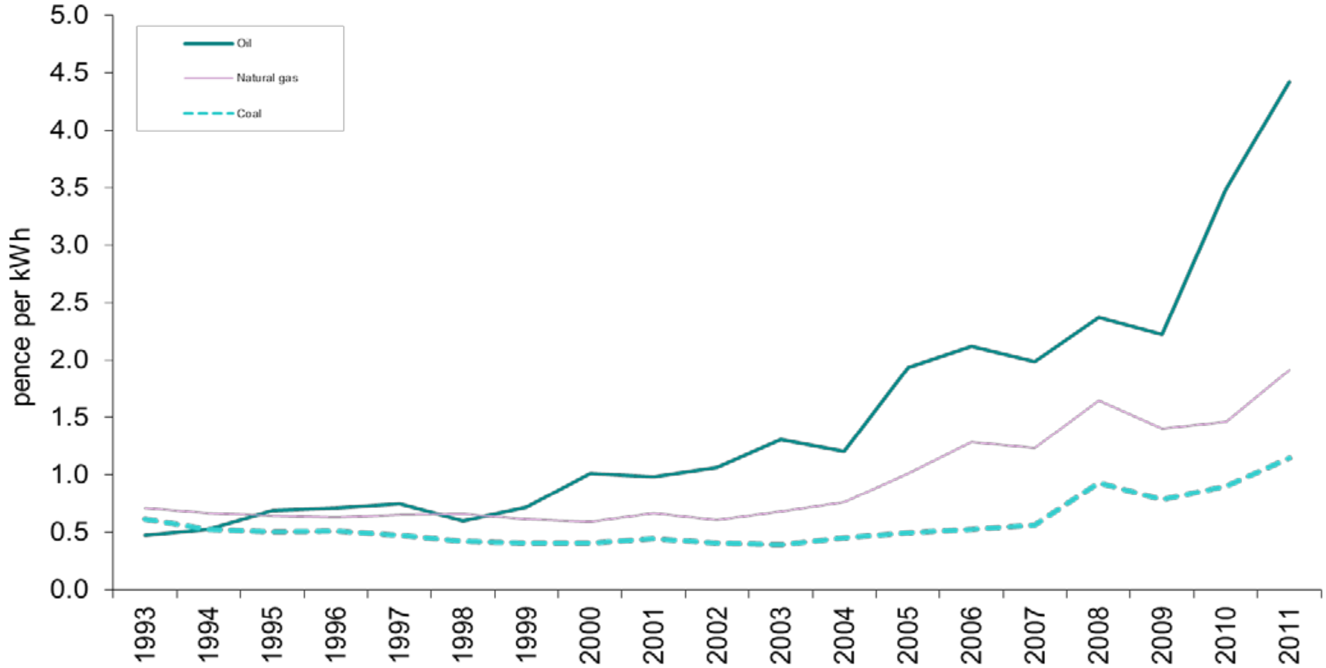


Figure 5.5 Impact of coal price change on wood pellet economy

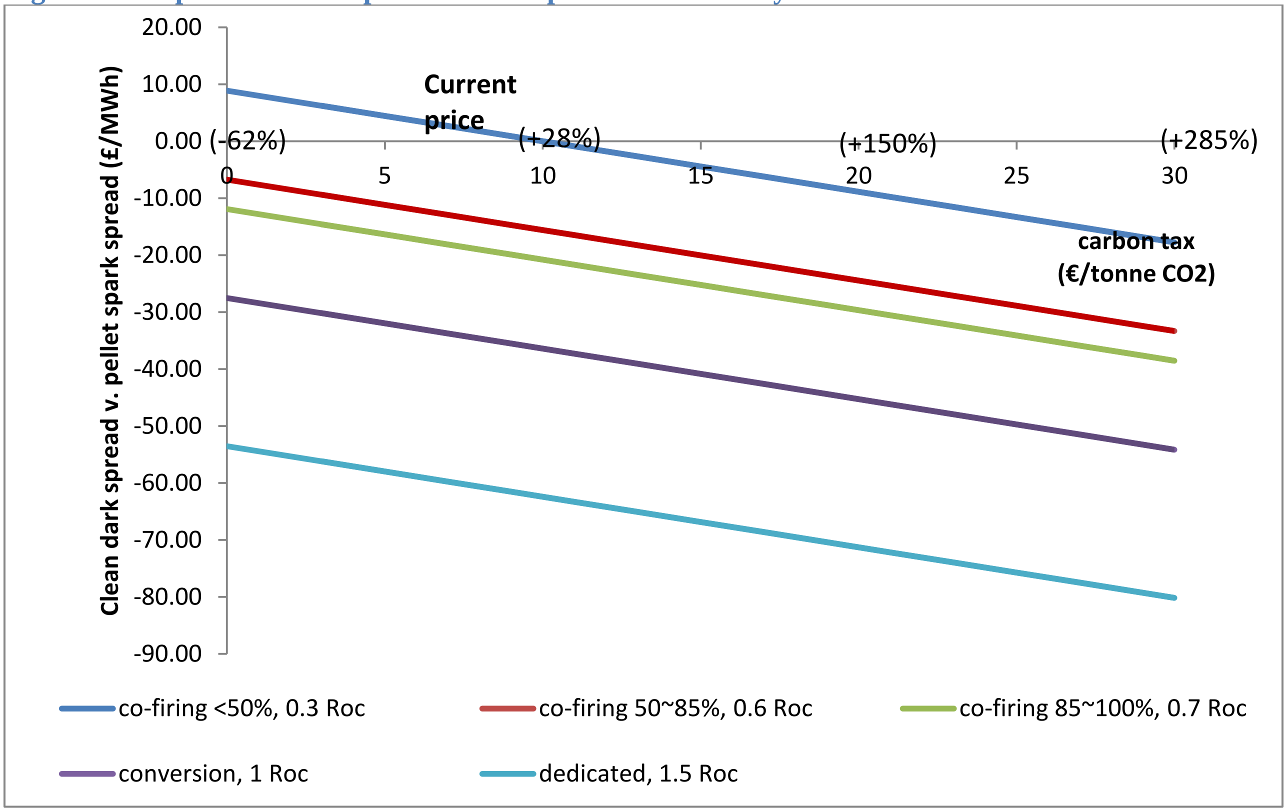


Data Source: (DECC, December 2012)

4) Carbon price

The last uncertain influencing factor is carbon price. Since the beginning of Phase 2 of the EU ETS (2008~2012), the spot price of carbon fell dramatically from between 20 and 30 €/tCO_2 to between 6~8 €/tCO_2. This is primarily due to the unexpected economic recession resulting in actual emissions way below the previous amounts. It is also uncertain what the future ETS scheme will require, leaving member states somewhat unwilling to commit to a long-term reduction goal for post-2020. As shown in Figure 8, for a co-firing plant with a 0.3 ROC support, the carbon price has to reach above €15/tonne CO_2 to achieve apparent competitiveness.

Figure 5.6 Impact of carbon price on wood pellet fuel economy



Chapter 6 Conclusion

Under the objective of finding opportunities to fund the US landowners to undertake increased sustainable management activities, this report examines the whole value chain to evaluate business opportunities and risks of each cost center. Below are key findings for each cost center

Supply - cost center #1: The value at the biomass supply cost center is created through stumpage value, harvesting activities and biomass delivery. The largest cost factors are stumpage price (28%), diesel (22%) and labor costs (17%). Price volatility of stumpage and diesel poses threats to all players in this supply system. In addition, the nature of fixed short-term supply of woody biomass not only results in the price volatility, but also influences the availability of feedstock. Thus, if prices or volatility increase significantly a long-term contract mechanism between biomass suppliers and buyers may be useful to minimize those risks. This cost center contains very little profit margin to enhance sustainable forest management and harvesting activities. Doing so will likely require some outside incentives from pellet manufactures or more likely EU utilities to address the increased costs associated with sustainability practices.

Production – cost center #2: Value at this stage is created through converting the biomass feedstock into pellet products. Feedstock cost, plant operation and delivery of pellet products from plant to port account for 50%, 30% and 20% of the total final value, respectively. Since feedstock is the single largest cost component, it is the most sensitive factor that influences the profitability of pellet producers. In addition, according to our research, pellet manufacturing industry may have a lower gross profit margin than the average manufacturing industry but greater than other forest industry markets. Thus, pellet producers might be able to support a very modest increase in feedstock costs to enhance sustainability practices.

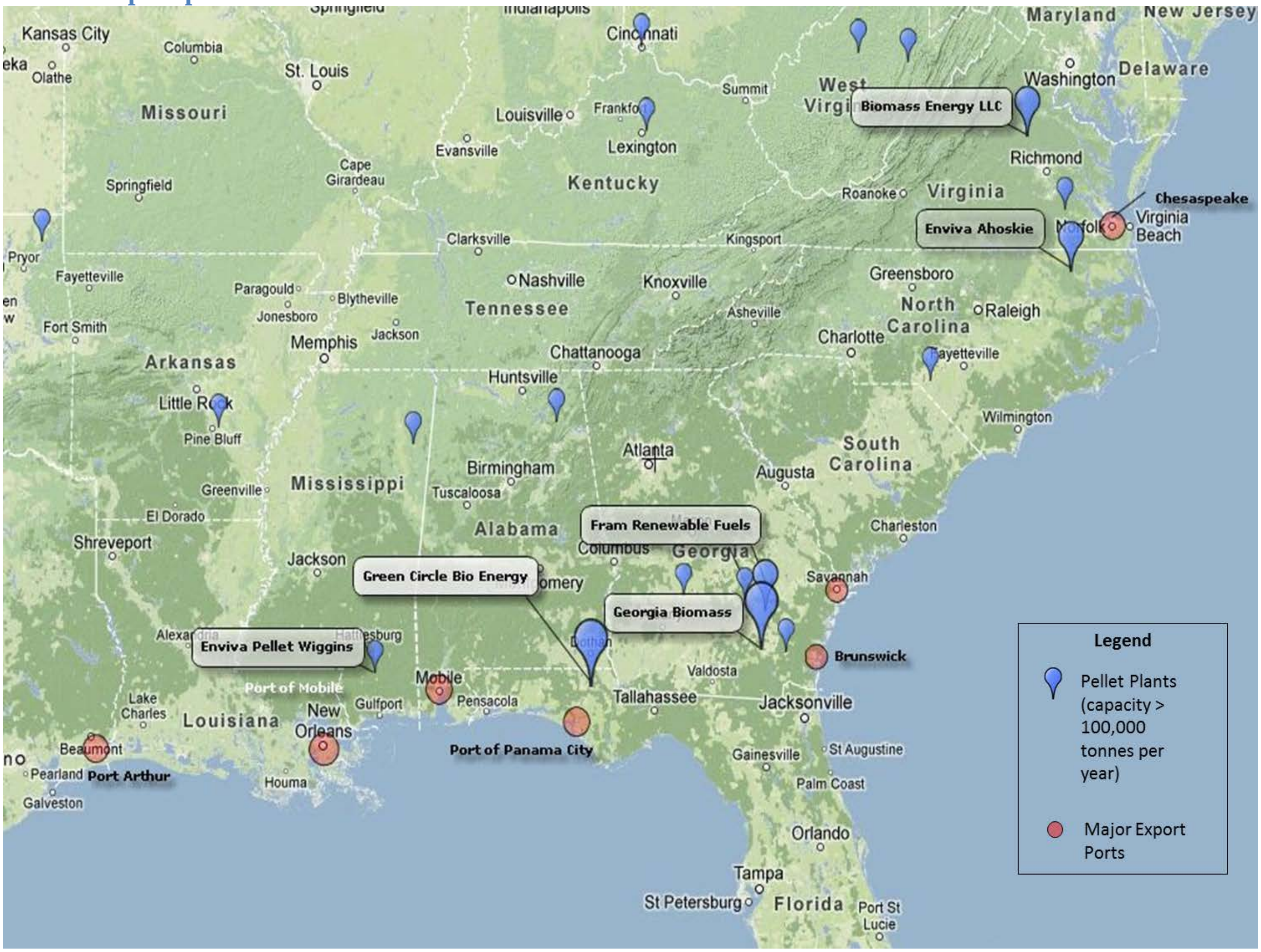
Distribution – cost center #3: International maritime shipping is the focus of discussion at this cost center. Freight cost is highly related to global economic condition that heavily affects the demand and supply for shipping vehicles. Whether exporters use FOB price or CIF price for pellet trading does matter, inasmuch that choosing the latter would have to accept risks out of the price transmission mechanism, such as currency exchange rate change and price lags. In addition, FOB prices vary across ports, and thus exporters situated close to cheap FOB ports might acquire strategic advantage. Finally, other important issues at this center include port efficiencies, storage and handling, and inland transportation systems.

Consumption – cost center #4: Pellets eventually realize their final value through conversion into energy output. Besides wholesale electricity price, pellets' economic values also lie in renewable policy incentives. In several European countries, eligible power generators could have additional income from marketable instruments that provide evidence for producing electricity from renewable sources. Under current policy mandates and incentives in European countries, wood pellets have become a very competitive type of fuel in either dedicated biomass plants, converted power plants or CHP plants. Alongside with the large market power held by utilities, we believe that European consumers have the capability and responsibility to undertake the main costs related to increased sustainable biomass procurement or forest management.

Throughout the study, we found that the main driving force that boosts the pellet demand is the competitive costs of wood pellet fuel under European countries' support schemes. As the prices of traditional fossil fuels continue to rise at a sharp rate, the cost advantage of burning biomass would be more obvious. European power utilities would enjoy the direct benefits from burning fossil fuels, but it might be difficult for the added value to flow back to landowners, since the value system is complex and includes many different players, which are across industries and geographical boundaries. Europe is serious about meeting biomass sustainability objectives, and some countries have already put forward sustainability certification requirements on biomass fuel. However, landowners alone are not able to undertake the cost burden. To achieve the sustainability objectives, the EU member countries and EU utilities must develop pathways to finance enhanced sustainability practices on the ground.

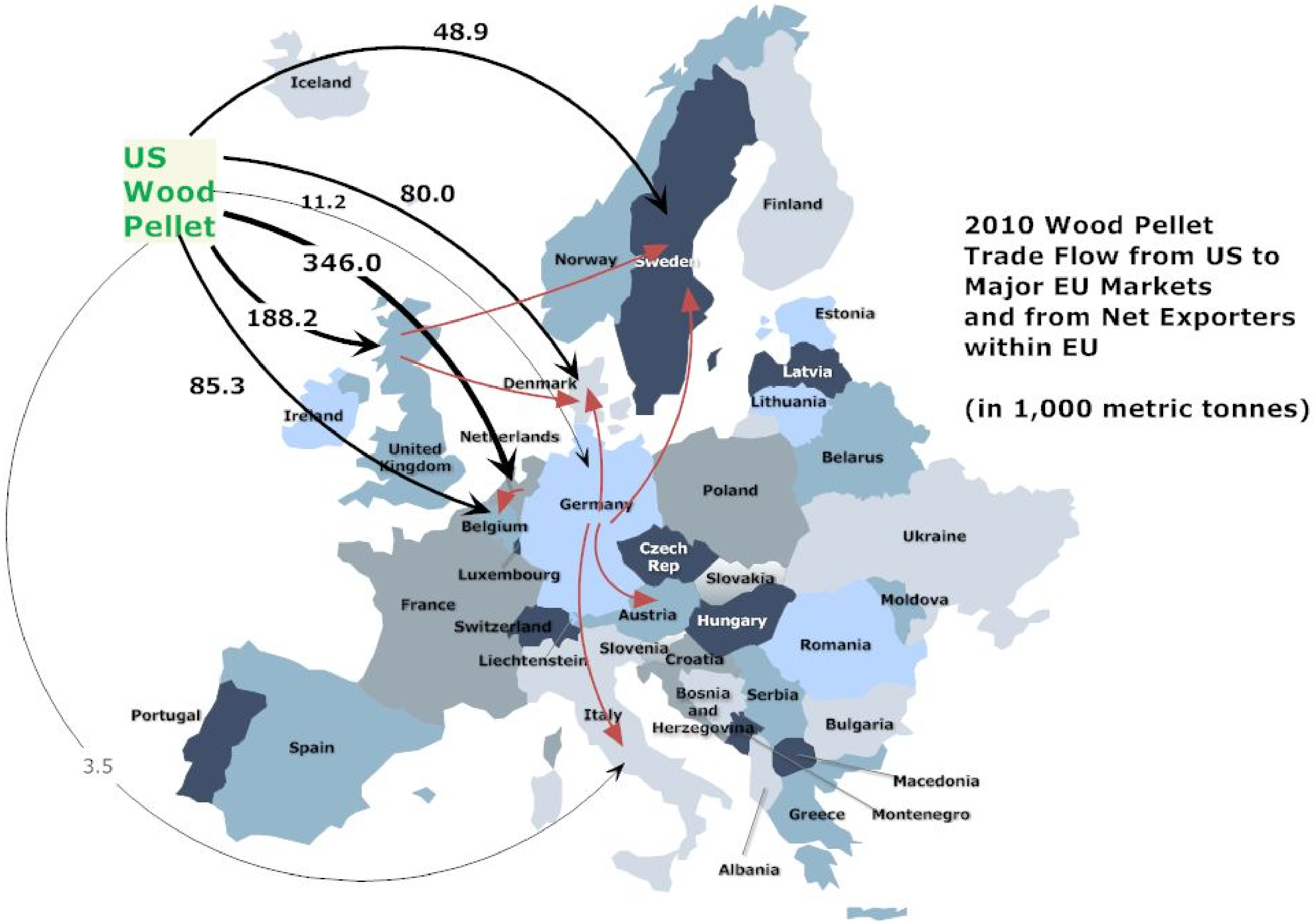
Appendix

1. Map of existing large pellet facilities (capacity>100,000 tonnes) and major wood pellet export ports



Adapted from data source: Export data of each port, (USITC, 2012); Pellet plant data, (Wood Bioenergy US Database, Forisk Consulting LLC, (June 25, 2012)

2. Map of wood pellet trade flow between the US and the EU



Adapted from data source: (Eurostat, 2012)

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