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European Market Study for BioOil (Pyrolysis Oil)

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Scope:

The EU has set energy targets at 10% of energy production and 22% of electricity generation from renewable sources by 2010. To achieve these objectives the EU projects a need for 162 TWh from biomass in 2010 compared with 42 TWh in 2002, requiring a major contribution from biomass imports. A biomass product that has long-distance transportation advantages over raw biomass and wood pellets is BioOil from fast pyrolysis, or Pyrolysis Oil. It was proposed to examine potential markets for Pyrolysis Oil and char in Europe, particularly in 2007-2012.

The approach is first to estimate Pyrolysis Oil/char potential production from regions identified as having meaningful export potential, including Canada, Brazil, South Africa, the Baltic and Ukraine. (Although large biomass resources exist in South East Asia, much of it will be used locally. Supply from this region is considered outside the scope of this paper.) The study then examines export potential and estimates production costs in these regions in order to compare delivered costs of Pyrolysis Oil at Rotterdam with the prices of competitive fossil fuels.

The study then examines potential markets in Europe, touching on environmental, logistics and policy drivers in several countries including Netherlands, Germany, Belgium, UK, Finland, Sweden and Denmark. Based on this setting, the report assesses the market segments in which Pyrolysis Oil imports can be competitive, including pulp mill limekilns, co-firing in large power plants and district heating applications, and in the long-term as a clean burning fuel to replace diesel in industrial engines and boilers, turbines for small-scale power production, blending with diesel for transportation, and development of Synfuel through gasification of Pyrolysis Oil for transportation. Analysis includes estimates market penetration and contribution to GHG reduction.

Definitions:

In North America the term “BioOil” is synonymous with oil from fast pyrolysis, while in Europe BioOil has a much wider definition, encompassing other biomass oils such as palm oil, other vegetable and fatty oils. This study deals exclusively with BioOil from fast pyrolysis, and thus the term Pyrolysis Oil is used.

All $dollar amounts are in $Canadian, unless otherwise specified. The exchange rate is $1Cdn = $0.871US = €.655 on Dec 8, 2006.

Executive Summary

Pyrolysis Oil is a dark-brown liquid made from plant material by a thermo-chemical process called fast pyrolysis, whereby biomass particles are heated in the absence of oxygen, vapourized, and condensed into liquid. The process typically yields 65-70% liquid BioOil (dry feed basis), 15-20% char (a black charcoal-like powder), and non-condensable gases. Manufacture of Pyrolysis Oil is just now at the commercial stage, following completion of a 100-tpd plant in Canada in 2005. Other commercial-sized plants are being built; one in Malaysia and two 200-tpd plants in Canada.

A number of regions are anticipated to become manufacturing centers for Pyrolysis Oil, and those with extensive reserves of low-cost biomass can be export centers, such as Canada, Brazil, South Africa, the Baltic region, and Ukraine. Canada has 28 million BDt (Bone Dry tonnes = 0% moisture) of available biomass, partly reflecting the mountain pine beetle infestation in BC. Almost 100% of Canadian sources are from certified sustainably managed forests. In Brazil and South Africa, bagasse from sugar cane is the chief low-cost source of biomass. Baltic sources are forest waste, while Ukraine sources are energy crops, such as miscanthus. As shown below, supply of Pyrolysis Oil is roughly estimated at 5 million tonnes by 2012; 4.5 million tonnes from imports, and 0.5 million tonnes produced in EU-25.

Pyrolysis Oil Supply (000 tonnes)

2007	2008	2009	2010	2011	2012
99	240	940	2,222	3,644	5,000

Pyrolysis Oil can be substituted for heavy fuel oil (HFO), light fuel oil (LFO) or natural gas in a number of applications, including pulp mill lime kilns, power plants and district heating. Char can be co-fired with coal, but so can Pyrolysis Oil. Additional applications include greenhouses, sawmill dry kilns, stationary diesel engines and industrial boilers.

In the EU, prices for heavy fuel oil and natural gas in 2005 were 5.5-11.5€/GJ, with coal at 1.5€/GJ, as shown below. Many EU countries have taxes on fossil fuels that inflate prices to the user, and many have incentives to promote the use of biofuel. The cost of Pyrolysis Oil delivered EU, if transported in small chemical tankers, ranges from 6.4€/GJ for Brazilian Pyrolysis Oil made from bagasse to 10.5€/GJ for Canadian product made chiefly from mountain pine beetle wood. It is anticipated that transportation using large 2-way tankers can lower delivery costs to 4.8-7.8€/GJ. Thus, Pyrolysis Oil can compete with oil and gas in many EU markets, while char can compete with all fossil fuels.

	€/GJ
Delivered Costs:	
Pyrolysis Oil- small tankers	6.42 - 10.46
Pyrolysis Oil- large tankers	4.82 - 7.75
Char	1.51 - 2.57
Wood pellets Canada	6.5
Prices:	
Heavy Fuel Oil	5.53 - 9.08
Natural Gas	6.01 - 11.50
Coal	1.52
Pellets	6.8-7.4

It is anticipated that supply of Pyrolysis Oil will grow slowly for 1-2 years, reaching 240,000 tonnes by 2008, as investors vie for opportunities to build, biomass supply is arranged, and markets and prices become more transparent. Then, Pyrolysis Oil supply is projected to increase rapidly, reaching 5 million tonnes by 2012. Demand will also start slowly as issues such as delivered cost, operational performance, and environmental sustainability become known. Demand will take off as target year 2010 approaches.

Supply in the first 2-3 years are expected to be chiefly to large companies which face obligations or penalties, or for which incentives are significant, and for which no special local distribution system for Pyrolysis Oil is required. These markets include pulp mill lime kilns, power plants fueled by coal, oil and natural gas, and district heating plants, and chiefly those with unloading facilities on a coast, or on an inland waterway.

Lime kiln markets, projected at 1.4 million tonnes Pyrolysis Oil, are most likely to develop first in Sweden, Finland, Portugal and Spain, with Finland and Spain facing difficulties with Kyoto targets. Initial district heating markets projected at 1 million tonnes, are likely to be Finland, Sweden and possibly Denmark, with both Denmark and Finland under pressure to meet Kyoto targets.

Initial co-firing markets are most likely to be large power plants in the UK and Netherlands, which can burn both Pyrolysis Oil and char. Though UK policies reflect a gradual phasing out of co-firing support, the 2006 Energy Review suggests a renewed emphasis on co-firing. As biomass certification work is completed in the Netherlands, incentive systems may be adjusted to support sustainable BioOils in the same way as pellets. Early markets are estimated at 2.9 million tonnes Pyrolysis Oil (or char equivalent) for coal co-firing, 3.1 million tonnes for co-firing with oil, and 4.5 million tonnes with natural gas in plants that are configured for fuel flexibility.

Other opportunities for fuel substitution are in 100% biomass fueled power plants in Belgium and UK, although these will depend on guaranteed delivery of large volumes of uniform Pyrolysis Oil. Another opportunity is for substitution for diesel fuel in small (<20MW) power plants in Germany, a growing segment.

In the next 2-3 years trials will take place for small-volume uses also, such as stationary diesel engines, greenhouses and sawmill dry kilns. Pyrolysis Oil suppliers will begin to collaborate and experiment with distribution systems in order to reduce costs of supply and maintain competitiveness.

Supply to UK, Spain, Netherlands, Sweden and possibly Finland is expected to come initially from Canada, and then Brazil. Increasingly the Baltic and Ukraine will supply Finland, Sweden and Eastern Europe. Also, the EU is expected to ramp up domestic production.

Assuming that half of the 5.0 million tonnes Pyrolysis Oil is substituted for coal and half for heavy fuel oil, GHG emissions would be reduced by 8 million tCO_2e in 2012.

1. Background (details in Technical Appendix 1)

1.1. What is Pyrolysis Oil?

Pyrolysis Oil is a dark-brown, free flowing liquid fuel that is derived from plant material. It is not an "oil", like a vegetable oil or petroleum oil, because it contains about 25% water in its composition. Fast Pyrolysis is a process by which small particles of biomass waste are rapidly heated to high temperatures in the absence of oxygen, vapourized, and then condensed into liquid fuel. Products of the process are typically 65-72% liquid Pyrolysis Oil, 15-20% solid char and 12-18% non-condensable gases (NCG), depending on the type of feedstock and other factors in manufacture. As shown in Table 1.1, wood biomass typically results in 70% Pyrolysis Oil, 14% char and 13% NCG. The process has no waste since both Pyrolysis Oil and char have significant commercial application and value, while non-condensable gases are recycled and produce approximately 75% of the energy required for the pyrolysis process.

Table 1.1

Mass/Energy Balances

	Range By Wt	Pine/spruce By Wt	Pine/spruce Energy	Gj/t
BioOil	65-72%	70.3%	70.6%	17.8
Char	15-20%	14.3%	22.6%	28
Non-condensible gases	12-18%	13.4%	6.8%	9
		98.0%	100.0%	

Common feedstock for Pyrolysis Oil is forest waste, such as sawdust and bark, and agricultural waste, such as sugar cane bagasse. Pyrolysis Oil yield depends on the feedstock, 60-75% for wood waste (white wood sawdust producing a higher yield than bark), and 60-65% for sugar cane bagasse and other agricultural waste streams.

1.2. Properties

Pyrolysis Oil can be stored, pumped and transported like petroleum products and can be combusted directly in boilers, gas turbines and slow to medium speed diesels for heat and power. It has a density of 1.2 kg/litre, and heating value 16-19 GJ/tonne, giving it approximately 55% of the heating value of diesel on a volumetric basis and 45% on a weight basis. It has an ash content averaging less than .02% by weight, compared with .01% for diesel. Pyrolysis Oil is CO_2 neutral, contains no sulfur and therefore does not produce SO_2 (sulfur dioxide) emissions during combustion, and usually produces approximately half the NO_x (nitrogen oxide) emissions in comparison with fossil fuels.

Pyrolysis Oil is not dangerous but it is acidic. pH is 2-3 compared with diesel at pH5. Pyrolysis Oil is combustible but not flammable, ignites and burns readily when properly atomized, and once ignited burns with a stable, self-sustaining flame[1]. It is flammable at extremely high temperatures. Pyrolysis Oil is not a homogeneous liquid. If left standing

[1] Overview of Applications of Biomass Fast Pyrolysis Oil- Jan 2004, S. Czernick and A.V. Bridgwater

for long periods, lignin will eventually precipitate, however it can be stirred back into the bulk with slow-speed agitation.

Char is the remains of solid biomass that has been incompletely combusted, similar to charcoal. Char is 65-76% carbon by weight, 5-12% ash, and less than 2% moisture. It has heat value of 28-30GJ/tonne. It is a charcoal powder with particle size less than 1 mm, and has bulk density of 0.25-3 tonnes/m^3.

1.3. Transportation and storage

The acidic and thus corrosive nature of Pyrolysis Oil means that enhancements are required for storage and transportation, but these are not onerous. Storage vessels and piping should be Stainless 304, PVC, Teflon or like substance. Layering of Pyrolysis Oil is not an issue for short-term transportation and storage. Neither trucks, nor rail, nor shipping are required to have mixing capability. Mixing capability in customer storage tanks is easily arranged with existing tanks. To prevent contamination, shipping vessels should have specialized compartments.

Pyrolysis Oil transportation has an advantage over fossil fuels. If a tanker ship containing fossil fuel sinks or otherwise causes a spill, petroleum will spread over water in a thin layer over a wide area with major environmental consequences. Pyrolysis Oil does not spread, but separates into a very heavy organic fraction that will sink and is largely inert[2], and an aqueous fraction that will be diluted and is very bio-degradable. Initial toxicology tests show that Pyrolysis Oil is non-toxic[3].

Since char is very fine and has low bulk density, around 250-350kg/m^3. As it can be more difficult to handle in powder form, pelletizing char is recommended if transported any great distance. Pelletized char can be added directly to the coal feed without limitation.

1.4. Plant Development

Canada is regarded as a leader in Pyrolysis Oil technology and development, with two systems at the commercialization stage and two near commercialization. Current development, as well as non-Canadian examples, includes:

- DynaMotive Energy Systems (Vancouver)- Is now operating the world's largest Pyrolysis plant (100tpd) at West Lorne Ontario. 2/3 of the liquid oil is used to fuel a 2.5 MW turbine for power, and the remainder is sold as a fossil fuel substitute. A 30% capacity increase has just been announced to maximize power production. Two 200-tpd modular plants are now being fabricated; one is destined for Guelph Ontario, now undergoing site preparation, and one is destined for British Columbia.

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[2] Dr. Tony Bridgwater, Aston University, Birmingham
[3] Blin J, Volle G et al, Biodegradability of Fast Pyrolysis Oil", CIRAD Forestry Dept, International Research Center for Agricultural Development, France

- Ensyn Corp (Ottawa)- Uses its core technology (Rapid Thermal Processing or RTP™) to transform carbon-based feedstocks, either woody biomass or petroleum hydrocarbons, to more valuable chemical and fuel products. The current focus is not energy, but flavouring for food products.

- Advanced Biorefinery Inc (Ottawa)- Has built and is testing a mobile fast pyrolysis unit to convert forest slash to Pyrolysis Oil using a process with a low parasitic load, and is now building a 50-tpd modular plant to convert harvest waste and hog fuel from existing bark piles to liquid Pyrolysis Oil.

- Agri-Therm (Dorchester)- Is in the final stages of testing its 10-tpd mobile pilot plant, which uses primarily agricultural residues in farm applications

- BTG Biomass Technology Group- Is in the final stages of commissioning a pyrolysis plant in Malaysia which produces 1.2 tonnes per hour of Pyrolysis Oil from palm oil residues.

1.5. Research and Technical Feasibility

Research and testing continue with all technologies. As an example, DynaMotive has completed several tests to confirm applications of its Pyrolysis Oil including:

- Tests in 2006 were successful in replacing Heating Oil #2 in a furnace at one of Alcoa's largest aluminum plants in Baie Comeau, Quebec.
- A 4-hour combustion test in 2006 was successful in replacing fuel oil #6 (Bunker C) with 2 tonnes of Pyrolysis Oil in a greenhouse application at Great Lakes Greenhouses Inc. in Leamington, Ontario.
- A 2005 conversion test was successful in converting Pyrolysis Oil to Syngas via gasification at the research institute Forschungszentrum Karlsruhe (FZK) in Germany.

As a future application, DynaMotive is researching the emulsification of Pyrolysis Oil and hydrocarbon diesel. The goal is to allow for co-burning of Pyrolysis Oil/diesel mix in stationary engines without significant modification to them. As energy prices reach record levels and environmental concerns take a centre stage, Pyrolysis Oil presents a strong potential as a partial fuel alternative.

2. Pyrolysis Oil-Char Supply and Export Potential

2.1. Canada

2.1.1. Biomass Supply

Canada has vast forest resources and also has a large agriculture sector. Excess woody biomass from forestry operations has been estimated and is considered an immediate feedstock for Pyrolysis Oil production from large plants. Estimates have been made for theoretical volumes of agricultural waste, but testing has been limited to small scale farming applications involving 1-tpd plants using chicken litter.

2.1.1.1. Mill Residues

Canada is one of the world's largest pulp, paper and lumber producers. Total paper-grade wood pulp production exceeds 27 million tonnes annually. In 2004 lumber production was 35,510 million board feet (MFBM). The forest products industry produces woody biomass as a by-product, including bark, sawdust and shavings. To reduce the cost of using fossil fuels, pulp mills and sawmills have increasingly used this biomass to produce heat for dry kilns and mill processes, and power for internal usage and to feed into the grid. Also, independent power companies have been buying excess residues to produce heat for steam hosts and power for the grid. As a result, surpluses of mill residue have been declining. In June 2005 a survey was completed to determine the surplus annual amounts of mill residue and hog fuel (bark and sawdust), and the results were combined into a single study released by Natural Resources Canada and the Forest Products Association of Canada[4]. Table 2.1- 1 and Fig 2.1-1 show the results of the inventory.

Table 2.1-1 2005 Mill Residue Inventory

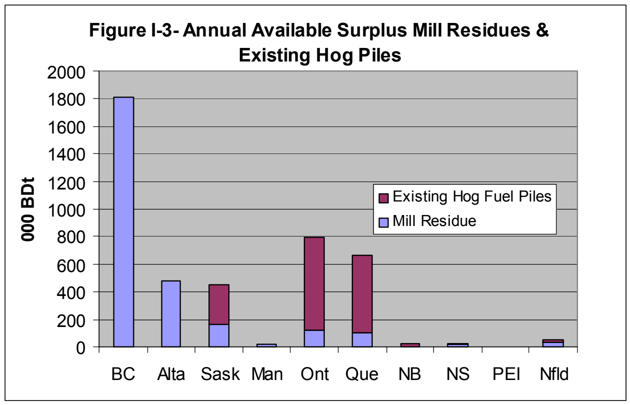
	Residue Production 000 BDt pa	Residue Surplus 000 BDt pa	Bark Piles 000 BDt
Province			
BC	6,554	1,815	
Alberta	2,406	481	
Saskatchewan	580	164	2,900
Manitoba	225	13	
Ontario	2,602	121	6,712
Quebec	6,669	100	5,652
New Brunswick	1,373	0	257
Nova Scotia	601	13	148
PEI	24	1	0
Nfld & Labrador	195	30	19
Total	21,229	2,738	15,688

As shown, Canadian pulp mills and sawmills produced over 21 million bone-dry tonnes (BDt, equivalent to oven dry tonnes) of bark, sawdust and shavings. Major producers

[4] "Estimated Production, Consumption and Surplus Mill Residues in Canada- 2004" Natural Resources Canada and Forest Products Association of Canada- Authors Doug Bradley (Climate Change Solutions) and Brian McCloy (BW McCloy and Associates Inc).

were BC, Quebec, Ontario and Alberta. The table shows that at the end of 2004 there was considerable annual surplus residue in Western Canada (BC to Saskatchewan), while in Eastern Canada surpluses have mostly disappeared. Overall Canada had an annual surplus of 2.7 million BDt in 2004, of which 1.8 million BDt were in BC alone. As of May 2006, some of the BC surplus has been committed, with startup of a 200,000 BDt cogeneration facility in Prince George and the approval of a large pellet plant. The BC surplus is estimated to have fallen from 1.8 to 1.3 million BDt. The national surplus has declined from 2.7 to 2.2 million BDt. Much of this surplus is widely dispersed, and thus some Pyrolysis Oil plants would have to supplement feedstock from other sources.

Fig 2.1-1 Annual Surplus of Mill Residues and Hog Fuel- 2005



2.1.1.2. Existing Hog Fuel Piles:

In BC, Alberta and Manitoba the approved method of residue disposal is incineration. In the East, excess hog not used by sawmills or pulp mills is simply piled up on the mill site. Until recently, bark/hog piles were considered an environmental problem, not a fuel source. Many piles were considered too contaminated, or moisture contents were considered too high for energy use. With annual residue production almost completely committed, companies are looking at hog piles with renewed interest. Some companies assessed that 90-100% of their hog piles were usable for energy, others at only 50%, either due to the level of deterioration, or simply to be conservative. As shown in Table 2.1-1, hog fuel piles identified, usable and available for energy in Canada are estimated at 15.7 million BDt, or 1.57 million BDt annually if mined over 10 years. It is quite possible that much more can be recovered.

2.1.1.3. Mountain Pine Beetle- Pulp Chips and Timber:

BC is currently incurring a massive infestation of Mountain Pine Beetle (MPB), a pest that attacks mature pine trees that have thick bark. The MPB population has undergone an unprecedented explosion in BC, spreading to over 7 million ha in 2004[5], with 26% of stands suffering moderate mortality and 11% severe mortality[6]. The estimated dead

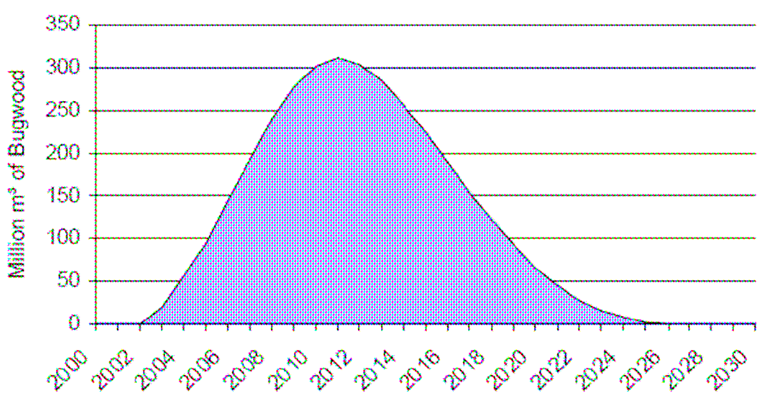
[5] COFI Mountain Pine Beetle Task Force
[6] Beetle Information Bulletin- Government of BC website

timber in 2004 as a result of the outbreak[7] is 170 million m^3. The annual kill is projected to peak in 2008 at which time over 450 million m^3 is projected to be killed[8]. The outbreak may last for 10 years and kill 80% of merchantable pine

In response, the BC government has increased the annual allowable cut (AAC) to allow the capture of economic value from dead trees in a way that maintains the highest possible environmental standards, speeds up regeneration, and restores the productivity of impacted forests. Unless MPB stands are harvested, vast amounts of forest will be lost, either to fire or decay. The BC harvest is estimated to increase from 38 million m^3 in 2000 to 50 million m^3 in 2006 and will remain at that level for 10 years. The result has been a 25% increase in lumber production and a glut of pulp chips. The annual surplus of pulp chips is estimated at 500,000 m^3 (200,000 BDt) and is expected to hit 1 million m^3, since pulp mills are not able to absorb these volumes. Surplus chips are being shipped to pulp manufacturers offshore, primarily to Asia, some of it at a heavily discounted $20Cdn/BDt. This biomass is available for energy domestically, creating an opportunity to manufacture Pyrolysis Oil.

In addition to using pulp chips or residues from MPB timber that has been cut for lumber, MPB timber can be cut strictly for energy. A 2005 study[9] by BIOCAP estimated 68 million m^3 of MPB fibre was recoverable for power, or 27 million BDt. Another study estimated that 400-500 million m^3 MPB fibre will remain unharvested by 2024[10]. Fig 2.1-2 illustrates the fibre that is not expected to be harvested.

Fig 2.1-2[7]



Cumulative Availability of Still Harvestable Bugwood Not Expected to Be Harvested at Current and Future Harvest Levels (assuming trees can no longer be harvested 15 years after they die)

The curve assumes that MPB fibre can no longer be harvested 15 years after a tree dies, and the resource is reduced by 1/11 each year through decay, beginning the fourth year

[7] BC Ministry of Forests- Brad Stennes, Natural Resources Canada
[8] Mountain Pine Beetle Project Team, Summary of year 1 report
[9] "British Columbia's Beetle Infested Pine: Biomass Feedstocks for Producing Power-April 2005- BIOCAP Canada and the Province of British Columbia
[10] Identifying Environmentally Preferable Uses for Biomass Resources- BC Bugwood, Final Report Feb 2006, Envirochem Services Inc http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/Envirochem_Bugwood.pdf

after a tree dies. The theoretical limit is perhaps 200 million m^3 harvested over a 10-year period, or 20 million m^3 annually (8 million BDt p.a.) The limit of supply is not the volume of fibre, but the capability to harvest it.

The cost to harvest and process virgin wood has been estimated at $80/BDt[11]. While efficiencies and incentives may bring the cost down marginally, it is still too high unless for the most lucrative of energy options. However, in May 2006 Tall oil Canada Inc announced the plan to begin the first of four 4-500,000 tonne, $97 million mills in North Central BC to produce wood pellets for electricity generating plants in Europe. The first will be in Vanderhoof, the second near Fraser Lake, and two near Quesnel. All plants would convert directly from logs to pellets. Clearly Tall oil considers harvesting MPB timber to be economic for some bioenergy markets.

2.1.1.4. Forest Harvest Residue:

Canada also has considerable potential in harvest residues. The forestry industry harvests 193 million m^3 of wood annually. In Ontario, 95% of harvesting is full tree harvesting, which involves delimbing and deposit of slash at roadside. 90% of this residue is burned, both to prevent uncontrolled forest fire and to free up more land for forest renewal. While in the past Quebec employed primarily full-tree harvesting, now 40% of harvesting is cut-to-length, whereby delimbing occurs at the stump. Since there is very little surplus of mill residues, and surpluses are projected to fall with the pending reductions the annual allowable cut (AAC) in Quebec, a new viable source of residue becomes the forest floor.

Trials in gathering forest floor biomass have shown costs to be relatively high, however this is not surprising as gathering of harvest slash in Canada has not been integrated into the harvest process as it has in Scandinavia. Gathering of residues should be integrated with harvest operations to minimize costs. A 2003 study[12] by BIOCAP estimated forest floor residue potential at 20 million BDt. A conservative estimate is 17.3 million BDt. Table 2.1-2 summarizes woody biomass availability in Canada, 28 million BDt annually.

Table 2.1-2- Woody Biomass Availability in 2006

	000 BDt pa
Annual Residues	1,300
Hog	1,570
Pulp Chips	200
Harvest Waste	17,347
Mountain Pine Beetle	8,000
	28,417

[11] Brad Stennes, BC Ministry of Forests

[12] "A Canadian Biomass Inventory: Feedstocks for a Bio-based Economy"- 2003, Susan M. Wood and David B. Layzell, BIOCAP Canada Foundation

2.1.1.5. Agricultural Residues

Farmland occupies 67.5 M ha (million hectares) in Canada, or 6.7% of the total land base. Crops are grown on 36.4 M ha, or 54% of farmland. Agricultural activity produces millions of tonnes of biomass annually, which can be classified as: virgin biomass (grown for energy), and waste biomass (residual fraction of primary harvest). In the 2003 study[13], the BIOCAP Canada Foundation estimated agricultural crop residues in 2001. Total crop production was estimated at 78.3 M Odt (million oven-dry tonnes), of which 70% was wheat, barley or tame hay. 56.1 M Odt of production was straw or stover, some of which must be returned to the soil to maintain soil fertility and carbon content. Residues recoverable and sustainably removable were estimated at 29.3 Odt annually, however some of this goes to traditional uses such as animal bedding and mulching. Agricultural biomass available for energy may be 17.3 M Odt annually, or 309 TJ.

Saskatchewan in the prairies likely will be the first region to supply agricultural residues for Pyrolysis Oil, since this region depends most heavily on farm incomes and commodity pricing for primary crops has been low. But how fast can this be developed? DynaMotive Energy Systems, in the forefront in Pyrolysis Oil manufacture, plans production first from forest residues since this biomass is already in place. It is likely that any Pyrolysis Oil production from the prairie region to 2012 will be for domestic use.

2.1.2. Pyrolysis Oil Production

Table 2.1-3 translates available woody biomass into realistic utilization for Pyrolysis Oil. Mill residue and annual hog availability are 1.3 and 1.6 million BDt respectively. However, some of these sources are small or widely separated geographically from other sources. When considering residue and hog availability within a reasonable radius of perhaps 100 km from prospective plant locations, a more realistic inventory is 1,085 million BDT of residues and 729,000 annual BDt of hog fuel. As shown in Table 2.1-3, this is sufficient for 20 200-tpd Pyrolysis Oil plants that use both mill residue and hog as feedstock. All are achievable by 2012, with Pyrolysis Oil production of 924,000 tonnes.

Table 2.1-3- Pyrolysis Oil Production from Woody Biomass

	Woody Biomass- 000 BDt		200 TPD Plants		BioOil Production
	Available	Realistic	Max	2012	000 BDt
Annual Residues	1,300	1085	12	20	924
Hog	1,570	729	8		0
Harvest Waste	17,347	4,042	43	26	1,201
Pulp Chips	200	200	3	2	92
Mountain Pine Beetle	8,000	5,000	53	5	231
	28,417	11,056	118	53	2,449

Forest harvest waste is estimated at 17.3 million BDt annually (8.1 million in BC, 2.9 million in Ontario, 4.4 million in Quebec, and 2.0 million in New Brunswick, Nova

[13] BIOCAP study as in Footnote #2.

Scotia, and Newfoundland). Some is at roadside from full tree harvesting, and some remains in the bush from cut-to-length harvesting. Roadside biomass, estimated at 7.8 million BDt, will be the lowest-cost source since it is already gathered at central points and thus is the first choice as a feedstock. Harvest waste at the stump, while a viable source, would be more costly to acquire. Perhaps half of the roadside biomass, or 4 million tonnes, might be economically accessible, as shown in Table 2.1-3.

Roadside forest waste in BC is estimated at 2 million BDt annually[14]. Assuming half of that is within economic distance of a Pyrolysis Oil plant, there is sufficient biomass for 15 plants from this source. However, owing to surplus mill residues and the priority to Mountain Pine Beetle fibre, it is unlikely that more than 5 200-tpd plants using harvest waste could be built by 2012. Contrastingly, Ontario is concerned about the loss of energy from roadside biomass, most of which is simply burned, and is contemplating strategies for its use. Roadside biomass is approximately 2.6 million BDt, sufficient for 39 200-tpd plants. Conservatively, 10 plants are achievable by 2012, though an aggressive strategy could double that. In Quebec, more biomass is at the stump and less at roadside. Potentially 6 plants could be in place by 2012. New Brunswick is open to using roadside biomass and with 389,000 BDt, perhaps half economically accessible, there is the potential for 8 plants. 2 might be in place by 2012. In Nova Scotia all harvest residues are at the stump, and the province is not readily in favour of harvesting it. However, shutdown mills have freed up fibre, and there is the potential for Pyrolysis Oil plants using this fibre. DynaMotive has a Memo of Understanding with E&R Langille for 500-tpd of biomass for Pyrolysis Oil production. Shown in Table 2.1-3, Canada-wide 26 plants using harvest waste are projected for 2012, with Pyrolysis Oil production of 1.2 million tonnes.

The surplus of pulp chips is estimated to be 500,000 m^3 (200,000 BDt annually), though it may reach 1 million m^3. The current surplus is sufficient for 3 200-tpd plants, of which perhaps two can be built, owing to the competition for this fibre.

Mountain Pine Beetle supply is essentially unlimited for the next 10-15 years. However it is impossible to develop plants to utilize all of it. A realistic estimate is 20 plants, of which 5 might be built by 2012, as shown in Table 2.1-3.

Table 2.1-4 gives a province-by-province potential roll out for construction of Pyrolysis Oil plants, totaling 53 by 2012[15]. With a maximum investment effort, there is biomass supply for over 200, but 53 plants are achievable. Projected plants for 2006-07 are already built, under construction, or in the final stages of planning. Since the cost of a 200-tpd Pyrolysis Oil plant from DynaMotive is $17 million, the estimated investment is $900 million for 53 plants. Annual production by 2012 would be 2.3 million tonnes Pyrolysis Oil, assuming half-year production from those plants built in 2012.

[14] Brian McCloy, BW McCloy and Associates, Vancouver

[15] This is a forecast by Climate Change Solutions. DynaMotive forecasts are confidential.

Table 2.1-4

Projected BioOil Plants Installed	2006	2007	2008	2009	2010	2011	2012
BC		2	5	10	13	16	18
Sask			1	2	3	3	3
Alta			1	2	3	3	3
Ont	1	3	6	8	10	12	15
Que			1	2	3	6	9
NB			1	1	2	2	2
NS		1	2	3	3	3	3
Plants	1	6	17	28	37	45	53
Max Plants	1	6	20	50	100	150	224
BioOil Production (000BDt)	23	139	531	1,040	1,502	1,894	2,264

2.1.3. Export Potential

It is likely that all Pyrolysis Oil production in Canada in 2006-07 will be used domestically. To maximize profitability Pyrolysis Oil plants will try to transport the oil over the shortest possible distance, choosing domestic customers over export markets. However, use of Pyrolysis Oil domestically depends on the cost for alternative fuels, and also depends on the climate change polices implemented by the Canadian government. Until 2006, the federal government was committed to Kyoto targets and intended to implement a Large Final Emitter system that would require large emitters to achieve GHG reduction targets, possibly at high cost to manufacturers. This system would promote switching from fossil fuels to renewable fuels. It is possible that the new Conservative government will design a made-in-Canada approach to climate change, with voluntary targets, in which case choosing renewable fuels would depend more on the alternative fuel costs.

One of the key markets for Pyrolysis Oil in Canada is lime kilns at chemical pulp mills. Chemical pulp production in Canada in 2002 was approximately 12.1 million tonnes. A typical 900-tpd pulp mill uses 60 MCF[16] (28.3 m^3) of natural gas per hour (or oil equivalent) in its lime kiln, or 1.6 GJ/t pulp. Thus chemical pulp mills require 19.2 million GJ to fuel lime kilns. Since Pyrolysis Oil is 17.8 GJ/t, Canadian pulp mills would require 1.1 million tonnes Pyrolysis Oil, the equivalent of 24 200-tpd plants. It is likely that early Pyrolysis Oil plants would be located near pulp mills, which are also near biomass sources, thus the potential is quite high for considerable Pyrolysis Oil usage at such mills if the delivered cost of Pyrolysis Oil were competitive with fossil fuels.

Although domestic lime kilns will be a key market for Pyrolysis Oil, alternative gasification technology is being assessed in BC which may reduce the domestic demand for Pyrolysis Oil and increase the potential for export. In May 2006 Nexterra Corp signed an agreement with a BC cellulose fibre mill and Paprican (Pulp and Paper Research Institute of Canada) to verify the application of Nexterra's innovative gasification

[16] Million cubic feet

technology for pulp mill lime kilns. The technology would enable conversion of boilers, kilns and dryers from fossil fuels to syngas, a biofuel produced by gasifying wood residue. This process may be economic since BC has one of the highest natural gas prices in the world, and pulp mills have access to “free” onsite residues. The disadvantage of gasification is that the synfuel has to be used on-site, while with Pyrolysis Oil, any production in excess of onsite needs can be shipped elsewhere and sold.

Although Ontario is developing strategies for utilization of harvest waste, it is also implementing strategies for developing renewable power. In March 2006, the government announced that the Ontario Power Authority will purchase electricity produced by biomass, wind and small hydro for 11¢/KWh. DynaMotive Pyrolysis Oil technology is already operating successfully with a 2.5MW turbine manufactured by Orenda, so Ontario plants could direct Pyrolysis Oil to electricity production. Based on the DynaMotive model, the purchase price amounts to $7.74/GJ. There likely will be Pyrolysis Oil plants in remote northern communities that are not connected to the grid.

Whatever the outcome of the gasification trial in BC, pulp mills will still be a major market for Pyrolysis Oil. Although they burn much biomass for energy, they still use a considerable amount of fossil fuel for which Pyrolysis Oil can be substituted. It is estimated that consumption of heavy fuel oil (#4, #5, #6) is over 60,000 TJ annually. At 17.8 GJ/t Pyrolysis Oil, if all Canadian pulp mills converted all heavy fuel oil needs to Pyrolysis Oil, that would be 3.5 million tonnes Pyrolysis Oil, the equivalent of 75 plants. However, the number of conversions depends on fuel costs. In Canada in 2004, the average cost of natural gas was $9.25/GJ[17], Fuel Oil #6 $9.68/GJ, and Fuel Oil #4 $13.73/GJ, shown in Table 2.1-5.

Table 2.1-5

Fuel Prices $/Gj

Natural Gas	9.25
Heavy Fuel Oil #6	9.68
Heavy Fuel Oil #4	13.73

Although Canada has considerable potential in the production of Pyrolysis Oil, the delivered cost of Pyrolysis Oil depends on many factors including proximity of biomass, distance to customer, but mostly the price of biomass. Fig 2.1-3 below illustrates the delivered price of Pyrolysis Oil compared with the cost of fossil fuels[18]. 100-tpd plants are the least competitive, and likely will not be built in Canada. A 200-tpd plant is competitive against natural gas and fuel oil #6 for feedstock ranging to $25-40/BDt. A 500-tpd plant is competitive against these fuels using proportions of more expensive feedstock, such as roadside harvest waste.

[17] Reducing Impediments to Pulp & Paper Mill Cogeneration- 2006- B. McCloy and D. Bradley

[18] Fuel prices vary considerably by region due to taxes, transportation costs etc, so a national average is used.

Fig 2.1-3 – Cost of Pyrolysis Oil vs Alternative Fuels

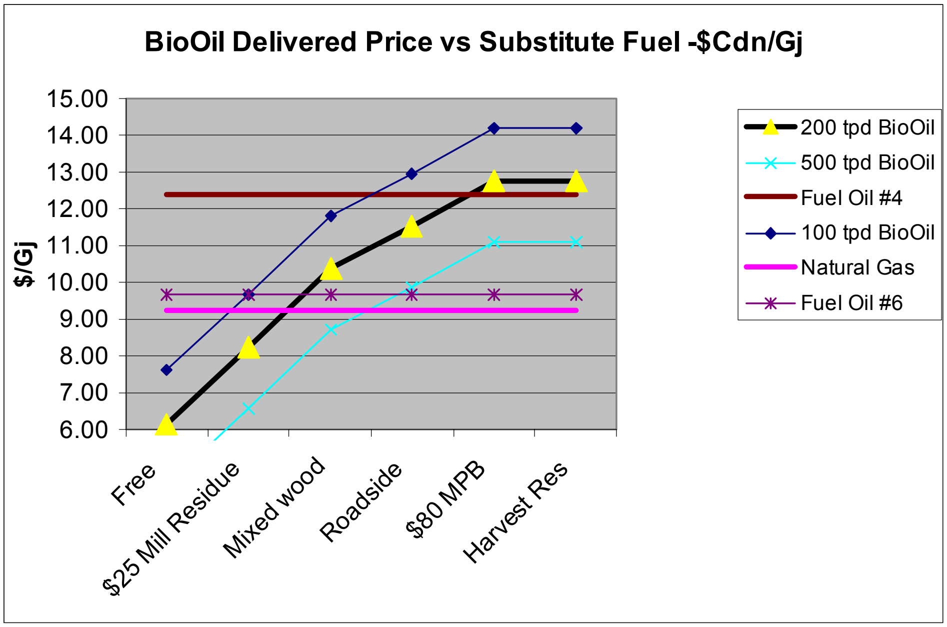
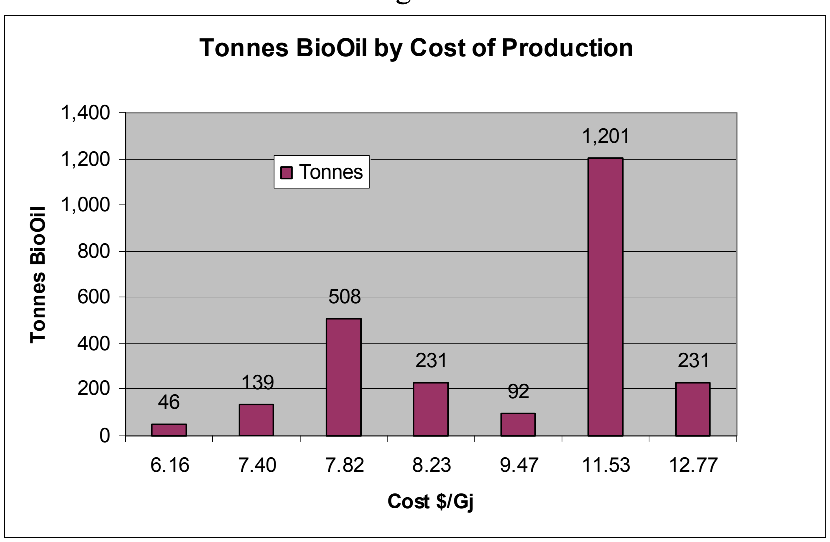


Fig 2.1-4 shows projected Pyrolysis Oil production by delivered costs, which total 2.3 million tonnes per Table 2.1-4. For example, based on biomass availability, 46,000t Pyrolysis Oil may be produced from free residues at a cost of $6.16/t (column 1), and 1.2 million tonnes can be produced from roadside waste at an average cost of $11.53/t (column 6). Of a projected 2.3 million tonnes of production in 2012, .8 million tonnes will be competitive with alternative domestic fuels and thus will be used in Canada. 1.5 million tonnes Pyrolysis Oil production in 2012 will use more expensive feedstock and may not be competitive domestically unless specific incentives are put in place. This 1.5 million tonnes by 2012 is a candidate for export.

Fig 2.1-4

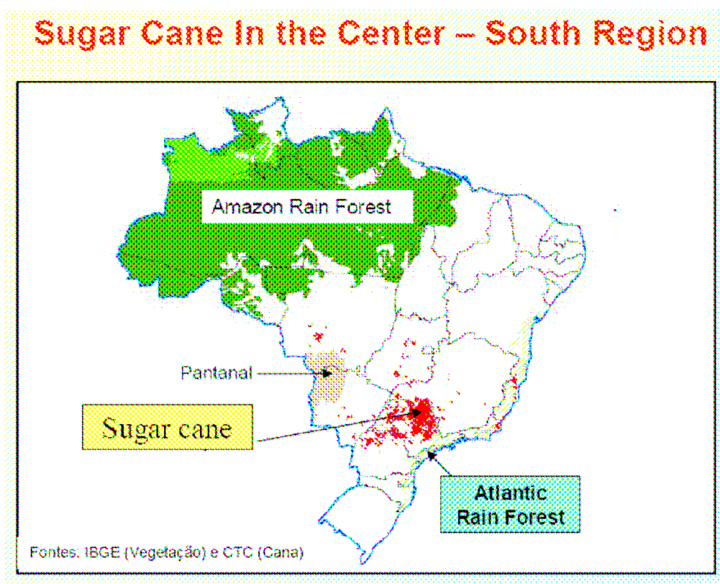


2.2. Brazil

2.2.1. Biomass Supply

To reduce its dependence on foreign oil, in 1975 the Brazilian government launched the Brazilian Ethanol Program to produce ethanol from biomass. Using sugar cane as a feedstock, Brazil built an ethanol industry and became the world's largest producer, in 2004 accounting for 37% of world ethanol production. About half of Brazil's sugar cane is used to manufacture ethanol, and half is for sugar production. Sugar cane is a more efficient source of fermentable carbohydrates than corn, is easy to grow and process, and growing requires little labour. Government tax and pricing policies have made ethanol production a very lucrative business for big farms. As a consequence, over the last 25 years sugarcane has become one of Brazil's main crops, and is now the largest sugarcane crop in the world, As shown in Fig 2.2-1 much of the sugar cane production is in the state of Sau Paulo (Centre-South region) in areas that are good for production, close to the largest consumer market and relatively close to harbours.

Fig 2.2-1-Sugar Cane Production Area[19]



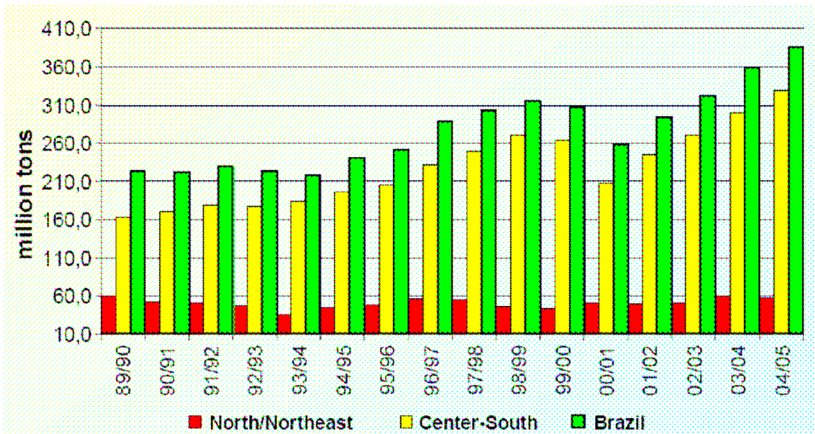
Sucrose accounts for 30% of the chemical energy stored in a sugar cane plant; 35% is in the leaves and tops (trash), which are left in the fields during harvest, and 35% is in the residue from processing cane (bagasse). Both field residue and bagasse can be used as a feedstock for heat and power production. Bagasse is preferred as it is already at the factories. Trash, in the fields, is more difficult and costly to acquire and there is no experience in utilizing it.

As shown in Fig. 2.2-2 below, sugar cane production has grown steadily since the 2000-01 growing season. Sugar cane production in 2005 was 420.1 million tonnes. Bagasse is estimated at 28%, or 117.6 million tonnes at 50% moisture (ie 58.8 million BDt[20]). Trash

[19] Eduardo Pereira de Carvalho, Unica: Presentation at Campinas, Dec 1, 2005
[20] Arnaldo Walter, IEA Task 40 Representative, Brazil- Unicamp University

is estimated at 14% of the mass content (with 35% of the energy) or 69 million tonnes at 15% moisture (58 million BDt).

Fig 2.2-2 - Brazil Sugar Cane Production (Carvalo)



Most of the bagasse is burned at sugar and ethanol plants to provide heat for the industrial processes including distillation, and electricity. This allows the plants to be energy self-sufficient and reduce the cost incurred by using fossil fuels. Bagasse is also used to generate electricity, often sufficient for mills to sell surplus electricity to the grid. Currently, 1,900 MW is produced at mills for internal use, and 600 MW is sold into the grid. This energy is especially valuable to utilities because it is produced mainly in the dry season, when hydroelectric dams are running low.

Sugar cane biomass that can be made available for Pyrolysis Oil production can come from four sources;

1. Making more efficient use of bagasse currently used internally
2. Investing in energy efficiencies to free more bagasse
3. Growing more sugar cane
4. Utilizing trash

1. More efficient use of bagasse: Steam demand in a typical sugar cane mill is relatively high, however available bagasse is sufficient to fill fuel demand for steam. If a mill has an opportunity to sell bagasse, ordinary actions on steam savings are a way to reduce internal bagasse usage and enable a surplus. It is estimated that 10% surplus bagasse can be achieved with minor changes, amounting to 12 million tonnes annually (6 million BDt)[21]. Sometimes there is a market for surplus bagasse, but it varies from year to year. In good years it will get $1US/GJ.

2. Investing in efficiencies: Electricity from bagasse is commonly produced using low-pressure boilers and turbines, with low efficiency. Mills that invest to upgrade old steam generators or to increase sugar cane production also invest to use bagasse more efficiently. With investments in energy saving it is possible to get an additional 10-20%

[21] Arnaldo Walter, IEA Task 40 Representative, Brazil, Unicamp University

surplus bagasse, or 12-24 million tonnes. Thus minor changes (1.) plus investments (2.) can yield 20-30% more bagasse, amounting to 24-36 million tonnes (12-18 million BDt).

3. Growing more cane: Brazil has 320 million hectares of arable land of which 60 million ha are cultivated. 6 million ha is in sugar cane, of which half is for ethanol[22]. 90 million ha has the potential for agricultural expansion. Table 2.2-1 projects cane production to 2012. It is estimated that sugar cane demand will be 560 MT (million tonnes) by 2010-11, so more cane now is being planted. Expansions of existing plants will raise sugar cane demand by 35-40 MT. New plants will produce 100 MT, and 90 plants already have been announced. In Sao Paulo alone 12 new mills started in 2006 and 19 more will operate in 2007. Expansions and new plants combined are projected to produce 140 MT of cane, resulting in 39 MT of bagasse, or 20 million BDt. If there is a market for the bagasse, excess will be sold. If there is no market, it will be burned in old or new boilers for power. The amount available for Pyrolysis Oil will depend on the price of Pyrolysis Oil vs the price of power.

Table 2.2-1 Sugar Cane Production (000 tonnes)

	2005	2006	2007	2008	2009	2010	2011	2012
Existing Production	420	420	420	420	420	420	420	420
Expansions		10	20	40	40	40	40	40
New Plants		4	20	63	70	80	90	100
Total Production	420	434	460	523	530	540	550	560
New Cane Production		14	40	103	110	120	130	140
New Bagasse		3.9	11.2	28.8	30.8	33.6	36.4	39.2

4. Utilizing trash: With current bagasse volumes almost entirely being burned, though inefficiently, trash is increasingly being considered for energy use. With sugar cane production at 420 MT in 2005, an estimated 14% or 69 MT (58.8 million BDt) of tops and leaves are burned after harvesting. As in the case with the forest industry, there is concern that enough nutrients from harvest waste are left in the forest to ensure sustainability. Specialists say that it is necessary to leave about 50% of sugar cane trash in the field. Thus 29 million BDt of trash is available for energy annually.

Table 2.2-2 summarizes estimated biomass availability from sugar cane 2006-12. Existing bagasse production is 117.6 million tonnes. Squeezing 10% through easy actions can yield 12 million tonnes annually. Investments in new boilers and efficiency equipment can yield 24 million tonnes, though it will take time to achieve this.

Growth in sugar cane production will yield 40 million tonnes by 2012, but it is assumed that at least half of that will be used to generate heat and power at sugar plants, so that 20 million tonnes of bagasse might be available for Pyrolysis Oil production. There are alternative uses for surplus bagasse; electricity production and additional ethanol production through hydrolysis, though the latter technology is not yet commercially available. Total bagasse available for Pyrolysis Oil at the mills is projected at 29 million tonnes in 2007, and 55 million tonnes by 2012. This will be the lowest cost source, and thus the first choice for development.

[22] Eduardo Pereira de Carvalho, UNICA, Sao Paulo Sugar Cane Agro-industry Union

Table 2.2-2 Estimated Biomass Availability (Million tonnes)

		2005	2006	2007	2008	2009	2010	2011	2012
Cane Production 2005		420	420	420	420	420	420	420	420
Bagasse Prodn 2005		117.6	117.6	117.6	117.6	117.6	117.6	117.6	117.6
Bagasse:									
Easy 10% surplus			12	12	12	12	12	12	12
Investment 20%			0	12	24	24	24	24	24
New Cane surplus 50%			2	6	14	15	17	18	20
Surplus Bagasse	MT		14	29	50	51	52	53	55
	BDt		7	15	25	25	26	27	27
Trash:									
50% existing trash			29	29	29	29	29	29	29
50% New Trash			1	3	7	8	8	9	10
Surplus Trash	MT		30	32	37	37	38	39	39
	BDt		26	27	31	32	32	33	33
Total Bagasse + trash	BDt		33	42	56	57	58	59	61

(bagasse- 50% moisture, trash 15% moisture)

Assuming that half of trash must be left in the field for nutrients, 29 million tonnes of trash biomass annually is available now for energy. While collection and drying systems aren't yet in place, strong demand for biomass ultimately will enable efficient gathering systems. It may be costly to acquire initially, but this will be a good supplemental source of biomass should plants not have 100% of required bagasse to warrant development. Anticipated new sugar cane planting will result in an additional 10 MT trash by 2012.

Total biomass availability in 2007 is 42 million BDt, of which 15 MT is bagasse and 27 MT is trash. By 2012, availability is projected at 61 million BDt, 27 MT of bagasse and 33 MT of trash.

2.2.2. Pyrolysis Oil Production Potential

In 2000 DynaMotive Energy Systems entered into a strategic alliance with Cosan Bom Jesus. Cosan is one of the world's largest producers of sugar and ethanol fuel and is also one of the largest sugar exporters in the world. Its five large sugar mills, located in the State of Sao Paulo, process over 52,000 tonnes of sugar cane per day. The alliance was made to validate production of Pyrolysis Oil from bagasse, and tests were successful. In Nov 2001, DynaMotive entered into an agreement with Intracom, a Brazil energy commodity trader. Intracom was established as the agent for development of commercial projects in Brazil. DynaMotive is poised for development in Brazil.

A 200-tpd Pyrolysis Oil plant operating 330 days per year will need 66,000 tonnes dry bagasse. The yield will be 66%, or 43,560 tonnes Pyrolysis Oil at 15.4 GJ/t. As shown in Table 2.2-3, there is the theoretical potential for 104 200-tpd plants from bagasse in 2006, with production potential of 4.5 million tonnes Pyrolysis Oil. The potential grows to 416 plants by 2012. Growers will have the option of using surplus bagasse to make power, manufacture Pyrolysis Oil, or even to hydrolyze it to ethanol, all depending on the economics. While trash is available, it is unlikely to be used as a primary fuel, but more likely as a supplement to bagasse. Hypothetically, if all surplus bagasse went to Pyrolysis Oil, at \$17Cdn million per plant, 104 plants would cost \$1.8Cdn billion, an unlikely investment in the next 5 years for Brazil. Though there is the theoretical potential feedstock for over 921 200-tpd Pyrolysis Oil plants by 2012, limitations in capital and the potential for alternative uses, such as more electricity production and ethanol production, a prudent projection for 2012 is 20 plants, producing 870,000 tonnes Pyrolysis Oil.

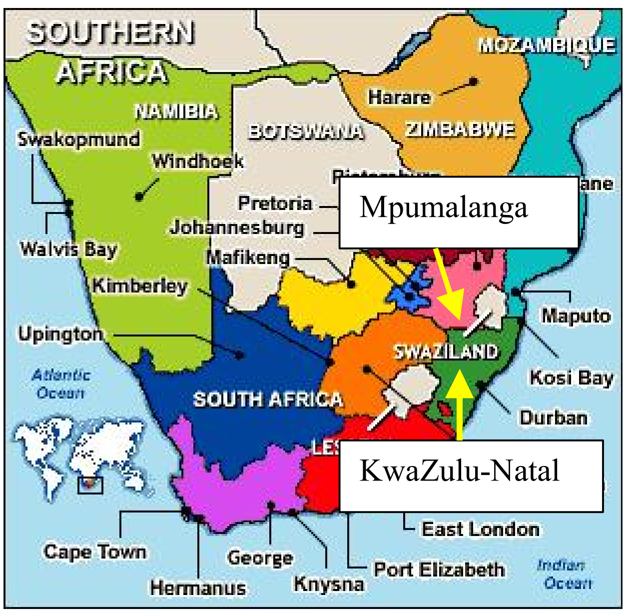
Table 2.2-3- Pyrolysis Oil plant and Production Potential.

	2006	2007	2008	2009	2010	2011	2012
Bagasse (BDt)	6.9	14.7	24.9	25.3	26.0	26.7	27.4
200-tpd BioOil plants	104	222	377	384	395	405	416
BioOil Production (000t)	4,528	9,689	16,401	16,724	17,186	17,648	18,110
Trash (Mt dry)	26	27	31	32	32	33	33
200-tpd BioOil plants	391	415	471	478	487	496	505
BioOil Production (000t)	17,043	18,064	20,538	20,813	21,206	21,599	21,991

2.3. South Africa

2.3.1. Biomass Supply

Commercial biomass in South Africa is mainly produced by the sugar industry, the forest industry, sawmills and the pulp and paper industry. The majority of this biomass is found in Mpumalanga and KwaZulu-Natal provinces.



2.3.2. Biomass Supply from Sugar Cane

The South African Sugar Association is a partnership between the SA Cane Growers Association and the SA Sugar Millers Association. The Growers Association administers 47,000 growers with a total area under cane of 430,000 hectares[23]. 2000 of the growers are large commercial farmers, and 45,000 are small-scale growers. 90% of the cane, or

[23] Assessment of Commercially Exploitable Biomass Resources: Bagasse, Wood & Sawmill Wasteand Pulp, in South Africa. Report # 2.3.4-29: Dept of Minerals and Energy, Pretoria

386,000 hectares, is grown in KwaZulu-Natal, primarily on the coast; 10%, or 47,000 hectares, is grown in Mpumalanga. Sugar cane production in 2002 was 25 million tonnes[24].

In the sugar industry, biomass sources are field residue and bagasse. During harvesting tops (14%) are removed and left in the field, trash (8%) is removed and sometimes burned, and the stalks (78%) are delivered to the factories. As in other jurisdictions, many agronomists consider that tops and trash left in the field are beneficial for nutritional value, and protection from soil erosion. However, they are also an important fuel source, and ways of recovering them are being explored. Trash and tops are typically 3% ash. Bagasse is fairly consistent at 30% on cane.

Table 2.3-1 shows the estimated residue and bagasse in 2004 if trash is not burned. Total sugarcane biomass is 11.47 MT, of which 6.1 MT is from bagasse and 5.3 MT is from trash. Energy content is 22.33 TWh. All of it is in either KwaZulu-Natal or Mpumalanga. Sugar manufacturers tend to look only at bagasse as a biomass source to generate electricity, since it is already on site.

Table 2.3-1

South Africa

Waste Biomass (000t)

	Kzn	Mpum	E Cape	Limpopo	W Cape	Gauteng	total	BioOil Potential
Sugar Cane Waste								
Residue	4,429	907	0	0	0	0	5,336	2,668
Bagasse	5,093	1,043	0	0	0	0	6,136	6,136
	9,522	1,950	0	0	0	0	11,472	
Forest	1,319	1,323	244	128	120	0	3,134	
Sawmills								
Chips	465	793	193	68	102	0	1,621	
Dust	237	404	98	34	52	0	825	825
Bark	144	245	60	21	32	0	502	502
	846	1,442	351	123	186	0	2,948	
Pulp & Paper								
Black Liquor	3,742	1,300	0	0	0	164	5,206	
Sludge	196	30	0	0	0	8	234	
Bark	225	120	0	0	0	0	345	345
	4,163	1,450	0	0	0	172	5,785	
Total	15,850	6,165	595	251	306	172	23,339	10,476

2.3.3. Biomass Supply from Forestry

In the forest industry, there were 1.37 million hectares of commercial timber plantations in 2003, 52% softwood (primarily pine), and 48% hardwood (mostly eucalypts). 57% is managed for the pulp and paper industry, 36% for sawmills, and 7% for other purposes. 78% is privately owned. Like sugar cane plantations, most of the wood plantations are in KwaZulu-Natal and Mpumalanga.

Forest biomass, wood unsuitable for commercial use, consists of: logging residues, wood from thinning young stands, waste from commercial thinning, and low quality trees. Most of the biomass is from logging residues. As shown in Table 2.3-1, KwaZulu-Natal and Mpumalanga each account for 1.3 MT, or 42% of total waste biomass in the forest

[24] Sugar Cane Bagasse for Electricity Generation on the African Continent- Dr. K. Deepchand

industry. Total biomass is 3.13 MT. At 19.35 GJ/t, the biomass has energy content of 10.89 TWh. Like sugar cane, agronomists see leaving some residue in the field as good practice. However it is not known how much should be left.

2.3.4. Supply from Sawmills

There are 109 sawmills in South Africa, mostly in KwaZulu-Natal and Mpumalanga. 50% of the sawmills are small, with annual wood intake of less than 20,000 tons, 21% are 20-50,000 tons, 19% are 50-100,000 tons, 10% are 100-200,000 tons and 3% are greater than 200,000 tons. Biomass waste after lumber yield consists of 55% pulp chips, 28% sawdust, and 17% bark. Table 2.3-1 shows sawmill biomass by province, 1.44 million tons from Mpumalanga, and .85 million tons from KwaZulu-Natal. The heat energy of the biomass waste is approximately 20.6 GJ/t, thus 2.95 million tons biomass have energy content of 8.5 TWh. It is believed that if all of the biomass could be converted to electricity, most would be used within the industry.

2.3.5. Supply from Pulp and Paper mills

Two companies, Mondi and Sappi, own all the pulp and paper mills in South Africa. Mondi owns five mills with a total capacity of 992,000 tons of pulp; Sappi owns seven mills with total capacity of 1,610,000 tons. Table 2.3-1 shows the biomass waste from these mills. 90% of the biomass waste is black liquor, residue from the pulping process that is subsequently burnt in boilers to recover process chemicals. Other biomass includes sludge and bark. The 5.78 million tons biomass has an energy content of 10.17 TWh. A Department of Minerals and Energy study suggests that most biomass from sawmills and pulp and paper mills will be needed in-house for electricity production, however to do so will take investment and government incentives. If the return on investment is higher to manufacture Pyrolysis Oil than electricity, then that is what will draw investment.

Table 2.3-2 below summarizes biomass potential for Pyrolysis Oil. The highest potential feedstock is bagasse from KwaZulu-Natal and Mpumalanga, at 5.7 and 1.8 million tons respectively. Bagasse, sawmill dust and bark and pulp mill bark yields potential biomass at 7.5 million tons. Forest waste and sugar cane residues can be considered a secondary source due to cost and environmental issues.

Table 2.3-2

Estimated Biomass Available for BioOil (000 tons)

	Kzn	Mpum	Total
Primary:			
Sugar Cane Bagasse	5,093	1,043	6,136
Sawmill Dust and Bark	381	649	1,030
Pulp Mill Bark	225	120	345
Total	5,699	1,812	7,511
Secondary:			
Forest Waste @ 25%	330	331	661
Sugar Cane Residue @ 50%	2,215	454	2,668
	2,544	784	3,329

2.3.6. Pyrolysis Oil Potential

A government study estimated that the 6.1 MT of bagasse has the potential to produce 3,031 GWh of power[25], however this estimate assumes a single efficient technology to convert bagasse energy to power, not the norm in the industry. Sugar mills use 700 GWh (23% of potential) for internal needs for heat and power. With inefficient conversion, it is perhaps safer to assume that internal needs draw 40% of onsite bagasse, or 2.5 MT leaving 3.6 MT available, or 1.8 million BDt. Table 2.3-3 shows the potential for 28 200-tpd Pyrolysis Oil plants from bagasse, which would produce 1.3 MT Pyrolysis Oil.

However there are pressures on this source also. In a bid to increase energy from green sources, a renewable-energy trading scheme was launched in South Africa in April 2005. The initial phase of the program targeted sugar mills, which burn bagasse for energy. For nine months of the year the mills produce more power than they consume, and send excess power into the grid. The trading scheme was to enable the mills to sell excess renewable power to others. The amount of biomass that will produce power instead of Pyrolysis Oil depends on the comparative prices of power and Pyrolysis Oil, and South African power prices have been traditionally low.

Table 2.3-3 Estimates of Biomass and Pyrolysis Oil Potential

	Biomass	Internal Use-est	Avail		200-tpd plants	Pyrolysis Oil production
Primary:	000 t	000 t	000 t	000 BDt		000 t
Sugar Cane Bagasse	6,136	2,500	3,636	1,818	28	1,236
Sawmill Dust and Bark	1,030	515	515	258	4	175
Pulp Mill Bark	345	173	173	86	1	59
Total	7,511	3,188	4,324	2,162	33	1,470
Secondary:						
Forest Waste @ 25%	661		661	330	5	225
Sugar Cane Residue @ 50%	2,668		2,668	1,334	20	907
					58	2,602

It is uncertain how much bagasse is still actually available. The government study suggests large amounts, but opinions are that much of it is already used. Similarly with sawmill and pulp mill dust and bark, it is uncertain how much is available, but even estimated volumes of biomass are insufficient to warrant a large number of plants. The next largest source is trash, or sugar cane residues. As with the case of Brazil, it is unknown what would be the cost to gather and transport sufficient quantities to a Pyrolysis Oil plant. There is sufficient quantity for at least 20 plants that would produce .9 MT Pyrolysis Oil, potentially .5 MT for export.

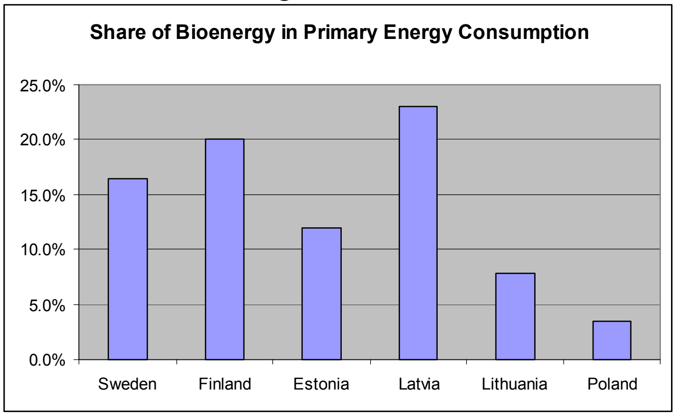
[25] IBID Dept of Mines and Minerals Report- Dec 2004

2.4. Baltic Region

2.4.1. Biomass Supply

Countries addressed in the Baltic Region include Sweden, Finland, Russia, Estonia, Latvia, Lithuania and Poland. As shown in Fig 4.2-1, these countries all have a significant share of biomass energy in their energy portfolio.

Fig 2.4-1



Finland and Sweden are already major players in biomass and bioenergy, and participate heavily in trade of biomass. Each has large diversified forest companies working in energy, wood processing and biofuels businesses[26]. These companies exploit industrial wood residues from their own mills for production of wood chips or pellets, and can integrate harvesting of logging residues. District heating is a major factor on the demand side. In Poland, big power producers that co-fire in power plants are also major players.

Generally, in the Baltic countries, bark, sawdust and dry wood by-products are already used for on-site energy, or in pellet and board production. Possibly an additional 20-30 PJ could be recovered from wood by-products in Poland. The only growth area is in forest chips. For example, 25% of Latvia, or 1.6 million hectares, is forest, most of which is privately owned. The forests contain a remarkable amount of small trees, low value wood, and wood waste. In Lithuania, in 2003 wood fuel accounted for 7.82 TWh. The additional wood fuel potential is estimated at 9.8 TWh, most of which is projected to be in production by 2010[27]. In the Russian pulp and paper industry the share of biofuels in energy is only 20-30%, compared to 52% in Europe. In Karelia, on the Finnish border of Russia biomass resources are several times greater than current use. However, the poor environment for business and subsequent lack of investment, and also Russian interest in developing its own biomass, limit biomass supply potential.

A projection for biomass supply from forest wood is shown on Table 2.4-1

[26] ET-Bioenergy WP1 Summary Report- VTT (Draft, Sept 30, 2006)
[27] Ibid. Nordcn Sept 2005

Table 2.4-1- Available Felling Residues in the Baltic Region (BDt)[28]

	Felling Residues	Balance	Stumps	Total
Finland	4.6	2.5	0.7	7.8
Sweden	6.0	2.8	0.9	9.6
Estonia	0.2	0.0	0.0	0.3
Latvia	0.7	0.6	0.1	1.4
Lithuania	0.3	0.4	0.0	0.8
Poland	1.4	1.2	0.2	2.8
	13.2	7.5	2.0	22.7

2.4.2. Pyrolysis Oil Potential

In January 2006, DynaMotive granted a master license to Rika Ltd, which has extensive operations in Latvia and Ukraine. Under terms of the license, Rika will market DynaMotive technology and will develop and operate Pyrolysis Oil facilities in the Baltic States and Ukraine. The planned feedstock in Latvia would be wood residue. The master license requires completion of two 200-tpd plants within two years, which will supply approximately 92,000 tonnes Pyrolysis Oil. One is to be built in the Baltic States. Potential for Pyrolysis Oil in Poland will depend on the demand for biomass by co-firing.

2.4.3. Export Potential

Any Pyrolysis Oil manufactured in Finland and Sweden would be used domestically and not available for export. In Estonia, Latvia and Lithuania, most if not all production could be exported to other European countries.

2.5. **Ukraine**

Rika and DynaMotive have agreed to scope the feasibility of bioenergy crops in Ukraine. Rika has leased 25,000 hectares of farm land, and the companies are considering the allocation of 10,000 ha for growth of biomass, such as miscanthus, for Pyrolysis Oil production. It is estimated that each hectare will yield up to 30 dry tonnes of biomass annually, thus providing for a total production capacity of 300,000 tonnes biomass, sufficient for 800-tpd of production. The master license requires completion of one 200-tpd plants by the end of 2007. While this license envisions Pyrolysis Oil production of 264,000 tonnes Pyrolysis Oil, 500,000 tonnes is likely, all for export.

Ukraine is regarded by DynaMotive to be a major potential source of Pyrolysis Oil exports to Europe. There are hundred of thousands of hectares of land that can economically produce energy crops, such as miscanthus, and which can be used as a feedstock for Pyrolysis Oil plants.

[28] Estimation of Energy Wood Potential 2004, Metla Working Papers

2.6. Export Summary

Table 2.6-1 projects potential exports of Pyrolysis Oil to Europe in 2012[29]. These projections are generally not limited by biomass availability but the speed of development. By 2012, it is estimated that 4.5 million BDt of Pyrolysis Oil could reach Europe from the above sources, and 0.5 million BDT would be produced in other EU countries from approximately 8 200-tpd plants.

Table 2.6-1 Pyrolysis Export Potential 000 BDt

	2007	2008	2009	2010	2011	2012
Production						
Canada	139	531	1,040	1,502	1,894	2,500
Brazil	0	33	100	300	600	870
South Africa	0	33	100	300	600	900
Baltic	66	100	400	800	1200	1,500
Ukraine	33	66	100	200	400	500
Domestic						
Canada	139	508	850	900	950	1,000
Brazil	0	15	30	100	200	300
South Africa	0	0	20	80	200	400
Baltic	0	0	0	0	0	0
Ukraine	0	0	0	0	0	0
Delivered Europe						
Canada	0	23	190	602	944	1,500
Brazil	0	18	70	200	400	570
South Africa	0	33	80	220	400	500
Baltic	66	100	400	800	1,200	1,500
Ukraine	33	66	100	200	400	500
EU Production	0	0	100	200	300	430
Supply	99	240	940	2,222	3,644	5,000

[29] This projection is made by Climate Change Solutions. The projected development plan of DynaMotive is confidential.

3. Price Competitiveness

3.1. Substitute Fuels

Pyrolysis Oil can substitute for fossil fuels in many applications (detailed in Section 6). When co-fired in power plants Pyrolysis Oil can replace natural gas, heavy fuel oil (#6), and coal, while char can replace coal. When used in pulp mill limekilns Pyrolysis Oil generally replaces natural gas, but often fuel oil #4. When used in stationary engines or turbines, Pyrolysis Oil usually replaces industrial diesel (fuel oil #2).

3.2. Price of Fossil Fuels

3.2.1. Fuel Oil

Table 3.2-1 shows prices of low-sulfur heavy fuel oil (#4, #5, #6) for industrial users in EU-15 countries (less Sweden) for the first quarter of 2006. The price ranges from €173/tonne in Luxemburg to €430/tonne in Portugal. The average price in the EU was €337/tonne, or €8.4/GJ, ranging from €4.32/GJ to €10.76/GJ.

Table 3.2-2 shows prices for light fuel oil (#1, #2, #3) in EU 15, ranging from €493/tonne in the UK to €1,109/tonne in Italy. The EU 15 average was €18.2/GJ, ranging from €12.3/GJ to €27.7/GJ.

Table 3.2-1 HFO

Heavy Fuel Oil 1Q-2006- for Industry

	Euro/tonne*	Euro/GJ
Portugal	430.3	10.76
Ireland	414.1	10.35
Italy	372.1	9.30
Finland	370.6	9.26
Spain	365.0	9.12
Denmark	362.8	9.07
Netherlands	351.5	8.79
Austria	350.2	8.75
UK	325.3	8.13
France	317.1	7.93
Germany	305.4	7.63
Belgium	296.2	7.41
Greece	282.4	7.06
Luxemburg	172.9	4.32
EU 15	336.9	8.4

Key World Energy Statistics'- IEA

Table 3.2-2 LFO

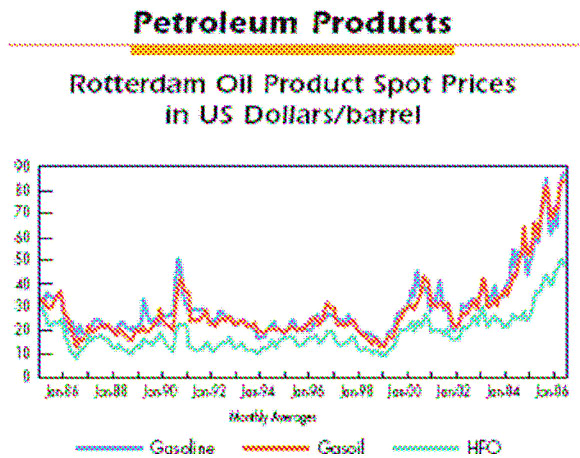
Light Fuel Oil 1Q-2006- for Consumers

	Euro/tonne*	Euro/GJ
Italy	1,108.6	27.7
Sweden	1,045.4	26.1
Denmark	1,012.7	25.3
Greece	868.2	21.7
Netherlands	865.8	21.6
Ireland	696.6	17.4
Austria	660.7	16.5
Portugal	657.2	16.4
France	643.5	16.1
Finland	627.9	15.7
Spain	598.5	15.0
Germany	567.2	14.2
Belgium	561.6	14.0
Luxemburg	523.7	13.1
UK	493.0	12.3
EU 15	728.7	18.2

Key World Energy Statistics'- IEA

Figure 3.2-3 illustrates the long-term price movements of light fuel oil (gasoil) and heavy fuel oil (HFO) in $US/Bbl. The oil price has skyrocketed since January 2002.

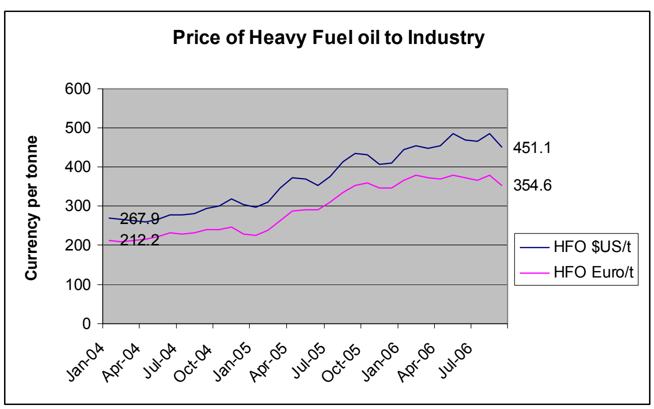
Fig 3.2-1- Prices- Light Fuel Oil (Gasoil) and Heavy Fuel Oil



IEA Bioenergy-Key World Energy Statistics 2006

Fig 3.2-1 shows the development of heavy fuel oil prices in both Euros and $US. While the exchange rate varied in the 1.18-1.34 $US/€ range in the 2004-06 period, the exchange rate at the beginning and end points (Jan 2004 and Sept 2006) were almost exactly the same at 1.26 $/€ and 1.27 $/€ respectively.

Fig 3.2-2



3.2.2. Natural Gas

Table 3.2-4 shows natural gas prices for large industrial consumers in the first quarter 2006[30]. Prices after taxes ranged from €6.01/GJ in Portugal to €11.5/Gj in Austria, with average of €9/GJ across the EU-15.

[30] epp.eurostat.cec.eu.int-Data collected according to Directive90/377/EEC. Large industrial consumers with annual consumption greater than 418,600 GJ.

Table 3.2-3

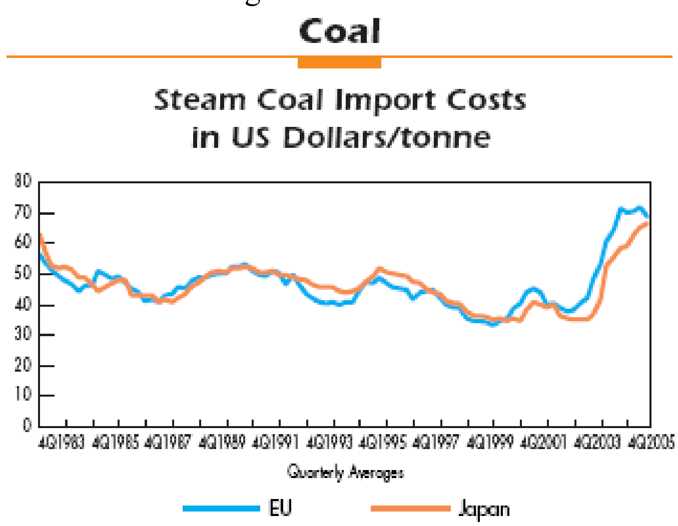
Natural Gas Prices 2006- Large Industry (Euro/GJ)

	w/o tax	w tax	% tax
Austria	7.40	11.50	55.4%
Germany	8.64	11.31	30.9%
UK	7.71	9.16	18.8%
Belgium	6.39	7.83	22.5%
Finland	5.75	7.59	32.0%
Denmark	5.23	7.37	40.9%
Portugal	5.72	6.01	5.1%
EU 15	**7.25**	**8.97**	**23.7%**

3.2.3. Coal

Fig 3.2-3 illustrates coal import costs to the EU. In the 4Q 2005 the price was approximately \$70US/tonne, or €55/tonne. At 30 GJ/tonne, the price was €1.84/GJ.

Fig 3.2-3 Coal Prices



3.3. Delivered Costs of Pyrolysis Oil/Char

To assess market viability of Pyrolysis Oil and char, it is useful to compare delivered costs with the prices of competitive fossil fuels. Estimated delivered costs from a 200-tpd plant to the port of Rotterdam are shown in Table 3.3-1 below. Actual manufacturing costs of DynaMotive plants are confidential, so all costs are lumped together including labour, utilities, maintenance, royalties, debt repayment and equity returns. Also, there are many regional differences in cost structure not reflected. Several biomass feedstocks are assessed. For comparability, all cases are shown in $Canadian. The cases are:

- Canada
  - BC plant fed 100% by mill residues at $10/BDt
  - BC plant fed 30% by mill residues and 70% by surplus chips from Mountain Pine Beetle at $40/BDt
  - Ontario plant using 60% hog at $25/BDt and 40% slash at $65/BDt
  - Quebec plant with the same feedstock
- Brazil
  - Sao Paulo region plant using 100% bagasse at $5/BDt
  - Sao Paulo region plant using 100% trash at $25/BDt
- South Africa
  - KwaZulu-Natal plant using 100% bagasse at $5/BDt
  - KwaZulu-Natal plant using 10% trash at $25/BDt
- Ukraine plant fed by an annual grain crop (miscanthus) ($25/BDt)
- Baltic plant using 50% mill residue ($10/BDt) and 50% forest chips ($44/BDt)

Table 3.3-1

Delivered Cost to EU by Region- 200 tpd plant

	Canada				Brazil		South Africa		Ukraine	Baltic
	BC	BC	Ont	Quebec	Sao Paulo	Sao Paulo	KwaZulu	KwaZulu		
Raw Material	Mill Residue	30% Res 70% chips	60% hog 40% slash	60% hog 40% slash	Bagasse	Trash	Bagasse	Trash	Switch Grass	50% Res 50% chips
BioOil ($/GJ)										
Feedstock	0.76	2.47	3.12	3.12	0.36	1.82	0.36	1.82	1.99	2.05
Share of Mfg (90%)	4.38	4.38	4.38	4.38	4.01	3.68	4.38	4.38	4.38	4.38
Rail Transport	1.10	1.10	1.43	0.61	0.61	0.61	0.41	0.41	3.45	0.50
Loading	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Ocean Transport	7.08	7.08	2.56	2.56	4.18	4.18	5.60	5.60	0.00	1.50
Cost- via 4700t 1-way	13.46	15.17	11.62	10.80	9.31	10.43	10.89	12.35	9.96	8.57
Cost- via 30,000 2-way	9.53	11.24	10.20	9.39	6.99	8.11	7.78	9.24	9.96	8.57
Char ($/GJ)										
Feedstock	0.15	0.49	0.62	0.62	0.12	0.60	0.12	0.60	0.49	0.41
Share of Mfg (10%)	0.28	0.28	0.28	0.28	0.26	0.24	0.28	0.28	0.28	0.28
Rail Transport	0.64	0.64	0.83	0.36	0.36	0.36	0.24	0.24	2.01	0.00
Loading	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Ocean Transport	2.09	2.09	0.76	0.76	1.24	1.24	1.66	1.66	0	0.44
Cost- via 30,000 2-way	3.38	3.73	2.71	2.23	2.18	2.64	2.51	2.99	2.99	1.35

Wood-fed plants are assumed to produce 68% Pyrolysis Oil (44,900 tonnes) and 20% char (5,500 tonnes), net after that used for process energy. Cane and agricultural crops are assumed to produce 63% Pyrolysis Oil and 20% char. 90% of manufacturing costs are attributed Pyrolysis Oil, and 10% attributed to the byproduct char. Labour costs in Brazil are assumed to be approximately 75% of those in Canada and South Africa. The capital cost of a 200-tpd plant is approximately $16.5 million (€11.3 million)

Rail transport in all regions are assumed to be 3.55¢/km[31]. Average rail distances to port are: BC 540 km to Vancouver, Ontario 700 km to Montreal, Quebec 300 km to Montreal, Brazil 300 km to Rio de Janeiro, South Africa 200 km to Durban, Ukraine 2,000 km to Rotterdam (@ 3¢/km), Baltic 250 km to coast.

Loading at port is assumed $2.55/tonne[32]. Shipping costs are a major variable. Analysis by Zeton Inc, citing several sources, suggested that ocean vessels suitable for Pyrolysis Oil would be 4,500 tonne tankers that are also suitable for methanol. Zeton assumed that these ships would be dedicated to carrying Pyrolysis Oil, and would not carry cargo on the return trip. This option is expensive at €45-77/tonne, averaging €61/tonne, for a 10,000 km haul. Contrastingly, wood pellets are transported in 25,000 tonne tankers that can carry other products on the return, thus warranting a cost of €21/t, one third of the cost of Pyrolysis Oil. Zeton suggests that larger tankers designed for Pyrolysis Oil-type products can be built, yielding a transportation cost of €30/tonne. Shipping costs are assumed to vary linearly with distances to Rotterdam; Vancouver- 14,400 km, Montreal- 5,200 km, Rio de Janeiro- 8,500 km, and Durban- 11,400 km. Shipping costs from the Baltic are assumed to be €1.50/GJ.

Estimated delivered costs are summarized in Table 3.3-2. With small, dedicated tankers the highest cost Pyrolysis Oil is from BC using largely MPB fibre, at €10.46/GJ, the lowest cost is Brazil using bagasse at €6.45/GJ. With large 2-way competitive shipping, these costs can drop to €7.75/GJ for BC and €4.85/GJ for Brazil. Delivered cost of Char ranges from €3.12/GJ from BC to €1.56/GJ from Brazil.

Table 3.3-2

Delivered Cost Rotterdam

		Small Tankers 1-way		Large Tankers 2-way	
		$Cdn/GJ	€/GJ	$Cdn/GJ	€/GJ
BioOil					
BC	Res + MPB	15.17	10.46	11.24	7.75
Ontario	Hog + slash	11.62	8.01	10.20	7.04
Ukraine	Crops			9.96	6.87
BC	Residue	13.46	9.28	9.53	6.57
Quebec	Hog + slash	10.80	7.45	9.39	6.47
KwaZulu	Trash	12.35	8.52	9.24	6.37
Baltic	Res + chips			8.57	5.91
Sao Paulo	Trash	10.43	7.19	8.11	5.59
KwaZulu	Bagasse	10.89	7.51	7.78	5.37
Sao Paulo	Bagasse	9.31	6.42	6.99	4.82
Char					
BC	Res + MPB			3.73	2.57
Sao Paulo	Bagasse			2.18	1.51

How competitive are these sources? The average cost of heavy fuel oil in Europe in 1Q 2006 was €8.4/GJ and the maximum was in Portugal at €10.4/GJ 1, as outlined in Section 3.2.1. The price of natural gas averaged €9/GJ in early 2006 and coal €1.84/GJ in 4Q-2005. While delivery costs will vary, the examples above show that biofuel imports can be competitive in most cases. If small tankers are used, BC sources at 10.46€/GJ are not competitive with fossil fuels on pure price. All Pyrolysis Oil options become more

[31] Quote from CN Rail for transporting Pyrolysis Oil; Task 38 Brochure "Greenhouse Gas Balance of a Forest Management and Bioenergy System in Canada- 2004, Doug Bradley, Climate Change Solutions

[32] Zeton Inc-

competitive when the ERC benefit from the EU carbon trading system (€1.5/GJ) is factored into the price, and especially if incentives such as feed-in-tariffs are in place.

All sources become very competitive if Pyrolysis Oil can utilize large, specialized, low-cost tankers. Clearly, minimizing the cost of feedstock and efficient shipping are critical drivers to competitiveness.

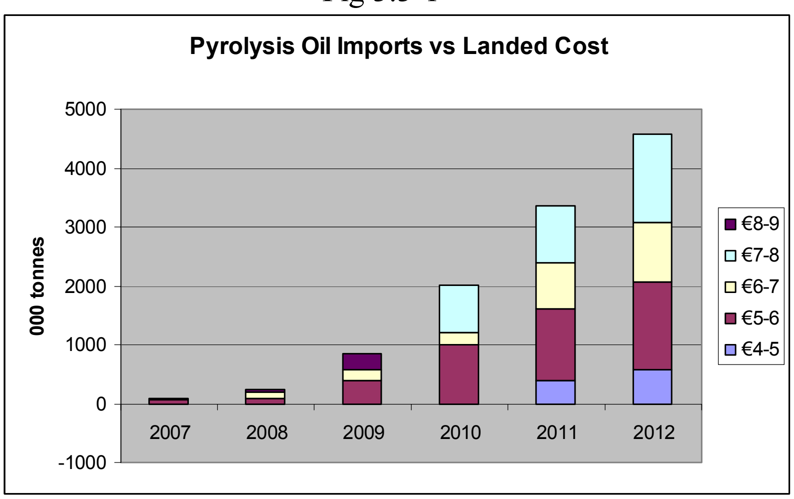
Table 3.3-3 summarizes projected annual imports to Europe from selected sources 2007-12, with imports totaling 4.6 million tonnes in 2012. Fig 3.3-1 combines this volume data with the landed cost per GJ from Table 3.3-2. For example, in 2008, of 240,000 tonnes of imported Pyrolysis Oil, 100,000 tonnes can be delivered at €5-6/GJ, 84,000 at €6-7/GJ, and 56,000 at €8-9/GJ. These costs assume small 1-way tanker delivery. By 2012 it is assumed that larger 2-way tankers will be used. Of 4.57 million tonnes of imports, 570,000 tonnes can be delivered at €4-5/GJ, 1.5 million tonnes at €5-6/GJ, 1 million tonnes at €6-7/GJ, and 1.5 million tonnes at €7/8. No source will require €8/9/GJ. Exports of 4.6 million tonnes in 2012 is less than 10% of the production potential of Canada, Brail and South Africa combined.

Table 3.3-3

Imports Delivered Europe (000 tonnes)

	2007	2008	2009	2010	2011	2012
Canada	0	23	190	602	944	1,500
Brazil	0	18	70	200	400	570
South Africa	0	33	80	220	400	500
Baltic	66	100	400	800	1,200	1,500
Ukraine	33	66	100	200	400	500
Imports	99	240	840	2,022	3,344	4,570

Fig 3.3-1



4. Market Determining Factors

While Pyrolysis Oil has been manufactured in small volumes and tested for several years, it is essentially a new product just now at the commercial stage. As it is largely unknown, there is no ready market in Europe, no line of customers waiting to buy it. The market has to be created and developed. There are obstacles that can make this a slow process if allowed to. For example, even if tests are successfully concluded for an application, environmental processes including permitting have to be undertaken for Pyrolysis Oil to be a readily accepted fuel. In some markets this can take two years or longer. On the other hand, market acceptance can be rapid. In Canada the output from the first plant is entirely sold out, and the output from the two plants now being fabricated also have fully committed production.

Pyrolysis Oil is versatile, and can be substituted for heavy fuel oil, light fuel oil, natural gas, or coal, depending on the application. Consumption of these fossil fuels is huge. For example, electricity production in EU25 from coal was 960 TWh, oil 162 TWh, and natural gas 582 TWh, as shown in Appendix 2. Furthermore, EU 25 industry GHG emissions were 597 MT CO_2e in 2003, equivalent to the use of 190 MT fuel oil or 400 MT Pyrolysis Oil on a GJ basis. Demand for Pyrolysis Oil can be taken as unlimited, and demand should grow much more quickly than supply. However, there are a number of factors that will influence both market penetration and growth in trade, for example;

4.1. Long range transportation logistics:

In raw form, biomass is too wet and bulky to transport long distances because of the expense of transport. To be economic, normally biomass has to be densified into pellet or liquid form. Pellet markets are well defined and growing, and low-cost transportation logistics are in place. Pyrolysis Oil is twice as dense as pellets and can have long-range transportation advantages, however no low-cost ocean transport options have been tested. The cost of long range transport depends on the availability of return freight. Loading, discharging and handling costs can be significant.

4.2. Distribution Systems:

Many market options, such as co-firing with Pyrolysis Oil in power plants on coastal waterways, require large and assured volumes of Pyrolysis Oil but no special distribution systems. However, markets such as greenhouses and sawmills will require inland transportation and storage centers so that small volumes can be purchased and utilized. These systems are not set up yet.

4.3. Straight Economics:

Pyrolysis Oil must be cost competitive, not just against fossil fuels for which it might be substituted, but against all other biomass alternatives. For example, district heating companies in Sweden use considerable raw biomass, which is relatively low cost (1-2€/GJ). Power companies in the Netherlands burn Palm Oil from Malaysia and local fatty oils. Palm Oil is currently a relatively expensive €11.4/GJ, however this product has been priced competitively in the past. Fatty oils are €9.6/GJ

4.4. **Incentive systems**:

A major driver is incentive systems. Subsidies, such as feed-in-tariffs for renewable electricity, and energy taxation seem to be the most effective, while obligations and renewable portfolio standards are arguably less so. The Emission Trading System in the EU has been effective in supporting use of biomass products. However, incentives can change rapidly, not only as 2010 emission reduction targets loom, but also to enhance or reduce existing incentive systems. For example, the subsidy system in the Netherlands for electricity produced from renewable sources was tremendously successful in promoting use of renewable biomass, but this system was withdrawn in August 2006, partially due to cost of the system, but also due to questions on the sustainability of Malaysian Palm Oil. Contrastingly, in Italy new directives will instantly increase demand for biomass.

4.5. **Consumer Acceptance**:

Pyrolysis Oil is essentially a new product. Some consumers will be ready to try anything to save money, other more-conservation consumers will wait until a new product has been proved over a long period. Often there has to be a major reason to induce a change.

4.6. **Certainty of supply**:

Petroleum products are largely commodities with many sources, and supply is generally assured, barring political upheavals in producing regions. Wood pellets have a viable market and there is a growing supply, but vagaries of ocean shipping rates can sometimes remove considerable volumes of competitive pellets. Major users that configure plants for Pyrolysis Oil will need large volumes of assured supply. This supply is not yet in place.

4.7. **Biomass Certification**:

In the Netherlands the use of Indonesian and Malaysian palm oil was found to be from unsustainable sources, which has led to developing criteria for biomass certification. Experience has shown that to certify biomass can take 2-4 years, when modes of transportation are included. In other markets, such as Sweden, certification is not a big issue, but in Germany and the UK, sustainability issues of biofuel imports gain interest[33]. In Belgium, sustainability requirements for imported biofuels exist already on the provincial level. The EU Commission is currently researching a common framework for sustainable biomass, and is likely to introduce respective legislation in the near future.

4.8. Proximity to Kyoto targets

Markets for Pyrolysis Oil will depend on the extent to which importing countries are close to reaching Kyoto emission reduction objectives. Appendix 3 illustrates the Kyoto targets and the projected level for 2010 for EU15 countries and for added EU10 countries[34]. A summary, in order or urgency, is shown on Table 4.1.

[33] Germany is to introduce sustainability requirements in mid-2007 through an ordinance of its new Biofuel Quota Law. Similarly, such requirements might be also introduced in the 2008 revision of the feed-in tariffs for biomass (Oeko-Institut 2006).
[34] European Environment Agency- 2004

For example, Denmark's burden share is to reduce emissions by 21%, but projections under existing policies are to increase emissions by 15.7%, a gap of 36.7% to make up. Spain's EU burden sharing target allows it to actually increase GHG emissions by 15% above 1990 levels, yet the projected emissions are 48.3% above 1990, a gap of 33.3% to achieve. Denmark, Spain, Portugal and Austria all have large gaps in excess of 20% to make up, while Belgium, Finland, Ireland, Greece and Italy have gaps in the 10-20% range. Germany, UK and Sweden are likely able to meet or exceed their targets.

With a different policy structure, Finland, Ireland and Greece are projected to be able to exceed targets. However many countries are in the position of either having to buy ERCs, or undertaking extraordinary measures to come close to targets, including Denmark, Spain, Portugal, Netherlands, Belgium and Italy.

Table 4.1

Kyoto Burden Sharing Status

	Target vs 1990	Projected with Existing Policies	Gap	Gap with New Policies
Denmark	-21.0%	15.7%	36.7%	36.7%
Spain	15.0%	48.3%	33.3%	13.0%
Portugal	27.0%	53.1%	26.1%	18.7%
Austria	-13.0%	8.7%	21.7%	3.8%
Finland	0.0%	16.5%	16.5%	-0.5%
Ireland	13.0%	29.4%	16.4%	-9.4%
Belgium	-7.5%	6.5%	14.0%	4.2%
Greece	25.0%	38.6%	13.6%	-2.6%
Italy	-6.5%	3.7%	10.2%	3.1%
Netherlands	-6.0%	3.3%	9.3%	9.3%
France	0.0%	9.0%	9.0%	-1.7%
Luxembourg	-28.0%	-22.4%	5.6%	5.6%
Germany	-21.0%	-19.7%	1.3%	1.3%
UK	-12.5%	-13.9%	-1.4%	-10.0%
Sweden	4.0%	-0.2%	-4.2%	-4.2%
EU-15	-8.0%	-1.0%	7.0%	0.3%

5. EU Policies and Perspectives

Each country in the EU has varying amounts of biomass and has implemented different policies in efforts to promote renewable fuels such as bioenergy. For example, the Netherlands, Germany, France, Austria and Denmark have feed-in-tariffs, while Belgium, Sweden, and the UK have Renewable Obligations supported by a Certificate program[35].

5.1. Netherlands

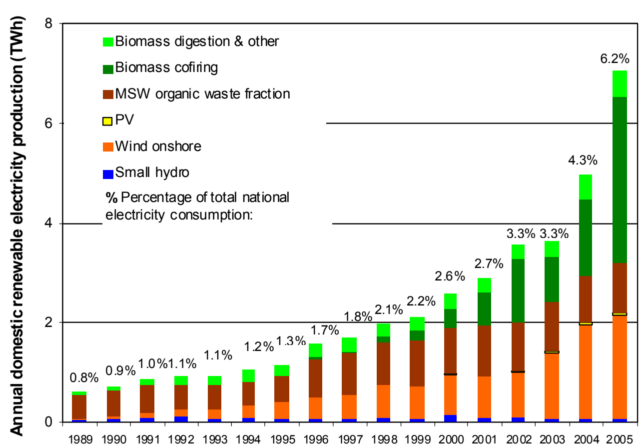
The Netherlands has a EU burden share target of 6% reduction in GHGs from 1990 levels, and a projected emission level 3.3% higher, a gap of 9.3%. This gap is one of the lowest in the EU15. The Netherlands has domestic targets of 5% renewable energy in 2010 and 10% in 2020, and 9% renewable electricity in 2010, 17% by 2020. Biomass and wind power are the backbone of a strategy to reach these targets. ECN projected that to reach the 10% target in 2020 (288PJ) will require 75 PJ from biomass, of which 20 PJ would come from co-firing in power plants, shown in Table 5.1-1.

Table 5.1-1[36] Dutch Renewable Energy Policy

	Business Policy Goal (PJth)		
	2000	2007	2020
Domestic Wood Combustion	8	8	8
Industrial Combustion	5	5	5
Co-firing- Fossil Fuel Plants	3	18	20
Distributed CHP Plants	2	6	30
Biogas (landfills, digestion)	6	8	8
Others			4
	24	45	75

ECN- 2004

Fig 5.1-1[37] Renewable Electricity Production in the Netherlands



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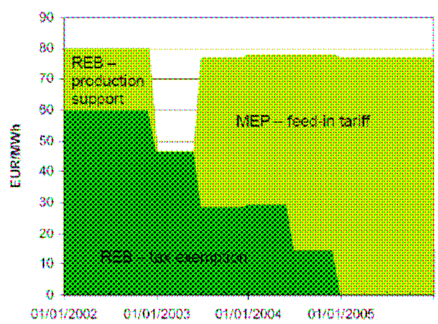
35 SenterNovem

36 Electricity from Biomass- State-of-the-art co-firing and stand-alone CHP technology development in the Netherlands- Dec 2003: Veringa H. et al

37 Developments in Biomass Use Trade, Policy and Sustainability in the Netherlands- Martin Junginger et al 2006- Copernicus Institute, Utrecht University

Impressive results have already been achieved. As shown in Fig 5.1-1, renewable electricity production rose from .8% of total production in 1989 to 6.2% in 2005. Since 1998, the most impressive gains have been from biomass co-firing. The main impetus to recent increases in biomass use was the switch in 2004 from a tax exemption support system to a feed-in tariff system, shown in Fig 5.1-2 below. The feed-in-tariff system was so successful that applications for feed-in-tariffs consumed the entire budget for this incentive. Rates were subsequently lowered in July 2006, and eliminated entirely for new projects as of August. An upcoming federal election will determine the future scope of these incentives.

Fig 5.1-2: Dutch Policy Change



The Dutch Parliament has asked questions about the sustainability of palm oil for generating electricity. As a consequence, the Netherlands is developing sustainable criteria for bio-liquids and bio-solids, projected for implementation in late 2007 or 2008. The intent is that every power company should act sustainably, and increase the level biofuels in its portfolio that are sustainably sourced, otherwise not receive a subsidy from the government.

5.2.Sweden

Sweden has a EU burden sharing target to increase emissions by 4%, while it is projected to actually reduce emissions by 0.2%. It has done so by almost totally eliminating oil from its energy picture. Sweden is one of the biggest consumers of biofuel in the EU[38], with 17% of total primary energy supply from bioenergy in 2003. 63% of biomass usage is in the forestry industry, and 23% is in district heating systems[39]. The infrastructure for supplying biomass is well developed; Sweden has a large forest products industry, its combustion technology is well advanced, and sourcing of raw material, shipping and international trade were part of their established businesses. Consequently, it was relatively easy in the emerging bio-energy trade to excel in practical handling and use.

Not only did Sweden develop internal biomass resources, but with strong incentive it developed imports from new sources, in particular the Baltic states. In 2000, Sweden imported 16.4 PJ of biofuel, about 4% of domestic use, mainly in the form of solid

[38] The prospects for large-scale import of….of critical issues- J. Hansson and G. Berndes, Energy for Sustainable Development Volume X No. 1- March 2006
[39] Biomass and Swedish Energy Policy- Bengt Johanson

biomass for heat and power production. Imports were driven principally by high domestic demand in the district heating system, and differences between European countries in energy and waste regulations, taxes and policies, which made export to Sweden attractive.

To reduce use of fossil fuels, Sweden implemented an energy tax and a carbon tax. To preserve international competitiveness of Swedish industry, there is no energy tax on fuels used in industry or for power generation. The carbon tax was raised to 530 Kr/tCO_2e in 2001 (€57.8/tCO_2e), but only 50% applies to industry, or €28.9/tCO_2e. This tax is equivalent to €2.2/GJ. Sustainability is not as important an issue in Sweden as in other countries, such as the Netherlands. For example, two large Swedish utilities burn palm oil, while Dutch companies dropped palm oil in 2005 for sustainability reasons.

5.3. Finland

Finland faces a considerable challenge to reach Kyoto targets. Its EU burden sharing target is a 0% increase in GHG emissions, while emissions are projected at 16.5% higher. In 2000-04 emissions averaged 20% higher than 1990[40]. The objective of the National Climate and Energy Strategy is for consumption of renewable energy to account for almost one third of primary energy consumption in 2025, compared with 23% in 2003.

The Government employs energy taxation, tax relief, production-based subsidies for electricity and forest chips, investment subsidies and funding of research and development projects as financial measures to implement the energy policy. Since the beginning of July 2005, fuels used for heat production have been taxed according to the following rates including precautionary stock fees[41].

- Light fuel oil 7.06 €c/kg (1.91 €/GJ)
- Heavy fuel oil 5.96 €c/kg (1.47 €/GJ)
- Coal 44.70 €/t (1.76 €/GJ)
- Natural gas 1.904 €c/nm^3 (0.53 €/GJ)
- Tall oil 5.68 €c/kg (1.54 €/GJ).

Power eligible for energy tax subsidies includes; wind power, hydropower below 1 MVA, electricity produced from wood and wood-based fuels, recycled fuels and biogas, and electricity produced with peat at CHP plants below 40 MVA. The subsidy for wind electricity and electricity produced from forest chips is 6.9 €/MWh, for electricity produced with recycled fuels is 2.5 €/MWh and for others is 4.2 €/MWh. Electricity produced from Bio-Oil will receive 4.2€/MWh subsidy. Generally, Finnish financial incentives to utilize biomass in energy production are moderate compared to some other

[40] Solid and Liquid Biofuel Markets in Finland- a study on international biofuel trade- IEA Bioenergy Task 40 Country Report 2006

[41] Council of State. 2005. Laki sähkön ja eräiden polttoaineiden valmisteverosta 30.12.1996/1260. Available: http://www.finlex.fi/fi/laki/ajantasa/1996/19961260. and Council of State. 2004a. Laki nestemäisten polttoaineiden valmisteverosta 29.12.1994/1472. Available: http://www.finlex.fi/fi/laki/ajantasa/1994/19941472.)

EU countries. In addition, the support system of bioenergy has been almost constant for several years. In 2004, as much as 42 million m^3 of wood, 306 PJ, was used for energy production, or 20% of total consumption of primary energy.

5.4. Germany

Germany is on track easily to achieve its Kyoto GHG emission reduction target. Its EU burden is to reduce emissions by 21% from 1990 levels, and Germany had reached 19.7% reduction by 2003[42]. In 2004 Germany revised its Renewable Resource Act, which defines feed-in-tariffs for renewable electricity generation from geothermal, hydro, biomass, wind and solar energy. However, the focus in Germany is small power generation so only biomass plants with capacity less than 20MW qualify for these incentives, which rise with smaller plant capacities, shown in Table 5.4-1. Furthermore, no feed-in-tariffs are provided for co-firing, only for plants using exclusively biomass.

Table 5.4-1 Feed-in-tariffs for biomass-based electricity (Aug 2004)- Germany

Biomass type	capacity up to kW_e	feed-in tariff in €c/kWh_e base tariff	cogeneration bonus	technology bonus	total (maximum)
All	150	11.5	2	4	17.5
	500	9.9	2	4	15.9
	5000	8.9	2	4	14.9
	> 5000	8.4	2	0	10.4
Energy crops. excl. wood	150	17.5	2	4	23.5
	500	15.9	2	4	21.9
	5000	12.9	2	4	18.9
	> 5000	12.4	2	0	14.4
wood, excl. demolition wood	150	14	2	4	20
	500	12.4	2	4	18.4
	5000	11.4	2	4	17.4
	> 5000	10.9	2	0	12.9

5.5. UK

The UK is projected to achieve its EU burden share target of 12.5% reduction easily. It is in fact projected to exceed it by 1.4%. Much of its success is due to the replacement of coal power with natural gas in the 1990s. In 2005, the total electricity supplied to the UK, including imports, was 386 TWh, of which 38% was from gas, 33% from coal, and 19% from nuclear[43]. 4% came from renewable resources, including large-scale hydro. 81% of renewable electricity was made from biofuel, or 7.3 TWh.

The Renewables Obligation (RO), introduced in 2002, is the main support mechanism for the expansion of renewable power in the UK, intended to achieve 10% of UK electricity from renewable sources by 2010. Suppliers must produce evidence of compliance to the regulator in the form of Renewable Obligations Certificates (ROCs). Each ROC is 1 MWh_e from eligible sources, and these can be traded. A supplier with insufficient ROCs must pay a buyout fee of £40/ MWh_e (£4.11/GJ, €5.63/GJ). With RO, co-firing of biomass grew to 7.2% of renewable electricity generation by 2004, reflected in Fig 5.5-1.

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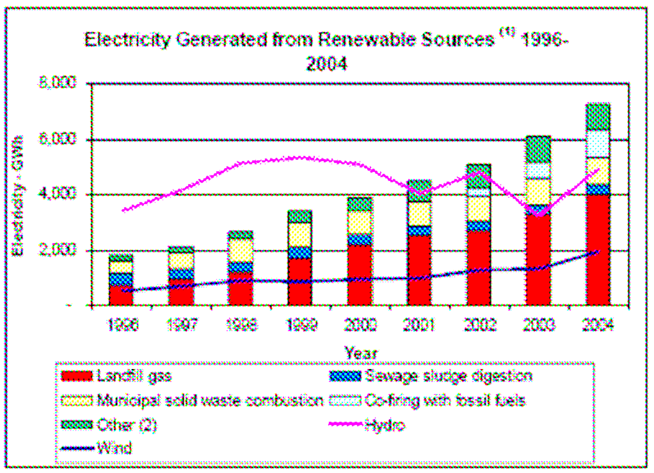
[42] GHG Emission Trends 2004- European Energy Agency
[43] IEA Bioenergy Task 40 Country Report for UK- July 2006, F. Rosillo-Calle, M. Perry

Fig 5.5-1



5.6. Belgium

Belgium has a target to reduce emissions by 7.5% from 1990, and yet it is projected to increase emissions by 6.5%. The gap of 14% represents a considerable challenge. Its renewable electricity target is 6% of total power production by 2010. Belgium has in place a tax regime that enhances the competitiveness of wood fuels for energy. For example, a tax per MWh on diesel is 6.6€, LFO 4.4€, HFO 3.7€, and natural gas 3-5.8€. To achieve reduction targets, Belgium has also implement a program of renewable obligations supported by a system of Green Certificates. Each region (Wallonia, Flanders, and Brussels) has its own targets and penalties for unrealized share of green power.

5.7. Denmark

Denmark's EU burden sharing target is to reduce GHG emissions by 21%, yet it is projected to increase emissions by 15.7%, a whopping 36.7% spread. While seemingly unreachable, in one study[44] Denmark is noted as being on track to achieve its national target for renewable electricity, largely through progress in wind power capacity. Denmark had relatively high feed-in-tariffs until 2004, which in combination with a carbon tax refund and production subsidy provided 8€ct/KWh reimbursement on average. By 1998 tax refunds and subsidies paid to wind power producers alone amounted to €75 million. Now incentives have changed. Renewable electricity plants connected before April 21, 2004 receive a benefit of 8.1€ct/KWh, while biomass plants connected after that date receive only 1.3€ct/KWh[45]. Despite the drop in benefit, wood pellet consumption rose from 593,000 tonnes in 2003 to 748,000 tonnes in 2004.

5.8.Italy

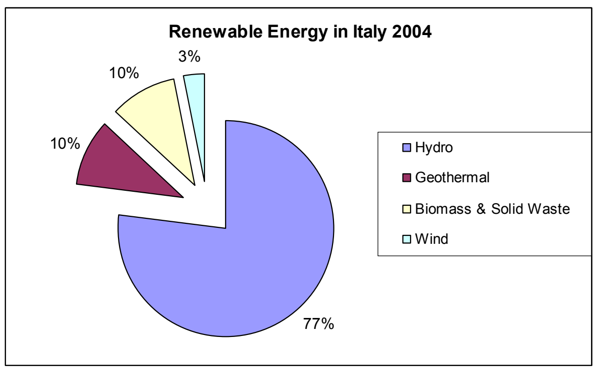
In 2004 the Italian economy grew at a lower rate than other European countries, in fact industrial production and exports decreased, however, energy consumption increased

[44] Green Energy Markets in Europe- Rolf Devos, 2005
[45] Kevin Porter, Exeter Associates- California Energy Commission Workshop, Aug 2006

1.3%. Greenhouse gas emissions are increasing and it will be very difficult for Italy to achieve its targets under the Kyoto Protocol. Following European directive 2002/91/CE, a law was created in Italy to commence in 2007 that all new houses and buildings have to meet energy efficiency criteria.

Only the 8% of energy consumption was from renewable sources in 2004, so the government established several programs for the development of renewable energy. A PV installation program was successfully developed in several regions, with citizens and banks participating actively. Biomass utilisation, while increasing, is limited to rural areas. Utilisation of pellets in 2006 will reach 350,000 tonnes. Wind energy utilisation is also active, though there are bureaucratic difficulties related to wind generator installation. Fig 5.8-1 presents the composition of renewable energies resources in Italy.

Fig 5.8-1



The Green Book set targets of 12% of energy production and 22% of electricity production from renewable energy sources in the year 2010. These targets were set to achieve a reduction of 6.5% of GHG emissions, as declared in the Kyoto Protocol. The Green Certificates market is expected to be a useful instrument to achieve these objectives, while tax reduction and simplification of procedures are other important instruments to be analysed. Green Certificates created in Italy for the year 2004 are shown on Table 5.8-1.

Table 5.8-1 Green Certificates Created in Italy 2004

Sources	# Green Certificates	%
Hydro	29,297	49%
Geothermal	12,138	20%
Wind	9,292	15%
Biomass & Solid Waste	9,229	15%
Photovoltaics	16	0%
Total	59,972	

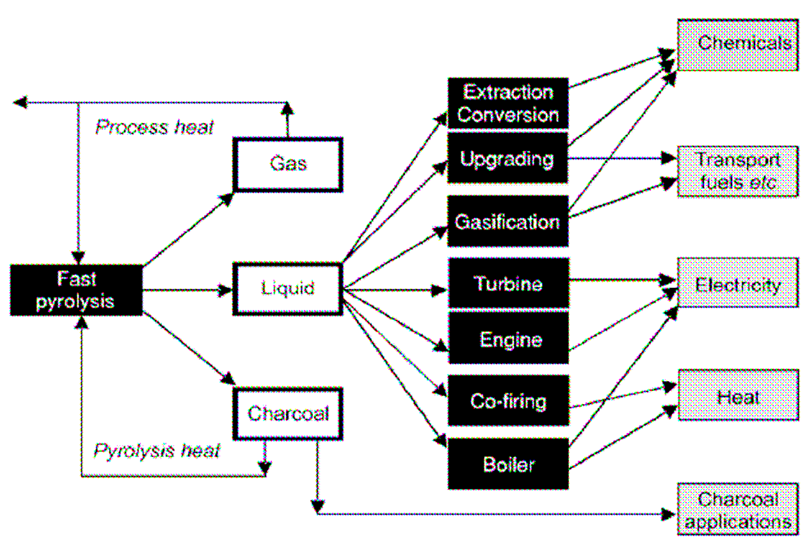
6. Potential European Markets

A 2004 analysis illustrates broad categories of uses for Pyrolysis Oil and char[46], shown on Fig 6.1. Char is viewed as a substance for charcoal applications, which includes co-firing in coal fired power plants.

Pyrolysis Oil ultimately has a whole suite of potential markets. Currently, applications are limited to the production of heat and power, while after some additional research Pyrolysis Oil will be a feedstock for transportation fuels and chemicals. Pyrolysis Oil is a suitable boiler fuel as long as it has consistent characteristics, provides acceptable emissions levels, and is economically feasible. An obvious choice is district heating to replace heavy fuel oil and gas. Other heat applications include greenhouses and sawmill dry kilns. Pyrolysis Oil can replace natural gas in gas power stations, and since most of these stations have multi-fuel capability, it can be used as a back up fuel also. Pyrolysis Oil should also be able to co-fire in large coal power plants, though the results of such tests are not complete. Pyrolysis Oil can also replace diesel in stationary industrial engines, but not in transportation owing to the requirement for fuel heating and specialized storage. Pyrolysis Oil can be used in small turbines to make power, such as in remote, off-grid locations, but also in locations where there is sufficient biomass.

In the future, Pyrolysis Oil can be used to create Syngas, a middle stage in the process to make transportation fuels. With the right emulsifiers, it can also be blended with diesel to make a lower-emission transportation fuel, however these emulsifiers currently are expensive and unstable.

Fig 6.1 Uses of Fast Pyrolysis Products



[46] Biomass Fast Pyrolysis- A.V. Bridgwater-2004

6.1. Pulp Mill Lime Kilns

6.1.1. Technical Feasibility:

Pyrolysis Oil from Dynamotive has been tested for use in limekilns used in pulp mills. The Pulp and Paper research facility at UBC completed a study on the use of Pyrolysis Oil in 2003, burning 2 tonnes at the rate of 150 litre/hour. Two Pyrolysis Oils, one from white wood and one from a bark-whitewood mixture, were compared with natural gas in firing the limekiln. Levels of calcinations and reactivity were found to be similar. The burner tests showed Pyrolysis Oil to be a viable substitute for natural gas since it atomized and burned well, with a similar "bushy" flame.

DynaMotive has recently concluded a full-scale industrial test burn of Pyrolysis Oil as a replacement for natural gas in the commercial limekiln owned by Caribou Pulp and Paper in Quesnel. During the testing, over 20 tons of Pyrolysis Oil was fired at a rate of approximately 2 tons per hour, utilizing existing equipment without any mechanical modifications. DynaMotive Pyrolysis Oil met all of the target test parameters, as set out by the host company, including maintaining the kiln temperature and lime yield while demonstrating complete and stable combustion of the fuel. The Pyrolysis Oil for the test was produced the DynaMotive West Lorne plant in Ontario and shipped across Canada, further demonstrating the versatility of the fuel. DynaMotive is currently in discussions with a number of pulp and paper producers in Western Canada[47].

6.1.2. Market

The limekiln market is ideal for Pyrolysis Oil, since CO_2 neutral Pyrolysis Oil can be used with very little modification to burning systems. The average limekiln fuel requirement in Finland is 1.5-20 GJ/t of pulp. Measured in a Canadian pulp mill, usage is identical at 1.6 GJ/t. Limekilns use both oil and natural gas in both Finland and Canada, depending on fuel distribution systems and price. Tall oil, also used as a fuel in limekilns, can be directly replaced with BioOil with no modifications to the system.

Table 6.1-1 summarizes fuel use in limekilns in EU 25 plus Norway in 2005[48]. 64% of EU pulp production is in Sweden and Finland, with a further 15% in Spain and Portugal. EU pulp mills produce 24 Mt of pulp annually, and use approximately 42 PJ of fuel in limekilns. There is the potential to utilize 2.4 million tonnes of Pyrolysis Oil, which is equivalent to the production from 53 200-tpd Pyrolysis Oil plants.

Sweden produces 7.8 million tonnes pulp annually, and limekilns consume 13.6 PJ of fuel, the equivalent of 766,000 tonnes BioOil. Pulp mills have a number of options to fuel lime kilns. Tall oil for example, a byproduct of the pulping process, is used in limekilns, but it is not believed that there is a surplus. Raw biomass or wood pellets are not used in lime kilns owing to carbon contamination. Direct gasification will be an option in the future, but this has not been proven economic at the commercial level yet.

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[47] DynaMotive Energy Systems Ltd
[48] Jussi Heinemo, Lappeenranta University of Technology- June 2006

Table 6.1.-1

FUEL CONSUMPTION OF LIME SLUDGE REBURNING KILNS
EUROPE (EU 25 + Norway) 2005

COUNTRY	Bleached Pulp	Unbleached Pulp	Total		Fuel Consump	BioOil Potential	200 tpd plants
	000 t	000 t	000 t	%	PJ	000 t	
Sweden	5,502	2,293	7,795	32.1%	13.6	766	17
Finland	7,112	671	7,783	32.1%	13.6	765	17
Portugal	286	1,555	1,841	7.6%	3.2	181	4
Spain	1,540	240	1,780	7.3%	3.1	175	4
France	946	434	1,380	5.7%	2.4	136	3
Austria	331	496	827	3.4%	1.4	81	2
Poland	360	431	791	3.3%	1.4	78	2
Norway	384	169	553	2.3%	1.0	54	1
Slovakia	402	0	402	1.7%	0.7	40	1
Czech Rep.	177	204	381	1.6%	0.7	37	1
Belgium	360	0	360	1.5%	0.6	35	1
Germany	310	0	310	1.3%	0.5	30	1
Estonia	0	70	70	0.3%	0.1	7	0
	17,710	6,563	24,274		42.5	2386	53

Finland also burns 13.6 PJ of energy in limekilns. Fuels used in limekilns are not taxed, therefore the price of Pyrolysis Oil has to be compared with the tax-free price of natural gas and heavy fuel oil. At the price of heavy fuel oil in mid 2006, the price of Pyrolysis Oil should not exceed €7.3/GJ to be competitive[49]. This price compared with delivered costs in Table 3.3-2 reveals that all sources of Pyrolysis Oil would be competitive for Finnish limekilns if large 2-way tankers were used. With small 1-way tankers, all sources are competitive except BC (Canada). As shown on Fig 6.1-1, some of the Finish pulp mill capacity is on the Baltic coast, ideal for minimizing Pyrolysis Oil transportation costs.

Fig 6.1-1 Finnish Pulp and Paper Mills

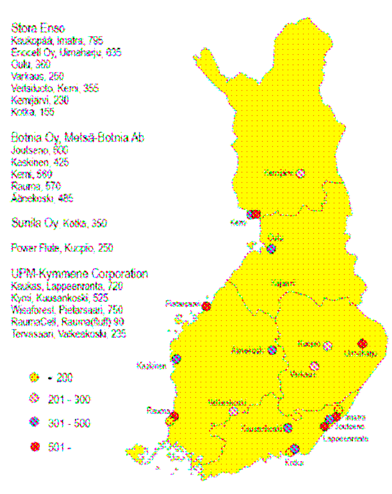

Figure 17. Finnish pulp mills (capacities in 1 000 tons).
Source: Finnish Forest Industries Federation and Power Flute Oy

[49] In 6/2006 VAT 0% price of HFO used in heat production was €8.81/GJ, including €1.47 energy tax

Portugal and Spain account for 15% of Europe's pulp production, and in limekilns burn fossil fuels equivalent 181,000 and 175,000 tonnes of Pyrolysis Oil, on a GJ basis.

6.2. Sawmill Dry Kilns

6.2.1. Technical feasibility

A combustion test of Pyrolysis Oil for drying lumber was carried out at a Canfor sawmill in BC, Canada in 2004. Two loads of lumber were dried in two separate runs. In the first, 9,987 kg of Pyrolysis Oil made from whitewood and bark was used to dry 396 m^3 of lumber over 46.9 hours, reducing the moisture content from 42% to 12.8%. In the second run, 8,501 kg of Pyrolysis Oil made from whitewood was used to dry an identical volume of lumber in the same 46.9 hours, reducing the moisture content from 56% to 15.4%[50]. The Pyrolysis Oil exhibited good ignition characteristics and was an effective substitute for natural gas. Canfor was very satisfied with the drying results, however in 2004 Canfor was not ready to spend the capital to build a Pyrolysis Oil plant.

6.2.2. Market

The market is any sawmill that has a dry kiln and uses natural gas or heavy fuel oil as a fuel for drying onsite. Only minor capital is needed for tanks and burners. Sawmills use relatively small volumes of fuel. They are most often found in the interior of countries, so transporting small volumes of Pyrolysis Oil would require a distribution system and tend to add to the cost. In Northern Europe sawmills utilize bark and sawdust for sawn timber drying, and the use of natural gas and heating oil is not feasible for dry kilns.

6.3. District Heating

6.3.1. Technical Feasibility

Furnaces and boilers are commonly used in heat and power generation. They are usually less efficient than engines and turbines but they can operate with a variety of fuels from natural gas to petroleum distillates to sawdust to coal/water slurries[51]. Pyrolysis Oil seems to be a suitable boiler fuel as long as it has consistent characteristics, provides acceptable emissions levels, and is economically feasible[48]. Several companies have been interested in using Pyrolysis Oil, especially to replace heavy fuel oil.

The Red Arrow Products pyrolysis plant in Wisconsin, dedicated to food-flavouring components, is the only plant to regularly use Pyrolysis Oil to generate heat commercially, doing so for 10 years. A 5 MW swirl burner uses different mixtures of fuel byproducts. The Pyrolysis Oil fraction is delivered to the combustor through a stainless steel nozzle and atomized with air, while char and gas are fed using different lines. A 600-m^2 exhaust gas/sir heat exchanger provides all the space heating needs of the plant[48].

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[50] DynaMotive Pyrolysis Oil Information Book
[51] Overview of Applications of Biomass Fast Pyrolysis Oil- Jan 2004, S. Czernik and A.V. Bridgwater

6.3.2. Market

District heating, due to its large scale, can manage the use of renewable fuels more easily and burn more types of fuels than small heating applications. 56 million EU citizens are served by district heating, 61% in the new members states. Several thousand district heating systems exist in the EU-25, with large systems in Warsaw, Berlin, Stockholm, Helsinki, Paris, Vienna, Munich, Prague and Copenhagen[52]. The current energy supply to district heating systems is dominated by the use of fossil fuels in combined heat and power (CHP) plants. Table 6.3-1 illustrates the district heat deliveries in European countries in 2003, and the proportion of CHP supply. The largest district heating system is in Germany, where 82% comes from CHP systems. Poland, Sweden and Finland also have sizable district heating capacity.

Table 6.3-1[53]

District Heat Deliveries- 2003

	PJ	GWh	% CHP
Germany	354	98,333	82%
Poland	309	85,833	62%
Sweden	170	47,222	34%
Finland	159	44,167	77%
Czech Rep.	111	30,833	77%
Denmark	103	28,611	82%
Romania	101	28,056	74%
Netherlands	98	27,222	100%
France	86	23,889	32%
UK	75	20,833	100%
Hungary	57	15,833	69%
Austria	54	15,000	65%
Sloval Rep.	43	11,944	69%
Bulgaria	38	10,556	78%
Lithuania	33	9,167	52%
Latvia	27	7,500	46%
Belgium	21	5,833	99%
Estonia	21	5,833	41%
Iceland	18	5,000	20%
Italy	17	4,722	64%

While the EU already has directives in place regarding renewable fuels for electricity and transportation, no directives are in place for heat, thus heat from biomass as a market is growing more slowly[54]. Legislation is planned for 2006. Existing district heating systems are prime candidates for renewable fuels.

In Poland, of the urban population 70% receive space heat and 50% receive hot water from district heating[55]. The sector is powered by over 8,000 boilers, which deliver 488 PJ of heat each year. 25-30% of this heat is derived from heat-only plants, which could economically upgrade to CHP. The energy system, including electricity production, is heavily dependant on low-cost coal. Heat prices remain subsidized as a result of political sensitivity of increasing costs to households long accustomed to cheap energy. Poland is not a likely early market for Pyrolysis Oil.

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[52] Sven Werner, Dept Energy and Environment, Chalmers University of Technology, Sweden
[53] Possibilities with More District Heating in Europe, Euro Heat & Power, Ecoheat Work Package #4
[54] Biomass Action Plan- Commission of European Communities
[55] Export Council for Energy Efficiency

In Finland, owing to the climate, it is necessary to heat homes most of the year. About 1/5 of the energy consumed in Finland is used for heating buildings[56]. 48% of the net effective heating energy of commercial, residential and public buildings comes from district heating, as shown in Fig 6.3-1[57]. District heat networks cover practically all towns and densely populated areas in Finland. District heating capacity is 20,100 $MW_{thermal}$. Municipalities own most of the district heating utilities. In 2004, as much as 202 PJ of fuels were used and 120 PJ of district heat was produced in Finland[52]. As much as 74% of district heat came from CHP plants, and 26% generated in heating plants in 2004. 202 PJ of fuels were used for DH and combined production of heat and electricity. Fossil fuels are the main fuels used in the district heating sector; natural gas (38%) and coal (25%). District heat plants in the capital area and in the biggest towns use natural gas and coal. A natural gas grid covers the southern part of the country and gas comes from Russia. Peat and wood fuels are more commonly used inland and they had 19% and 11% shares respectively in 2004[58].

The target of energy policy is for energy consumption from renewable sources to grow by 25% by 2015, and 40% by 2025. It is anticipated that natural gas and wood will increasingly replace oil, coal, and peat. In Finland, 8PJ heavy fuel oil is used in district heating, the equivalent of 460,000 tonnes Pyrolysis Oil, or 10 200-tpd plants. This is a large potential market for Pyrolysis Oil. With delivered costs at 4.8-7.8€/GJ, Pyrolysis Oil is competitive with HFO as shown in Fig 6.3-3 below, and even more so after the ERC is included. In Finland district heating plants with boiler capacity less than 20 MW_{th} are excluded from emission trading.

In Sweden the fuel mix used in district heating has been completely transformed. In 1980, 90% of 34.5 TWh of energy used in district heating was from imported oil, as shown in Table 6.3-2. By 2004, biofuel, waste and peat accounted for 32.9 TWh or 62% of district heating energy requirements, compared to 4.1 TWh, or 8%, for oil. Biomass-fueled district heating systems usually operate on lower cost feedstocks, such as forest chips and bark. If these sources are unavailable, more expensive sources such as wood pellets are used, especially for peak load. District heating plants can use tall oil, but tall oil is more expensive than alternatives, such as pellets. Palm oil can be used, but Sweden is becoming more hesitant to use it because of the poor environmental reputation it has received, and also palm oil is currently expensive at 11.5€/GJ. Pyrolysis oil can replace all palm oil, where it is used. As shown in Table 3.3-2, Pyrolysis Oil from all sources can compete against heavy fuel oil. This market is 4.1 TWh, or 14.7 million GJ, equivalent to 820,000 tonnes of Pyrolysis Oil, or 18 200-tpd plants. Pyrolysis Oil can also compete in the biofuel market, almost ten times larger than the oil market, but it has to compete on price and convenience. Pellet prices as of Sept 2006 are $Cdn175-190 per tonne delivered to a Swedish port[59], or 7.1-7.7€/GJ, so Pyrolysis Oil from most sources is competitive.

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[56] Solid and Liquid BioFuels Markets in Finland (Country Report of Finland-2006): Jussi Heinimö, Lappeenranta University of Technology.
[57] Energia Finland- Presentation Mirja Tiitinen, Dec 23, 2005
[58] Statistics Finland. Energy Statistics 2004. Official statistics of Finland. Helsinki. 149 p.
[59] Staffan Melin, Canadian Bioenergy Association, for pellets of 4.8 MWh/tonne

However using Pyrolysis Oil would require retrofitting, which may be easy in some locations but more difficult and costly in others.

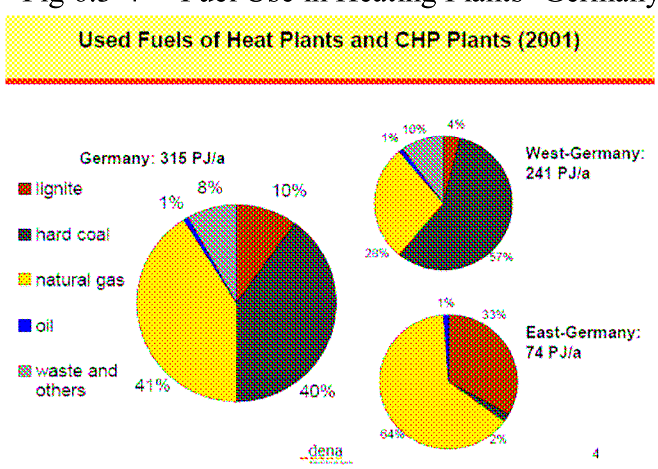
Table [60]6.3-2 Sweden

Energy Input for District Heating- TWh

	1980	2004
Oil	30.9	4.1
Natural Gas		2.4
Coal	0.4	3.5
Biofuels, waste, peat	2.3	32.9
Other	0.7	10.6
Total	34.5	53.5

Germany produces and delivers 1,281 MW of district heat in CHP plants, as shown in Fig 6.3-4. In East Germany 64% of the fuel used in district heating is natural gas, while 33% is lignite coal. In West Germany 28% of capacity is fueled by natural gas, and fully 57% by hard coal. Only 1% is fueled by oil. District heating capacity has declined from 1990, partially due to a reduction in heat demand, partially due to an increase in individual gas or oil residential heating systems. The government's focus is on decentralization, to develop small, local heat networks instead of large district heating plants. Furthermore, the trend is to upgrade from coal to combined cycle natural gas. Any plant can co-fire, but there is a strong movement against co-firing in Germany, and without the benefit of a meaningful feed-in-tariff, Pyrolysis Oil must compete against fossil fuels on price adjusted for any benefit from the EU ETS. Replacing oil in oil-fired district heating systems is only a small potential market. Of 315 PJ used in district heating, only 1% is fueled by oil, creating a market for perhaps 175,000 of Pyrolysis Oil, or 4 plants. There is a considerable amount of other biomass available[61] at low cost (€2-3/GJ), chiefly straw and in some cases forest thinnings.

Fig 6.3-4[62] -Fuel Use in Heating Plants- Germany



[60] Energy in Sweden- Fact and Figures- 2005
[61] Uwe Fritsche, Oeko- Insitut, Germany
[62] District Heating Policy in Transition Economies- Lars-Arvid Brischke, Dena 2004

In Denmark, district heating and CHP plants satisfy more than 80% of heat demand and more than 50% of electricity demand[63]. Publicly owned heating supply includes; 120 heat-only plants of which half are wood-based, 6 large CHP plants that use biomass as well as other fuels, and 30 CHP plants fueled chiefly by biogas. There are 200 privately owned heat and cogeneration plants, primarily delivering heat to greenhouses, the manufacturing industry, and institutions. Overall, 27% of district heat is from heat only plants (2% from oil and 2% from natural gas), and 73% is from CHP plants (17% from CO_2 neutral fuels and 58% from coal and oil)[64]. The Danish District Heating Association (DFF) acts as co-op buyer of pellets for its members, comprising over 400 district heating plants. DFF buys high-quality pellets- no bark, and less than 0.5% ash. With the severely reduced feed-in-tariffs, pellets and thus BioOil have to compete against fossil fuels largely on price and the ERC. While it is possible that a district heating plant or CHP plant could switch from pellets to Pyrolysis Oil based on price, they would only do so with demonstrated ability to provide large consistent volumes at competitive prices.

In Feb 2006, EU finance ministers agreed to add district heating to the list of sectors eligible for a reduced 5.5% VAT rate, extending this rate to 2010. France now has a VAT rate of 19.6%, and pressure is mounting to apply the reduced rate as soon as possible. Under the high rate, users of district heating networks were overtaxed by as much as €300 million over 5 years[65]. The French and Portuguese stand the most to gain as both countries had high VAT rates.

While the UK district heat market appears small relative to other EU countries, this market accounts for approximately 30% of the bioenergy consumed in the UK, representing about 0.5 Mtoe. An interesting feature is that there are currently 4.42 million unconnected dwellings to the main gas grid in the UK which represent a technical potential market of nearly 79 TWh/yr. The technical potential for all sectors is estimated at about 180 TWh/yr, compared to a current production of 6.31 TWh/yr. The heat market is very attractive, firstly for its size, and secondly for its competitiveness with natural gas, 1.5 pence/kWh for pellets compared to 2.34 p/kWh for natural gas. It is expected that this market will largely be supplied domestically rather than by imports given that the majority of applications are small-scale. It would require the development of a good production and supply infrastructure. Traditionally, UK lacked experience in the production of pellets, as shown in this report.

6.4. Power Plants- Co-firing and Alternate Fuels

6.4.1. Technical Feasibility

6.4.1.1. Pyrolysis Oil

Technical feasibility encompasses transportation, storage and firing. Transportation and storage are outlined in Section 1 and Appendix 1. To accommodate the acidity of

[63] Bioenergy 2003-05- Development of the Production and Use of Bioenergy in the Baltic Sea Region- Norcn Final report, Sept 2005
[64] Danish Board of District Heating. www.dbdh.dk
[65] www.euroactiv.com

Pyrolysis Oil requires tanks made of stainless steel, PVC etc. With a pour point of -30° C, BioOil can be stored below freezing but it will become very viscous and very difficult to pump or transport. Similar to Bunker "C", Pyrolysis Oil can be heated prior to use in order to facilitate flow. Some Pyrolysis Oils may experience single-phase separation during long storage and transport, and if so it must be mixed prior to use. It is easier to keep Pyrolysis Oil mixed rather than allow it to separate and then mix it later. Adding alcohol stabilizes phase separation. Both glycerin from biodiesel[66], and ethanol[67] have been successfully used as additives.

While Pyrolysis Oil can be co-fired with coal, the most natural substitution is for oil in both oil-fired plants and natural-gas fired plants. Many natural gas plants co-fire with bio-oils, such as palm oil (CPO) and PFAD. All that is needed for these fuels are separate burners. Many natural gas plants are configured to run on oil in case of technical or market problems with natural gas. For example, the Clauscentrale plant in Maasbracht (Essent) has two identical 640 MW units, each of which burns 180,000m^3 gas per hour, but can also operate on fuel oil. To reduce GHG emissions and to take advantage of Dutch incentives to use biomass, Clauscentrale has been using vegetable oils as fuel. In 2004, Claus co-fired from 20% up to 70% crude palm oil (CPO), palm fatty-acid oil (PFAD), and vegetable fatty-acid oil, depending on availability and price. Essent questioned Malaysian palm oil in mid 2005 as the sustainability of this oil came into question and alternative oils were used. The alternative oils with a lower pH level than palm oil caused Essent to invest in stainless steel pipes, pumps and coated/isolated tanks at the plant. Co-firing bio-oil in a natural gas plant requires dedicated burners. Also, to prevent pipe corrosion, fuels should have pH between 4 and 7. Pyrolysis Oil has pH of 2-3 and would require separate burners, stainless steel tanks and pipes.

Co-firing with Pyrolysis Oil in a natural gas plant may cause other technical difficulties, such as at Clauscentrale. The heat value of palm oil is 36 GJ/tonne while Pyrolysis Oil is only 18 GJ/tonne. At the Clauscentrale, alternative fuels need to have similar heating values and maximum water content of 0.5% in order to secure maximum load capacity. The capacity of the oil pipes and pumps at Clauscentrale limit the amount of Pyrolysis Oil that could be burned. The plant would have to either run at less than full capacity with Pyrolysis Oil, spend capital to replace pipes, pumps and burners to maintain generating capacity, or burn Pyrolysis Oil at night or on weekends when the plant does not have to supply maximum load.

Ash levels are another issue with alternative biofuel. In the Netherlands the limit for fly ash is 0.06%. Since PFAD is above 0.06%, it must be burned with crude palm oil (0.01%) in order to reduce average ash emissions.

Pyrolysis Oil also can be co-fired in coal plants. In June 1997 Manitouwoc Public Utilities of Wisconsin USA conducted a commercial trial of co-firing Pyrolysis Oil in their #6 unit, a 20 MW coal-fired stoker boiler. The Pyrolysis Oil used was RTP™ oil from Ensyn. The Pyrolysis Oil was delivered to the power station by 18,000 litre tankers.

[66] Peter Fransham- Advanced Biorefinery Inc.
[67] Colin McLerracher- DynaMotive Energy Systems

The boiler was modified to permit co-firing, though the retrofit was minimal, with two injection ports being installed according to specifications from Ensyn. During co-firing, Pyrolysis Oil provided 5% or about 1 MW of the 20 MW output. Co-firing took place over one month for 370 hours. Plant monitoring showed no detrimental performance, sulfur emissions were down by the predicted 5%, no physical changes to the ash were observed, and there was no observed effect on the boiler or peripheral equipment.

DynaMotive is moving forward with development of 500-tpd of Pyrolysis Oil capacity in Nova Scotia, Canada, the first phase being a 200-tpd plant. It is intended that production be utilized in a large-scale coal power plant. Tests were scheduled for the summer of 2006 to co-fire Pyrolysis Oil in the plant. The plant also requires oil as a start-up fuel and a back up fuel. Pyrolysis Oil will replace fossil fuel for these purposes. Permanent fuel handling systems are being installed now. Co-firing test results are expected in late 2006. Similar tests are being undertaken in the UK.

6.4.1.2. Char

Char is a significant co-product of the pyrolysis process. It is a granular solid with properties similar to coal and therefore it simply can be added to the coal feedstock entering the burner[68]. While there is a maximum amount of raw biomass that can be co-fired with coal before the biomass begins to gum up grinders, char can be co-fired without limit. Tests co-firing char with coal in power plants are going on now.

6.4.2. Markets

Pyrolysis Oil can be co-fired in oil plants, or in natural gas plants that are already configured to burn oil as an alternate, or with coal. Pyrolysis Oil also can be used as a start up fuel or back up fuel for these facilities. As shown in Table 6.4-1, in 2003 27% of European power production (860,000 GWh) was from coal, 19% from natural gas, and 5% from oil. At 38% efficiency, coal produces 2.9MWh_e/t, thus 297 million tonnes coal was used to generate power. Even to replace 10% of the coal, 30 million tonnes, it would require approximately 45 million tonnes Pyrolysis Oil (17.8 GJ/t) or 28 million tonnes of char (28 GJ/t)[69]. Demand is unlimited, if the price and incentives are right.

Table 6.4-1

Europe Electricity Production 2003

	Power Production			Efficiency		Fuel
	GWh	%	GJ/tonne	MWhe/t	%	MT
Coal	860,301	27%	27	2.9	38%	296.7
Oil	161,779	5%	42	4.9	42%	33.0
Natural Gas	605,992	19%	50	7.6	55%	79.7
BioMass	38,061	1%				
All Other	1,530,530	48%				
Total	3,196,663					

[68] Dr A.V. Bridgwater- Aston University, Birmingham UK

[69] Assumes same approximate plant efficiency as coal. Char may increase efficiency due to fewer required tonnes and less grinding. Pyrolysis Oil may also increase efficiency due to less coal grinding.

6.4.2.1. Coal Fired Power Plants

Coal is by far the lowest cost fuel on a GJ basis. The average import price to the EU in 4Q 2005 was €1.84/GJ. The delivered cost of Pyrolysis Oil or char has to be competitive with the heat equivalent value of coal, adjusted for any relevant Emission Reduction Credit and any domestic incentive or Green Certificates. The value of an Emission Reduction Credit in the EU trading system in July 2006 was €16.25/tCO_2e, or €1.59/GJ, so a power plant may be willing to pay up to €3.43/GJ (€1.84/GJ + €1.59/GJ), even before considering domestic incentives. As shown on Table 3.3-2, imported char is competitive from the lowest through the highest cost feedstock (BC residue + MPB at €3.12/GJ and Brazil bagasse at €1.56/GJ). Thus, char production should be competitive with coal, when the ERC is included in the price. However, it is unlikely that the customer will pass all of the ERC value to the char manufacturer. Also shown on Table 3.3-2, Pyrolysis Oil delivered costs are €4.8-7.8/GJ for large tankers, and €6.4-10.5/GJ for small tankers, so for Pyrolysis Oil to replace coal will depend on domestic incentives.

Cost is a major consideration, especially transportation. For imports, delivered costs will be lowest for power plants near ocean ports or on an adjacent waterway. VTT is currently undertaking a study[70] scheduled for completion in late 2006 that analyses coal plants near ports and on close waterways in Finland, Sweden, Denmark, Germany, Netherlands and the UK. Roughly 70 coal-fired power plants are on ports or inland waterways. They use more than 400 TWh coal annually. If these power plants converted 10% of fuel to biomass, they would need 40 TWh/year of biofuel. This is equivalent to 21 million solid m^3 of forest chips, or 4.3 million tonnes of wood pellets (at 19GJ/tonne), or 4.7 million tonnes Pyrolysis Oil (at 17.8 GJ/tonne), or 2.9 million tonnes char (at 28 GJ/tonne). This is equivalent to Pyrolysis Oil production from over 100 200-tpd plants, or char production from 200-300 plants, depending on the feedstock.

Pyrolysis Oil can be used as a start-up fuel in coal power plants. A popular renewable startup fuel is tall oil, a byproduct of pulp manufacturing. The market for start-up fuel is approximately 400,000 tpa. Since tall oil is 25.1 GJ/tonne and Pyrolysis Oil is 17.8 GJ/tonne, the market is equivalent to 560,000 Pyrolysis Oil or 12 200-tpd plants, a reasonably sized market.

The large coal co-firing market will depend on domestic incentives, feed-in-tariffs in the Netherlands, Germany, France, Austria and Denmark, and Renewable Obligations supported by a Certificate program[71]in Belgium, Sweden, and the UK. These markets are addressed in Regional Issues 6.4.3 below

6.4.2.2. Natural Gas and Oil Fired Power Plants

The natural market for Pyrolysis Oil is natural gas power plants for co-firing and as backup fuel. As shown in Table 6.4-2, 582 TWh of power was produced in EU25 in 2003

[70] Study on Potential Users of Solid Biofuels in Selected EU Countries in the Baltic Sea and the Nordic Sea Regions- VTT- Finland [Note- Incomplete; Confidential until Oct 6, 2006]
[71] Bioenergy Implementation in Europe- SenterNovem

(slightly different from Table 6.4-1 above). The largest six users of natural gas for power, representing 80% of gas-fired power in Europe were UK (151 TWh), Italy (123 TWh), Germany (66 TWh), Netherlands (60 TWh), Spain (41 TWh) and Belgium (24 TWh)[72]. The seven largest users of oil for power were Italy (76 TWh), Spain (24 TWh), Greece (8.7 TWh), France (8.7 KWh), UK (7 TWh), Portugal (6.2 TWh) and Germany (4.7).

Table 6.4-2- Power production in EU by fuel

Gross Electricity Generation
2003 (in TWh)

	Total	Conventional Thermal	- Coal	- Oil	- Gas	- Other	Nuclear	Pumped Storage	Renewables (*)
EU25	**3121**	1714	960	162	582	10	974	35	*399*
EU15	**2766**	1452	739	150	554	9	898	32	385
BE	**84.6**	34.5	9.6	1.0	23.6	0.3	47.4	1.1	1.7
CZ	**83.2**	55.1	51.0	0.4	3.7	0.0	25.9	0.4	1.9
DK	**46.2**	37.5	25.3	2.3	9.8	0.0	-	-	8.7
DE	**599.5**	382.3	306.5	4.7	65.8	5.4	165.1	5.2	47.2
EE	**10.2**	10.1	9.4	0.0	0.7	-	-	-	0.0
EL	**58.5**	52.1	35.2	8.7	8.0	0.2	-	0.6	5.8
ES	**262.9**	139.4	74.7	24.0	40.6	0.0	61.9	2.8	58.8
FR	**566.9**	55.6	26.3	8.7	20.6	0.1	441.1	5.2	65.1
IE	**25.2**	23.7	8.2	2.5	13.1	-	-	0.4	1.1
IT	**293.9**	239.3	38.8	76.0	122.6	1.9	-	10.5	44.0
CY	**4.0**	4.0	-	4.0	-	-	-	-	0.0
LV	**4.0**	1.6	0.0	0.1	1.5	-	-	-	2.3
LT	**19.5**	3.0	-	0.3	2.5	0.2	15.5	0.7	0.3
LU	**3.6**	2.6	-	-	2.6	0.0	-	0.8	0.2
HU	**34.1**	22.8	9.2	1.6	12.0	-	11.0	-	0.4
MT	**2.2**	2.2	-	2.2	-	-	-	-	0.0
NL	**96.8**	87.5	24.3	2.9	60.0	0.3	4.0	-	5.4
AT	**63.2**	22.7	8.4	1.8	12.2	0.3	-	2.0	38.5
PL	**151.6**	147.8	140.7	2.5	4.4	0.3	-	1.6	2.3
PT	**46.9**	28.4	14.5	6.2	7.7	0.0	-	0.3	18.1
SI	**14.0**	5.5	5.1	0.1	0.4	-	5.2	-	3.3
SK	**31.2**	9.6	6.0	0.7	2.8	0.1	17.9	0.2	3.5
FI	**84.2**	42.1	26.2	0.9	14.5	0.5	22.7	-	19.4
SE	**135.6**	8.7	2.7	3.9	1.8	0.3	67.4	0.1	59.4
UK	**398.6**	296.0	138.2	7.0	150.7	0.0	88.7	2.7	11.2

Source: Eurostat
Note: (*): not including hydro from pumped storage

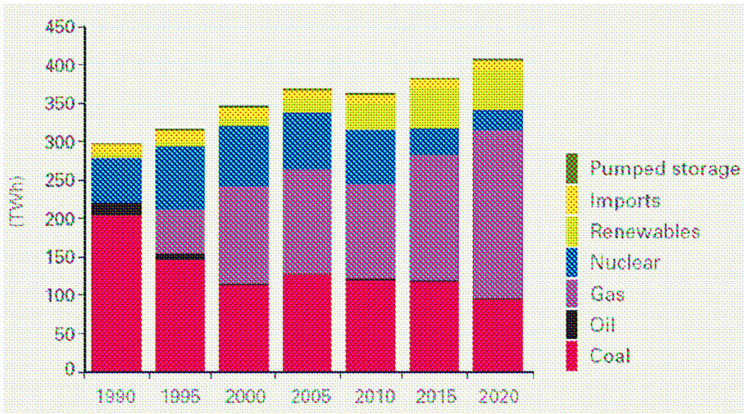
6.4.3. Regional Issues

6.4.3.1. UK

The UK generates 37% of its electricity from gas-fired power stations, 34% from coal, 20% from nuclear, and 5% from renewables[73], as shown in Fig 6.4-2. As a result of EU environmental legislation, 8 GW of coal power generation, about 1/3 of coal capacity, must shut down by 2015. In addition, 10 GW of nuclear power will have reached the end of its useful life by 2024. As shown, much of the new capacity to replace coal and nuclear has been projected to be from gas-fired power stations, however that will depend on the price of natural gas, which is currently high.

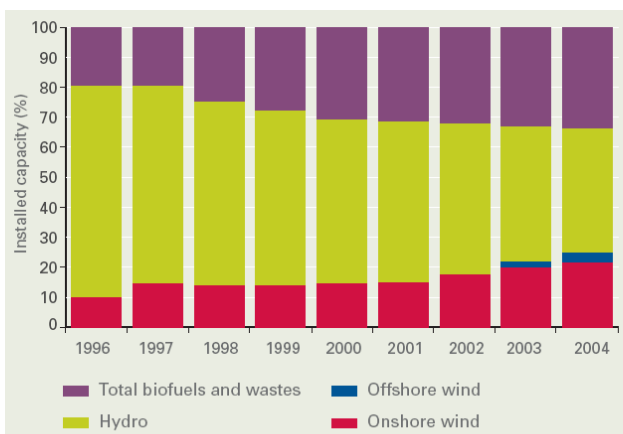
[72] Eurostat
[73] Energy Review July 11, 2006

Fig 6.4-2 Generation Mix Projection to 2020



To ensure a stable investment environment and encourage investment in electricity generation, the UK is committed to a strong carbon price signal and expects the EU Emissions Trading System to be the mechanism. The government will strengthen its commitment to the domestic Renewables Obligation (RO) system, effective in increasing power from RO-eligible sources from 1.8% in 2002 to 4% in 2005 (Energy Review). As shown in Fig 6.4-3, biomass and wind provide a growing proportion of renewable energy.

Fig 6.4-3 UK Power Mix



There are 17 coal-fired power stations in the UK. Fifteen of them, with a total capacity of 28 GW, have co-fired biomass as shown in Table 6.4-3 below. The largest coal power plant is Drax Power Ltd in Selby North York, with capacity 4,000 MW. Drax is investing in co-firing technology with the aim to significantly increase biomass usage by 2009.

Table 6.4-3

Biomass Co-firing at Coal Plants

	Capacity MW	Biomass
Drax	4,000	Various
Longannet	2,400	Waste
Didcot	2,100	Wood
Ferrybrid.	2,035	Various
Kingsnorth	2,034	Various
Ratcliffe	2,010	Various
Cottam	2,000	Various
Fiddler's Ferry	1,995	Various
West Burton	1,980	Olice Cake
Eggsborough	1,960	Various
Aberthaw	1,445	Various
Cockenzie	1,200	Wood
Tilbury	1,085	Wood
Rugeley	1,000	Various
Ironbridge	950	Various
	28,194	

Co-firing material varies. To-date one company has imported wood pellets from the Baltic, Shea meal and pellets from Scandinavia, palm kernel expeller, and olive pulp and olive pellets from the Mediterranean. Prices were £3.50-5.50/GJ. Drax buys pellets from the Baltic and Sweden, and is looking at bark and sawdust. For Drax, volumes of 100,000 tonnes annually are expected to grow to 2-300,000 tonnes. Although imported biomass is allowed, the focus of the UK government has been to promote growth of domestic energy crops as biomass fuel. For example, local authorities are encouraging development of energy crops within 50 miles of the Drax plant, such as short rotation coppice willow, forestry, miscanthus, and rape[74].

Legislative measures have encouraged co-firing, but have created uncertainties and restrictions as well. The key aspect is the declining cap on the level of co-firing allowed, and an increasing level of biomass fuel that must come from energy crops, as shown in Table 6.4-4. Under existing guidelines, by the time coal plants are scheduled to have shut down, a maximum of 5% of energy can come via co-firing biomass, and 75% of the biomass must be from energy crops, as opposed to waste biomass currently imported. Accordingly, the maximum allowed from biomass waste is in excess of 2,200 GWh in 2006-10, but falls to 550 GWh in 2013-14. This is still a sizable amount of biomass. Within the context of the Energy Review issued July 12 2006, there was broad consensus that co-firing should play a long-term role in reducing carbon emissions. So, while the incentives in the RO system still decline over time, changes in the future could reinstate meaningful support for co-firing.

[74] www.draxpower.com

Table 6.4-4

Targets/Restrictions- Co-firing

	RO	Co-firing Cap	Max Co-firing*	Min. Energy Crops	Max from Imports	
	%	%	TWh	%	GWh	
2002/03	3.0%	25%	2.4			
2003/04	4.3%	25%	3.4			
2004/05	4.9%	25%	3.9			
2005/06	5.5%	25%	4.4			
2006/07	6.7%	10%	2.2		2,200	
2007/08	7.9%	10%	2.5		2,500	
2008/09	9.1%	10%	2.9		2,900	
2009/10	9.7%	10%	3.2	25%	2,504	**
2010/11	10.4%	10%	3.4	50%	1,790	
2011/12	11.4%	5%	1.9	75%	490	
2012/13	12.4%	5%	2	75%	534	
2013/14	13.4%	5%	2.2	75%	576	
2014/15	14.4%	5%		75%	620	
2015/16	15.4%	5%		75%	663	

* estimate   ** UK Country Report est

Today ROCs are eligible only up to 10% biomass for co-firing, while for a dedicated biomass power plant unlimited ROCs are eligible if no more than 10% fossil fuels are used. Policy favours biomass plants. In 2005-06 almost 900,000 ROCs were issued for biomass generation, while 3.4 million were issued for co-firing. Under current policy, a major opportunity exists to convert a fossil fuel power plant to burn only biomass.

It is estimated that plants in the UK can co-fire 3-5% biomass using existing milling equipment, but that higher levels will require capital investment, such as separate milling systems and direct injection systems. Due to uncertainty of future incentives, companies generally have not invested in special equipment or developed secure long-term supply chains[75]. Since char is much more like coal, no special equipment is required to increase co-firing beyond 5%, and therefore this presents a major market for char.

In the UK very little is said about co-firing BioOil with natural gas, though the Netherlands has had considerable success with it. No known bio-liquids for co-firing have been imported. Since more power is created by natural gas than coal, this represents a sizable market. In 2006, in the UK the price of gas was 9.16€/GJ after tax. The landed price of BioOil is projected to be 4.8-7.8€/GJ, and in addition the plant would receive a ROC equivalent to 4.6-5.6€/GJ.

Though the 2006 Energy Review renewed notional support for co-firing, it noted that co-firing is economic in many instances, if supported by ERCs, and therefore may not need full support of the RO. RO may support co-firing for a decade but at lower benefit (less than 1 ROC per MWh), and with no cap on total volume of co-firing.

With buy-out fees for insufficient ROCs at £4.11/$GJ_{primary}$ (€5.63/GJ), and companies recently paying £3.50-5.50/GJ (€4.40-7.53/GJ) for biomass waste, all char imports would be competitive and almost all Pyrolysis Oil imports if by large tanker.

[75] IEA Task 40 UK Country Report-2006

6.4.3.2. Italy

There is an opportunity for biomass for co-firing in coal power plants. In 2004 coal imports increased 16%, partly due to the increase in price of alternative fossil fuels. A focus on renewable resources creates an opportunity for the forest sector to provide biomass for co-firing, however there is the risk of a reduction of standing carbon stock in forest ecosystems, which would run contrary to the objectives of the Kyoto Protocol. Currently two power plants use biomass. Enel, the largest electricity producer in Italy, is co-firing and has a permit to mix 10% of biomass to coal without major modification to the plant. The Torrevaldaliga Nord power plant in Civitavecchia also is fuelled with coal and biomass. The government intends analyse the results obtained by co-firing at these plants, and if no technical or logistics problems occur, such as with biomass supply, then new initiatives in this sector will be taken.

Power plants fuelled exclusively with biomass are operated during periods of very high electrical demand. There are 27 such biomass power plants; Lombardia (7), Calabria (5), Piedmonte (4), Emilia Romagna (3), Veneto (2), Molise (1), Campania (1), Puglia (1), Toscana (1) and Umbria (1). They have a combined production of 257.2 MW. This production is miniscule compared with the production from other fuels, 53,000 MW, but it is a first effort to produce the 25% of electricity by renewable energies by 2010.

Bio-oil production and utilisation is increasing in Italy. The Italgreen Energy power plant (100 MW), known as Pentesilea, was built and started commercial operation in the spring of 2004. The plant supplies electricity to the Italian public grid and produces steam for industrial processes. The plant was commissioned using bio-oils (vegetable oils) from the very start of power generation. ItalGreen is part of the Casa Olearia Italiana Group (COI), a world-leading supplier of household and commercial food oils.

In Italy, power generation companies must produce 3% of their power from renewable sources, or buy green certificates to make up the shortfall. Many have encountered a shortfall and hence a lively market has been created for these certificates. With this market, power plants that have low greenhouse gas emissions benefit twice from their investment; firstly from selling their electricity to the national grid, and secondly from trading their green certificates. The Italian government has imposed very tight emission controls on plants burning liquid biofuel.

6.4.3.3. Germany

There is a large political opposition to co-firing in Germany. Although a system of feed-in-tariffs has been implemented, none are provided for co-firing, only for plants using exclusively biomass. Furthermore, the focus in Germany is to promote small and decentralized power generation from renewables, so only biomass plants with capacity less than 20MW qualify for these incentives. Consequently, there are now 200 MW generated in small plants with diesel engines running on palm oil, of which 20 plants have been recently built. This could be a meaningful market for Pyrolysis Oil. As in the Netherlands, palm oil has been a concern of the NGO community due to concerns over sustainability, and a hearing on palm oil took place in October 2006 in the Federal

Parliament. It is important that palm oil, possibly unsustainable, be differentiated with sustainable pyrolysis oil. A debate of the feed-in-tariff system is scheduled for 2007 with possible change in 2008, but its importance may make it happen sooner.

6.4.3.4.Netherlands

In 2004-05 Essent Energy Trading BV increased biomass co-firing to 10-20% at its 1245 MW Amer coal-fired power facility at Geertruidenberg, mainly using wood pellets. As long as biomass is cost-competitive, the level of co-firing at Amer is limited only by fly ash rules and permits. In the same time period, Essent co-fired in its Clauscentrale natural gas power plant. In 2005 the Gelderland and Harculo power stations (Electrabel) initiated procedures to obtain a new environmental permit to co-fire with biomass, however the plant experienced technical difficulties with co-firing with palm oil, and objections were raised on questions of sustainability resulting in problems with permitting.

Considerable growth in biomass energy production and applications for the MEP feed-in-tariff resulted in a government budget for feed-in-tariffs in 2004-05. Also, Malaysian palm oil, which received the tariff, was later assessed to be from unsustainable sources. Accordingly, the government decided in May 2005 that large bioenergy projects would receive no feed-in-tariff 2005-07. They were reduced effective July 1 2006, with power from clean wood pellets to receive $€_{ct}$6.4/KWh, and power from agricultural residues, waste wood and Pyrolysis Oil to receive € $_{ct}$2.4/KWh. In a surprise policy move, in mid August 2006 feed-in-tariffs for all new applicants were set to zero, with feed-in-tariffs to previous applicants to continue, in some cases to 2013. A federal election was held in November 2006 and the feed-in-tariff policy will not be known until after that, however, it is possible that incentives will be reinstated for new applicants, but only at low levels. Incentives may soon be based on the level of sustainability. Also, the incentive system may evolve to a bidding system, whereby producers will bid on providing power at a bid price. In this way government hopes to provide power at the lowest cost.

As a result of technical and permitting difficulties with co-firing, and the drop in feed-in-tariff for Pyrolysis Oil use, which jeopardizes the economic viability of biomass co-firing, Electrabel has decided not to pursue Pyrolysis Oil co-firing at the Harculo power plants. It also has iced studies for similar projects at the Eems and Bergum plants.

As a result of the unsustainable palm oil situation, the Netherlands is now developing sustainable criteria for bio-liquids and bio-solids, scheduled for implementation in 2007. If they are too demanding, the biomass market in the Netherlands could disappear in short term. For example, if the guidelines require establishing the sustainability of an entire supply chain, companies will not be able to do so immediately. In the experience of Essent, active in its Green-gold program, it takes 3-4 years to establish sustainability for a whole chain. It may make sense to phase in criteria, over a 3-4 year time period, and agree to accept sustainability for perhaps 75% of a supply chain.

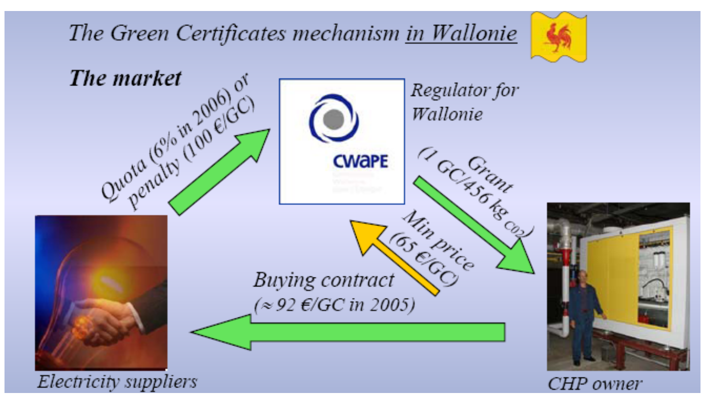
With the current incentive system, biomass is not always competitive with fossil fuels. For example, Essent finds it makes business sense only to co-fire bio-oil with natural gas in Q4 and Q1, during cold months when natural gas prices are high. Permitting is also a major barrier to biomass use. Now a company needs a new permit for co-firing in Netherlands, which can take 24 months.

Dutch policy in the last 15 years has been extremely volatile, and incentives now favour wood pellets over other renewable fuels. As a result, Canadian pellet manufacturing capacity is growing exponentially, as are plans to co-fire with pellets in Netherlands coal plants. Until Pyrolysis Oil is recognized as being from sustainable sources and subsequently receives the same treatment as pellets, the market for Pyrolysis Oil will be limited. It is uncertain what category char is in, and until that is defined and power plant owners know the official feed-in-tariff, use of char is likely to stall also. It is anticipated that recognition of Pyrolysis Oil as being sustainable over perhaps 100 years that large volumes will be destined for the Netherlands.

6.4.3.5. Belgium

Electricity generation in 2003 was approximately 84TWh; 10 TWh from coal, 24 TWh from natural gas and 47 TWh from nuclear. Belgium is divided into two major regions, Flanders and Walloon, and each has implemented its own approach to a rather complex Green Certificate (GC) mechanism. For example, in Walloon electricity suppliers must achieve 6% green power by 2006, or pay a penalty to the regulator (Cwape) of €100/GC. Producers are granted 1 GC for each 0.456 tCO_2e in GHG reduction. Suppliers must earn or buy sufficient GCs to achieve 6% green power, or face the penalty. The current cost to suppliers for green certificates is €30/GC, but only when they are available.

Fig 6.4-4



In Flanders, the regulator (Vreg) grants electricity producers 1 GC for each MWh_e of green power they produce. Electricity suppliers buy power from producers at €30/MWh_e, but suppliers must achieve a target of 3% green electricity by 2006, for which they currently pay producers €111/GC. If they do not achieve 3%, they must pay the regulator €125/GC needed to meet the target. This penalty is 2-3 times the value of the power and is thus a very high penalty. Green credits can only be purchased from power producers if they are available. If they are not, the penalty must be paid.

Both certificate mechanisms are on a sliding scale, that is the amount of renewable electricity production goes up each year, as shown in Fig 6.4-5. By 2010 the projected quota in Flanders is 6%, while Walloon and Brussels are undecided.

Fig 6.4-5

The Green Certificates mechanism

Evolution of the green electricity production (expected…)

Years	Quota/Penalty Green Cert.		Quota/Penalty Cogen Cert.		Quota/Penalty		Quota/Penalty	
2002	0.8%	75 €	-	-	-	-	-	-
2003	1.2%	100 €	-	-	-	-	3%	75 €
2004	2%	125 €	-	-	2%	75 €	4%	100 €
2005	2.5%	125 €	1.19%	40 €	2.25%	75 €	5%	100 €
2006	3%	125 €	2.16%	45 €	2.5%	75 €	6%	100 €
2007	3.75%	125 €	2.96%	45 €	?	100 €	7%	100 €
2008	4.5%	125 €	3.73%	45 €	?	100 €	?	?
2009	5.25%	125 €	4.39%	45 €	?	100 €	?	?
2010	6%	125 €	4.9%	45 €	?	?	?	?
2011	?	125 €	5.2%	45 €	?	?	?	?

In Walloon GCs are not awarded for actual GHG reduction but against GHG reduction of the most efficient reference case, a combined cycle gas turbine. So, reducing coal consumption reduces GHG emissions at 0.385 $tCO_2e/MWhp$, but reductions are only awarded at the factor for natural gas, 0.251 $tCO_2e/MWhp$. This stipulation hinders incentive to co-fire in coal plants, and consequently no co-firing occurs in Walloon. As an example, shown in Fig 6.4-6 below, co-firing Pyrolysis Oil with coal but using natural gas as the reference case results in 40% of GCs being awarded. This restriction only applies to co-firing, and not to 100% biomass plants. Walloon also has a biomass certification system in place to ensure sustainability of biomass sources.

Fig 5.4.3-8 Co-firing BioOil with Coal

Green Certificate Calculation- Walloonia, Belgium

$$\frac{\text{CO2 coeff co-firing fuel}}{\text{CO2 coeff nat gas}} \times \frac{\text{efficiency reference plant}}{\text{efficiency of co-firing fuel}}$$

$$\frac{\text{70 Kg/MWh}}{\text{251 Kg/MWh}} \times \frac{0.55}{0.38} = 40\%$$

Flanders has not adopted a legal certification system, but energy consumption of the entire supply chain must be included when calculating GCs. For example, if a tonne of wood pellets is co-fired with coal and produces 1.77 MWhe, the benefit must be reduced by the energy consumption of the supply chain, including pelletizing, drying, and transportation, as shown Table 6.4-4.

Table 6.4-4

Flanders- Wood Pellets from Canada

	KWhe
1 tonne pellets	1,770
pelletizing	-100
drying	-6
train transport	-108
sea transport	-232
Subtractions	-446
Net benefit	1,324

Electrabel is the largest producer of electricity in the Benelux countries and a leader in Europe. Within this policy framework, Electrabel has been converting older units to combined cycle gas turbine (CCGT) units with efficiencies of over 55%. In 2005, Electrabel commissioned three new CCGT power stations including Zandvliet in Belgium (395 MW), and Amercouer (420 MW). In the Netherlands it is looking to replace two older units in the Flevo plant with two 400-450 MW CCGT units. Co-firing at these new plants is possible since savings in GHG emissions receive a Green Credit.

Electrabel is also increasing the amount of power generation from burning biomass, from 440 GWh in 2004 to 1146 GWh in 2005. In 2005 it converted the Awirs coal-fired power station into a unit fully fuelled by biomass (80 MW-wood dust)[76]. All co-firing in Electrabel takes place in Flanders. In 2005, facilities for co-firing biomass with coal were commissioned in Langerlo (28 MW- wood dust), and Rodenhuize (66 MW- wood pellets). Ruien took measures to increase wood dust combustion by 30 MW, and Langerlo and Mol were granted permission to co-fire with coffee grounds.

Policies do not favour co-firing in Walloon, and although allowed in Flanders the future of coal power there is in question. Co-firing with char can be a major market in Belgium, because it is cost competitive with coal, does not depend on Green Credits, and is a by-product. Co-firing Pyrolysis Oil with coal is feasible in Flanders, if it allows Green Credits. There is almost no oil power generation in Belgium. Co-firing Pyrolysis Oil with natural gas should be a major market. The price of gas in Belgium June 2005 was 6.2€/GJ, and landed costs of Pyrolysis Oil are 4.8-7.8€/GJ, before ERCs.

6.4.3.6. Finland

Total consumption of electricity in Finland was 87 TWh in 2004. The primary energy sources of electricity production were: 25% nuclear, 18% coal, 17% hydro, 12% natural gas, 12% solid biofuels, 8% peat, and only 2% from oil. Renewable energy sources, mainly hydropower and wood fuels, covered 28.7% (28.2 TWh) of domestic electricity production. The EU RES-E Directive set a target of 22.1% of electricity from renewable energy sources by 2010 in the EU. The European target has been transformed into targets for the Member States, which for Finland is 31.5% renewable electricity by 2010.

In Finland, electricity is generated in about 400 power plants using different energy sources and production technologies. The overall efficiency of electricity production is high thus major utilization of CHP. 28 TWh (34%) of electricity was produced in CHP plants of which approximately 10 TWh is from biomass. Cogeneration has been the natural choice in Finland since both heat and electricity are required in industry as well as in municipalities. In Finland electricity generation from biomass took place almost totally in power plants using fluidized combustion technology (FBC), which can utilize many types of solid fuels with difficult properties such as uneven particle size and high moisture content. Several FBC plants co-fire peat and coal with woody biomass and there seems to be no technical obstacles to use Pyrolysis Oil in FBC boilers. Nevertheless, Pyrolysis Oil is not competitive with solid wood fuels, that have a market price of 3 €/GJ.

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[76] Electrabel Environmental Report 2005

The other technically potential market for Pyrolysis Oil is co-firing in coal and natural gas fired boiler plants. In 2004, 171 PJ of coal was used in separate electricity generation in condensing power plants and 51 PJ in CHP or heat only plants. The consumption of natural gas was approximately 160 PJ, almost totally in CHP or heat production. Fuels used in electricity production are not taxed in Finland and subsides for electricity generation from biomass are at a relatively low level (2.5-6.9 €/MWh_e depending on the fuel) compared for some other EU countries. Unless Pyrolysis Oil is at a very low cost, it is not economic for in power production, despite the positive effect of emission trading.

6.5. Green houses

6.5.1. Technical Feasibility

Pyrolysis Oil was tested at the Top Gro Greenhouse, Aldergrove, BC, Canada in 2004. The test was a simple demonstration of substituting #6 fuel with Pyrolysis Oil fired in a standard industrial type 100 psig Cleverbrook hot water fire tube boiler. The existing fuel train was used with changes made to the electronic flame safety system, the mechanical fuel air ratio and the burner management. One tonne of Pyrolysis Oil was fired as a single fuel, maintaining the heating requirements for several hours. Substantial reductions in NO_x were noted. The existing automatic instrumentation followed the load demand and no smoke or lingering Pyrolysis Oil odour was noticed, clearly indicating complete and successful combustion.

In a second demonstration in 2006, Pyrolysis Oil replaced Bunker C (#6 heavy fuel oil) at Great Lakes Greenhouses Inc in Leamington Ontario, Canada. Two tonnes of Pyrolysis Oil from the West Lorne plant were burned during the 4-hour test. No modifications were necessary to switch from Bunker C to Pyrolysis Oil. The Pyrolysis Oil demonstrated very good ignition properties, steady flame characteristics, and a low emissions profile. The Greenhouse owner commented that the Pyrolysis Oil was very easy to pump and it allowed a much wider combustion tolerance and stability than Bunker C oil. Whereas Bunker C would typically extinguish, Pyrolysis Oil did not. The Pyrolysis Oil burned without any problems[77].

6.5.2. Market

While the greenhouse market could be large in terms of fuel need, it is also one of small users that would require a distribution system to move small volumes of Pyrolysis Oil. Many greenhouses are already served by district heating, and do not need separate systems for drying. As a result, greenhouses are regarded as a secondary market only.

6.6. Industrial Boilers

6.6.1. Technical Feasibility

Pyrolysis Oil is an effective substitute for diesel, heavy fuel oil, light fuel oil or natural gas in industrial, commercial and residential boilers. This is a relatively simple application requiring modifications to fuel nozzles and introduction of transportation

[77] DynaMotive News Release March 21, 2006

systems[78]. DynaMotive has repeatedly demonstrated successful burning of Pyrolysis Oil in boilers. The most recent demonstration was in June 2005 and involved firing in steam boilers at Erie Flooring, beside the West Lorne plant. The steam produced is used to heat the lumber kilns at the flooring company.

6.6.2. Market

The market for industrial boilers is large enough to be incalculable. Applications include boilers to produce steam for refineries, processing plants, manufacturing operations, hospitals, and universities. Many of these operate on fossil fuels and are potential Pyrolysis users. However, many are small systems requiring far less volume than a limekiln of power plant. Many may not have access to GHG benefits such as feed-in-tariffs. The extent to which these users will change fuels depends on a number of localized factors. Critical questions are;

- How much will is cost to change?
- How will my specific system operate?
- What support can I get if things go wrong?
- How dependable and consistent is the fuel source?
- Will I need a backup?
- Can I get locally produced Pyrolysis Oil?

These factors lean toward a slower penetration of small markets than for larger markets such as power plants. As such, these markets will not be estimated as part of this study.

6.7. Industrial Diesel Engines

6.7.1. Technical Feasibility

Pyrolysis Oil has been successfully demonstrated as a clean fuel substitute in slow and medium speed stationary diesel engines. Ormrod Diesels (UK), Wartsilla Diesels (Finland), Pasquali/Lombardini (Italy) and Sener-Tac (Germany) all have undertaken demonstrations.

6.7.2. Markets

Similar to industrial boilers, stationary diesel engines is a large and viable market, but individual applications are apt to be small, and will require a long lead-time for consumer acceptance to develop, distribution systems to be set up etc. As such, these markets will not be estimated as part of this study.

6.8. Turbines for Small Scale Power

6.8.1. Technical feasibility

DynaMotive designed its 100-tpd West Lorne plant to test both Pyrolysis Oil production at the commercial scale, and also to demonstrate its utilization in a small-scale turbine. DynaMotive linked with Magellan Aerospace, Orenda Division, to utilize Pyrolysis Oil in Orenda's OGT2500 gas turbine. Magellan developed the proprietary fuel handling and combustion systems to run on biofuel, and Pyrolysis Oil was extensively tested in Jan-

[78] DynaMotive Energy Systems website

May 2004. The pyrolysis oil met quality, efficiency and emission standards for commercial operation. In June 2005, DynaMotive and Magellan commenced power generation with Pyrolysis Oil from the West Lorne plant. As part of the demonstration phase, power was generated and delivered to the Ontario energy grid. As previously mentioned, the plant will be undergoing a 30-tpd expansion in early 2007 to increase power production for the grid.

6.8.2. Market

In Canada there are many remote communities that are neither on the grid nor connected to natural gas pipelines. In such communities diesel fuel is transported in at high cost, either by truck or plane, to fuel small turbines to create power. These communities often have access to forest biomass, and would be prime candidates for a Pyrolysis Oil plant to produce CO_2 neutral fuel for their turbines. Recently the provincial government in Ontario, as part of a plan to replace coal-generated power with renewable power, allowed for a price of 11¢/KWh for small-scale renewable power. With these incentives, even communities on the grid have the potential to generate local power from Pyrolysis Oil.

Small-scale power production is not prevalent in most of the EU, though it would be in far northern communities, or in countries with large area and small populations, such as Brazil. As in the applications of industrial boilers and diesel engines, viable distribution systems have to be set up in order for this market to grow. This will tend to be a limited market in the period to 2012.

6.9. Blending with Diesel

The simplest use of Pyrolysis Oil as a transportation fuel is in combination with a diesel fuel. Although biomass pyrolysis oils are not miscible with hydrocarbons, with the aid of surfactants they can be emulsified with diesel fuel[79]. Pyrolysis Oil is highly miscible in alcohols such as ethanol and methanol[80].

6.9.1. Technical Feasibility

Processes for producing stable micro-emulsions with 5-30% of Pyrolysis Oil in diesel have been developed at CANMET (Canada), and at the University of Florence where emulsions from 10 to 90% Pyrolysis Oil in diesel were produced. The resultant emulsions showed promising ignition characteristics. The drawback of this process is the high cost of surfactants and the high energy required for emulsion. In addition, significantly higher levels or corrosion/erosion were observed in engine applications with emulsions than with Pyrolysis Oil or diesel alone.

6.9.2. Market

DynaMotive indicates that this market is anticipated in the short term[81]. However, transportation fuels are not considered an early market, rather slow-speed, non-transportation diesel applications

[79] Overview of the Applications of Biomass Fast Pyrolysis oil- 2004- S. Czernik, A.V. Bridgwater
[80] DynaMotive website www.dynamotive.com/biopoil/industrialfuels.html
[81] Paul Hughes, COO DynaMotive.

6.10. Synfuel for Transportation Fuels

Synthetic fuel, or synfuel, is any liquid fuel obtained from coal, natural gas, or other solids including oil shale, tar sands or even biomass. The best known synthesis process is the Fischer-Tropsch synthesis, a well established technology. It was used on a large scale in Germany in World War II to make synthetic fuel when oil resources were scarce. The process is a chemical reaction whereby carbon monoxide and hydrogen are converted to liquid hydrocarbons, with the principal purpose to produce a synthetic substitute for petroleum.

Syngas is an intermediate in producing synthetic petroleum. It can be reformed into synthetic diesel, or Syndiesel, a CO_2 nuetral fuel that can replace diesel produced from crude petroleum. Syndiesel can be used in diesel engines without modification, including cars, trucks, buses and industrial diesel turbines. The performance of engines run on Syndiesel is equal or better than if run on conventional diesel[82].

Synfuel from the Fischer Tropsch process has been manufactured commercially in South Africa for decades. After World War II, since South Africa had plenty of coal but little petroleum, the government formed Sasol, a coal and oil company, which set out to develop domestic gasoline production from coal. As a favoured company in South Africa, Sasol enjoyed cheap credit, land, and labour, and in the late 1970s, using government loans, the firm built a large complex at Secunda, which has produced some 1.5 billion gallons of synthetic fuel. Sasol now has factories at Sasolburg and Secunda and has taken a stake in projects under contruction in Qatar, Iran and Nigeria. The privatized company continues to make profits off of earlier investments and enjoys significant cost advantages operating in South Africa. However, even with oil prices at $60 a barrel, the cost to build a plant is prohibitive, twice as much as a conventional oil refinery.

6.10.1. Technical Feasibility

In 2005 DynaMotive announced the successful conversion of Pyrolysis Oil to Syngas following full-day gasification testing at the research institute Forschungzentrum Karlsruhe (FZK), one of the largest research institutions in Germany. The objective was to establish if DynaMotive Pyrolysis Oil could be gasified and converted to Synfuel within a certain range of characteristics. The gasifier chosen for the tests processed 600kg/hr of Pyrolysis Oil and char mix on a continuous basis. Four tonnes of Pyrolysis Oil enriched with 25% char were provided for the tests. The test showed that Pyrolysis Oil is suitable for Syngas production, by demonstrating that a consistently good quality, industrial grade Syngas with low methane was achievable. Further tests are planned.

6.10.2. Market

In 2005 more than 50% of new cars in the EU were powered by diesel, representing the largest-growing market for mobile fuels. This is a vast market for synthetic diesel. However, the only way to produce synthetic fuel commercially is on a large scale. A

[82] DynaMotive news release Sept 22, 2005

commercial Fischer-Tropsch facility would require an investment on the order of $100 million. To supply feedstock to this facility would require a circle of Pyrolysis Oil production centers supplying Pyrolysis Oil to the plant. This format in turn would require a large volume of biomass in close proximity. A project of this magnitude is a long-term opportunity[83].

[83] Paul Hughes, COO DynaMotive

7. Assessment of Best Markets for Pyrolysis Oil/Char

7.1. Summary;

- Supply of Pyrolysis Oil will probably grow slowly for 1-3 years as investors vie for opportunities to build, biomass supply is arranged, and markets and prices become more apparent. Supply is estimated at less than 1 million tonnes in 2009, but can reach 5 million tonnes by 2012 if the large plants currently under construction prove successful and if sufficient capital investment is available.

Table 7.1 Pyrolysis Oil Supply to EU

	2007	2008	2009	2010	2011	2012
Supply	99	240	940	2,222	3,644	5,000

- Conveniently, demand for Pyrolysis Oil is also expected to grow slowly in the next 1-2 years as issues such as delivered cost, operational performance, environmental impact and sustainability become known. Demand will take off as target year 2010 approaches. There will be no unsold Pyrolysis Oil.

- Sales in the first 2-3 years will be chiefly to large companies which face obligations or penalties, or have significant incentives, and for which no special local distribution system is required. These would include: pulp mill lime kilns; coal, oil and natural gas power plants; and district heating plants, chiefly those with unloading facilities on a coast, or inland waterway.

- Limekiln markets are most likely to develop first in Sweden, Finland, Portugal and Spain, with Finland and Spain facing difficulties with Kyoto target. The early market is estimated at 1.4 million tonnes Pyrolysis Oil, shown in Table 7.2.

- The market for coal co-firing is estimated at 4.7 million tonnes Pyrolysis Oil (or char equivalent), needed by 70 plants on coasts or inland waterways. Key markets are likely to be UK and Netherlands, with the UK apparently reemphasizing co-firing in its 2006 Energy Review, and Netherlands likely to adjust incentive programs to promote certified sustainable BioOil.

- Co-firing in oil-fired power plants is estimated at just over 3 million tonnes Pyrolysis Oil, with major markets being Italy, Spain, Portugal and UK. Although four times as much power is generated in natural gas power plants than oil, higher efficiency of gas, lower GHG benefit, and need for installed multi-fuel flexibility in plants may limit co-firing in gas plants.

- Policies in both Belgium and UK favour 100% biomass plants over co-firing, therefore retrofitting an outdated fossil fuel power plant to Pyrolysis Oil is an excellent opportunity. A project of this size would require large guaranteed supply of uniform-grade Pyrolysis Oil, possibly taking several years and necessitating integration of supply and generation within one company.

Table 7.2 Early Demand for Pyrolysis Oil

Demand for Pyrolysis Oil
000 tonnes

Lime Kilns	Early Mkt	Total Mkt	Assumptions to estimate early market
Sweden	575	766	75% of market due to transport from coast
Finland	574	765	"
Portugal	136	181	"
Spain	131	175	"
	1,415	1,887	"
District Heating			
Finland	345	460	75% of market due to transport from coast
Sweden	615	820	"
Germany	17.5	175	10% of market due to transport from coast
Denmark	?		
	978		
Co-firing in Power Plants			
Coal	4,700	45,000	10% cofiring in 70 plants on or near waterways
Oil	3,120	78,000	20% co-firing on 20% of plants (ie near coast)
Natural Gas	4,480	224,000	2% co-firing
Start-up Fuel	560	560	all
	12,860		
Total	15,253		

- In Germany, policies favour small power, so substitution of Pyrolysis Oil for diesel in new power plants up to 20MW is an excellent and growing market.

- Initial district heating markets, estimated at just under 1 million tonnes[84], are likely to be Finland, Sweden and possibly Denmark, with Denmark and Finland facing pressure to achieve Kyoto targets.

- Large volume users will begin to put significant volumes of Pyrolysis Oil into long-term plans only as sustainability of biomass sources, operational success and consistency of supply become apparent.

- In the next 2-3 years trials will take place for small-volume users, such as stationary diesel engines, greenhouses and sawmill dry kilns. Pyrolysis Oil suppliers will begin to collaborate and experiment with distribution systems in order to reduce costs of supply and maintain competitiveness.

- Supply to UK, Spain, Portugal, Netherlands, Sweden and possibly Finland is expected to come initially from Canada, and then Brazil. The potential for supply from the Baltic and Ukraine will be explored to supply Finland, Sweden and Eastern Europe. Also, the EU is expected to ramp up domestic production.

[84] No estimate of fuel demand in Denmark available at the time of writing

7.2.Pulp Mill Lime Kilns:

Sweden and Finland have the greatest potential for substituting Pyrolysis Oil in limekilns, with 64% of European pulp production. Limekilns generally are not able to burn raw biomass or pellets because of carbon contamination, so oil or natural gas is used. Pyrolysis Oil is a natural substitute and it has been tested, but it has to compete against alternatives, like palm oil, tall oil, and direct gasification of biomass. The price of palm oil fell briefly due to an oversupply situation in December 2005, but now it is again expensive. A long-term price for palm oil is estimated at 80% of HFO, but if it is produced unsustainably then it may not be a competitive product to sustainable Pyrolysis Oil. Tall oil is a natural substitute in limekilns, but EU tall oil is being used elsewhere. Direct gasification of biomass is a possibility for the “pulp mill of the future”, but it is not yet proven technology. In addition, the gaseous fuel cannot be transported but has to be used on site, so investing in gasification would only be viable if the pulp mill were large, new and competitive with third world pulp mills. Few northern pulp mills are in this category. So, limekilns should be an excellent market Pyrolysis Oil.

In Sweden, fuel requirements are equivalent to 766,000 tonnes of Pyrolysis Oil. The best prospects are mills on or near ports, to minimize inland transport. The commercial price of medium/heavy fuel oil in 2004 was 17.3 öre/Kwh[85], or 5.3 €/GJ. To promote competitiveness, industry does not pay the tax of 32.5 öre for small users. With the price of crude about 50% higher than in 2004, the price of HFO might be closer to 8 €/GJ. The estimated delivered cost of Pyrolysis Oil is 6.4-10.5 €/GJ using small tankers, or 4.8-7.8 €/GJ with large efficient tankers, so clearly Pyrolysis Oil can be competitive against fossil fuels. If the long-term price of palm oil is indeed 80% of HFO, or 6.4 €/GJ, Pyrolysis Oil from Brazil, South African, Ukraine and parts of Canada is competitive.

In Finland, the theoretical potential market is also 700-800,000 tonnes Pyrolysis Oil, and some of the pulp mills are on the coast at or near ports. The tax-free price of heavy fuel oil in 1Q-2005 was 7.3 €/GJ, so Pyrolysis Oil should be approximately at this level to be competitive. All sources in this study are competitive with large tankers. In future, it might be possible that Pyrolysis Oil destined for Finland will be manufactured in the Eastern Baltic States. However, unused forest residue-based biomass can be found in Finland that is suitable for local bio-oil production. In 2005-2006, the price of raw biomass delivered to power plant was approximately 3 €/GJ. In cases where Pyrolysis Oil can be consumed onsite and avoid transport costs, such as at a pulp mill, local production seems previously indicated at a manufacturing cost of 4.4 €/GJ makes Pyrolysis Oil an attractive alternative in Finland.

Spain and Portugal are major pulp producers. Spain needs the equivalent of 175,000 tonnes Pyrolysis Oil annually, and Portugal 181,000 tonnes. Both countries are in serious jeopardy of not achieving Kyoto targets and will be predisposed to develop imports. The prices for heavy oil in Spain and Portugal in 1Q-2006 were 9.1€/GJ and 10.8€/GJ

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[85] Energy in Sweden- Facts and Figures 2005

respectively. From a geographic point of view, imports from Brazil and South Africa would be most desired to minimize shipping costs.

7.3. District Heating

The largest district heating systems are in Sweden, Finland, Germany, and Eastern Europe, including Poland, Lithuania, Estonia and Hungary. Eastern Europe district heating systems are mostly old, with poor design and outdated control systems[86], and the green movement is not strong there. One of the largest district heating systems is in Poland, but structural factors such as dependence on low-cost coal, antiquated plant, and lack of capital due to low energy rates suggest that this will be a poor market for Pyrolysis Oil.

At 20,100 MW, Finland has one of the largest district heating systems in the EU, fueled 39% by natural gas, 26% by coal and 4.5% by heavy oil. 8 PJ of heavy fuel oil used in district heating is equivalent of 460,000 tonnes of Pyrolysis Oil, or 10 200-tpd plants. This is a large potential market for Pyrolysis Oil, although district heating utilities having less than 20 MWe of boiler capacity are excluded from emission trading in Finland. With HFO priced at over 8 €/GJ plus 1.6€/GJ for the ERC, Pyrolysis Oil would be competitive from many sources. With gas prices at 5.4€/GJ and the ERC at 1.6€/GJ, co-firing in natural gas plants is a possibility, but only from the low cost sources. Co-firing char in coal plants is a major market.

In Sweden, 62% of district heating systems are already running on low-cost biomass, much of it residues and forest chips, but increasingly more costly wood pellets are being used as low-cost biomass becomes unavailable. 8% runs on heavy fuel oil, and at 4.1 TWh, or 14.7 million GJ, this is a large market, equivalent to 820,000 tonnes of Pyrolysis Oil, or 18 200-tpd plants. Pyrolysis Oil from all sources can compete here. Pyrolysis Oil can also compete against pellets, and it has to compete on price and convenience. Pellet prices delivered to a Swedish port[87], are 7.1-7.7€/GJ, so Pyrolysis Oil from most sources is price competitive. However using Pyrolysis Oil would require retrofitting, which may hinder market penetration.

In Denmark, 58% of district heating is from CHP plants using oil and coal. A major portion of CHP capacity is in or near Copenhagen with port facilities. With reduced feed-in-tariffs, Pyrolysis Oil and char have to compete against fossil fuels and pellets on price, the ERC, and convenience. The price of HFO in Denmark 1Q-2006 was 9.1€/GJ, so Pyrolysis Oil can be competitive from several sources. Char can be competitive if the ERC is factored into the price. While it is possible that a district heating plant or CHP plant could switch from pellets to Pyrolysis Oil based on price, they would only do so with demonstrated ability to provide large consistent volumes at competitive prices.

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[86] Sven Werner, Chalmers University of Technology

[87] Staffan Melin, Canadian Bioenergy Association, for pellets of 4.8 MWh/tonne

7.4.Substituting Pyrolysis Oil or char in power plants

With 860 TWh of power from coal, 162 TWh from oil and 606 TWh from natural gas, substitution of Pyrolysis Oil or char for these fuels should be a huge market in Europe. Power plants are tied into emission reduction programs as 2010 approaches. To co-fire on average 10%, the 70 odd coal-fired power plants on coasts or inland waterways would need 4.7 million tonnes Pyrolysis oil, or 2.9 million tonnes char, or some combination thereof. Assuming a similar proportion of oil power plants near coasts and 20% co-firing, oil plants would need 3.1 million tonnes Pyrolysis Oil. Many natural gas power plants are configured already to run on alternate fuels. If 2% co-firing took place, 4.5 million tonnes Pyrolysis Oil would be required.

The Netherlands has strongly supported co-firing, but budgeting and sustainability issues led to a drop in feed-in-tariffs for all fuels except pellets. It is surmised that current efforts to develop sustainability criteria, looming Kyoto targets, and proof of sustainability and operational performance of Pyrolysis Oil and char will result in a meaningful feed-in-tariff for these fuels. In the UK current legislation dictates a cap on co-firing at 10% for ROC eligibility, falling to 5% in 2011, combined with minimum levels from domestic energy crops in 2009. However, this gives sufficient time for Pyrolysis Oil and char to prove themselves as viable, competitive, sustainable options for co-firing, and with the new Energy Review continued support of imported co-firing fuel is possible.

Germany currently has considerable opposition to co-firing, and can be discounted as a major market thrust until Pyrolysis production exceeds demand in other markets. Spain, Denmark and Finland are major users of coal for power, and should be early markets for competitive char, and later Pyrolysis Oil if penalties for non-compliance on EU targets loom.

Appendix 1
Technical Properties and Development of Pyrolysis Oil and Char

A.1 **What is Pyrolysis Oil?**

Pyrolysis Oil is a dark-brown, free flowing liquid fuel that is derived from plant material. It is not an "oil", like a vegetable oil or petroleum oil, because it contains about 25% water in its composition.

Biomass is converted to Pyrolysis Oil by thermo-chemical processes, either direct liquefaction or fast pyrolysis. Direct liquefaction, not covered in this report, is a slow process that is conducted at high pressure and moderate temperature, and uses a catalyst to create a heavy, thick bio-oil with low water content and low oxygen content. With fast pyrolysis small particles of biomass waste are rapidly heated to high temperatures in the absence of oxygen, vapourized, and then condensed into liquid fuel. This process breaks down the biomass structure instantly to produce a high yield of condensable organic liquids. The products are typically 65-72% liquid Pyrolysis Oil, 15-20% solid char and 12-18% non-condensable gases. Wood biomass typically results in 70% Pyrolysis Oil, 14% char and 13% gases. Since char has a higher heat value per tonne, almost 23% of the heat output is from char. In the process there is no waste biomass since Pyrolysis Oil and char have significant commercial application and value. Non-condensable gases are recycled and produce 75% of the energy required for the pyrolysis process.

Table 1.1

Mass/Energy Balances

	Range By Wt	Pine/spruce By Wt	Pine/spruce Energy	Gj/t
BioOil	65-72%	70.3%	70.6%	17.8
Char	15-20%	14.3%	22.6%	28
Non-condensible gases	12-18%	13.4%	6.8%	9
		98.0%	100.0%	

The feedstock for Pyrolysis Oil is commonly forest waste, such as sawdust and bark, and agricultural waste, such as sugar cane bagasse. The Pyrolysis Oil yield depends on the feedstock, approximately 60 to 75% for wood waste (white wood sawdust produces a higher yield than bark), and 60 to 65% on average for sugar cane bagasse and other agricultural waste streams.

A.2 P**roperties**

Pyrolysis Oil can be stored, pumped and transported like petroleum products and can be combusted directly in boilers, gas turbines and slow to medium speed diesels for heat and power. It has a density of 1.2 kg/litre, and heating value 16-19 GJ/tonne, giving it approximately 55% of the heating value of diesel on a volumetric basis and 45% on a weight basis. It has an ash content averaging less than .02% by weight, compared with .01% for diesel. Pyrolysis Oil is an ideal clean fuel because it is CO_2 neutral, contains no sulfur and therefore does not produce SO_2 (sulfur dioxide) emissions during combustion, and usually produces approximately half the NO_x (nitrogen oxide) emissions in comparison with fossil fuels.

Pyrolysis Oil is not dangerous but it is acidic, containing substantial amounts of acetic and formic acid. pH is 2-3 compared with diesel at pH5. Vapour can cause eye irritation, so goggles are recommended. Dermal exposure can cause temporary staining of skin, so gloves and protective clothing are recommended for handling. Pyrolysis Oil is combustible but not flammable, ignites and burns readily when properly atomized, and once ignited burns with a stable, self-sustaining flame[88]. It is flammable at extremely high temperatures.

Pyrolysis Oil is not a homogeneous liquid. If left standing for long periods, lignin will eventually precipitate. There are varying qualities of Pyrolysis Oil; some are stable for years, while others are not. For example, DynaMotive Pyrolysis Oil has been fired successfully three years after its manufacture. After extended periods of storage in containers some Pyrolysis Oil's will develop a 2-5 cm thick floating viscous layer, however this is easily stirred back into a single phase when the Pyrolysis Oil is heated to 40º C. After cooling it will slowly reform at the top as a separate layer. The bulk, which may represent 75-95% of the volume, is a dark brown liquid with the viscosity of cooking oil, density 1.2, and water content of 42-43%. At the bottom eventually will form a 15-40 cm layer consisting of lignin fragments, which has the viscosity of thick honey, density of 1.2, and is 15% water. It shows no distinct line of separation from the bulk but rather a gradual diffuse transition. The bottom can be stirred back into the bulk with slow-speed agitation, aided by heating to 40-60^o C. Adding up to 5% alcohol aids the remixing. With a pour point of -30^o C, Pyrolysis Oil can be poured well below freezing, but it will be viscous and difficult.

Char is the remains of solid biomass that has been incompletely combusted, similar to charcoal when wood has been incompletely combusted. Char is 65-76% carbon by weight, 5-12% ash, and less than 2% moisture. It has heat value of 28-30GJ/tonne. It is a charcoal powder with particle size less than 1 mm, and has bulk density of 0.25-3 tonnes/M^3. It is a renewable fuel that can easily be co-fired with coal in power plants as it does not gum up coal grinders like raw biomass. After char manufacture, the presence of oxygen on the surface of the char particles causes heat, and if densely packed or stored improperly, char can self-ignite and begin to smoulder. This tendency can be prevented by first fluttering the particles through air, which increases oxygen on the surface and prevents later oxidation in an uncontrolled environment[89].

A.3 Transportation and storage

The acidic and thus corrosive nature of Pyrolysis Oil means that enhancements are required for storage and transportation, but these are not onerous. Storage vessels and

[88] Overview of Applications of Biomass Fast Pyrolysis Oil- Jan 2004, S. Czernick and A.V. Bridgwater
[89] Peter Fransham- President, Advanced Biorefinery Inc.

piping should be Stainless 304, PVC, Teflon or like substance. It takes several months for good-quality Pyrolysis Oil to layer, and thus not an issue for short-term transportation and storage. Neither trucks, nor rail, nor shipping are required to have mixing capability. Mixing capability is recommended in customer storage tanks, however this is easily arranged with existing tanks. Tanks with a sloped bottom work best, allowing the lignin to flow into a small area and thus ease mixing back into the bulk.

To prevent contamination, shipping vessels should have specialized compartments. After transport, tankers can be cleaned with Ethyl or Methyl alcohol.

Despite these apparent restrictions, Pyrolysis Oil transportation has a major advantage over fossil fuels. In the event a tanker ship sinks or causes a spill, the property of petroleum to spread over water in a thin layer over a wide area has disastrous environmental consequences. For example, in 1989 the oil tanker Exxon Valdez struck a reef off Prince William Sound, Alaska, spilling 11 million gallons of crude oil that subsequently spread over 10,000 square miles of Alaska's coastal seas and contaminated 1500 miles of shoreline, devastating the ecosystem in the oil's path. The clean up cost $2.5 billion, and even 15 years after the spill studies indicate that the environmental impacts are far longer than anticipated. Pyrolysis Oil will not spread, but separates into a very heavy organic fraction that will sink and is largely inert[90], and an aqueous fraction that will be diluted and is very bio-degradable. Acidity is not a problem if spilled into large bodies of water as it is so diluted that the acids will be biologically degraded quite quickly. Initial toxicology tests show that Pyrolysis Oil is non-toxic[91].

Since char is very fine and has low bulk density, around 250-350kg/m^3, or 1/5 that of Pyrolysis Oil, it can be somewhat difficult to handle in powder form. Pelletizing char makes handling easier, especially if transported any great distance. Pelletizing eliminates the risk of self-ignition and decreases freight costs. Pelletized char can be added directly to the coal feed without limitation.

A4 Plant Development

Canada is regarded as a leader in Pyrolysis Oil technology and development, with two systems at the commercialization stage and two near commercialization. Current development, as well as non-Canadian examples, includes:

- DynaMotive Energy Systems (Vancouver)- Has a patented fast-pyrolysis process using a fluidized bed that converts forest and agricultural residues into Pyrolysis Oil. It is now expanding its 100-tpd Pyrolysis Oil plant, already the worlds largest, and has two 200-tpd plants under construction.
- Ensyn Corp (Ottawa)- Uses its core technology (Rapid Thermal Processing or RTP™) to transform carbon-based feedstocks, either woody biomass or petroleum hydrocarbons, to more valuable chemical and fuel products. The current focus is not energy, but flavouring for food products.

[90] Dr. Tony Bridgwater, Aston University, Birmingham
[91] Blin J, Volle G et al, Biodegradability of Fast Pyrolysis Oil", CIRAD Forestry Dept, International Research Center for Agricultural Development, France

- Advanced Biorefinery Inc (Ottawa)- Has built and is testing a mobile fast pyrolysis unit to convert forest slash to Pyrolysis Oil using a process with a low parasitic load, and is now building a 50-tpd modular plant to convert harvest waste and hog fuel from existing bark piles to liquid Pyrolysis Oil.
- Agri-Therm (Dorchester)- Is in the final stages of testing its 10-tpd mobile pilot plant, which uses primarily agricultural residues in farm applications
- BTG Biomass Technology Group- Is in the final stages of commissioning a pyrolysis plant in Malaysia which produces 1.2 tonnes per hour of Pyrolysis Oil from palm oil residues.

DynaMotive is the furthest ahead of all competitors in commercializing Pyrolysis Oil production for energy. In February 2005 it began start-up of the world's largest Pyrolysis Oil plant in West Lorne Ontario. The West Lorne plant was designed to use 100-tpd of wood fibre, primarily from the adjacent flooring and wood products plant, to produce 72-tpd or 26,000 tonnes p.a. of Pyrolysis Oil. 48-tpd was to be used to fuel a gas turbine to produce 2.5 MW power. In June 2005, the gas turbine generated power that was delivered to the Ontario energy grid. DynaMotive commenced commercial shipments of Pyrolysis Oil to a US company in 2005, and in 2006 made agreements for the sale of both pure Pyrolysis Oil and slurries, a combustible mixture of Pyrolysis Oil and char. Almost two years of testing has resulted in implementation of technological advances that are expected to achieve a 35% reduction in operating costs. In October 2006, the company announced a 30% expansion to the West Lorne plant planned for 2Q 2007, to maximize electricity production at the site.

In June 2005 the conceptual design was completed for a 200-tpd modular plant, expected to be the minimum sized plant in the future for most applications. 500-tpd plants are planned. Fabrication of the first 200-tpd plant is almost complete and site work is underway in Guelph, Ontario. In May 2006, DynaMotive confirmed a delivery schedule for a 200-tpd plant to Classic Power in Western Canada, which will be completed in 2006 and commissioned in early 2007. Dynamotive and E&R Langille of Nova Scotia are analyzing the feasibility of a 500-tpd facility in Nova Scotia. The proposed plant, to utilize wood chips and other biomass sources, would be completed in two stages; an initial 200-tpd facility, and a second module added later. Outside Canada, in March 2006, DynaMotive licensed a 200-tpd plant with an option for two others of similar size to Rika Ltd., a company with operations in Latvia and Ukraine. The plant will be located at Rika's 8,700-hectare farm operations in the Ukraine, which is capable of supporting the three plants envisaged. Rika has leased 25,000 ha of farmland and is considering allocating 10,000 hectares for growth of biomass for Pyrolysis Oil.

The second major Pyrolysis Oil producer, Ensyn, has a mission is to develop industrial applications for its core technology, Rapid Thermal Processing (RTP™), in two distinct applications- biomass (wood) processing and petroleum upgrading. In wood or other biomass operations Ensyn's process produces high yields, typically 75% by weight, of a light liquid Pyrolysis Oil from which natural high-value chemicals and fuels are recovered. By 1996, there were four plants in commercial operation. In 2002, Ensyn built and commissioned what was at that time its largest new RTP™ plant, with a capacity to process almost 100 green tons per day. A sixth commercial RTP™ biomass plant, designed to produce specialty chemical products, was built and put into service in 2003. Ensyn's largest RTP™ biomass refinery is presently under construction in Renfrew, Ontario. It will convert 160 green tons of wood per day into natural resin products, co-polymers, other chemicals, liquid fuel and green electricity. Other projects are being developed with strategic partners in Canada, the USA and Europe.

In a third Canadian Pyrolysis Oil development, the Ontario Ministry of Natural Resources plans is contemplating a small business model to improve economic fortunes in Northern Ontario, recently hit with closures of pulp & paper and lumber mills. The intent is to develop and test mobile 50-tpd Pyrolysis Oil units to convert harvest waste to Pyrolysis Oil, and implement a number of service hubs and export centres to support distribution. There is sufficient harvest slash, currently burned at roadside, to manufacture a considerable amount of Pyrolysis Oil, even for export. The 50-tpd plant is under construction.

In a fourth Canadian Pyrolysis Oil development Agri-Therm of Dorchester, Ontario, is in the final stages of testing a mobile plant that is capable of producing Pyrolysis Oil from 10-tpd of dried agricultural residues, wastes and transition crops. The plant is functional, transportable and demonstrable. On completion of testing, the equipment will be scaled up to use 40-tpd of feedstock.

In the Netherlands, BTG Biomass Technology group and Zeton designed and built a pyrolysis plant that was shipped to Malaysia in January 2005. The plant has undergone extensive testing, modification and optimization, and is in the final stages of commissioning. It is designed to utilize palm biomass from an adjacent palm oil mill, which produces about 6 tonnes/hour of biomass, empty fruit bunches (EFB). The EFB is dried onsite, from which the pyrolysis plant produces 1.2 tonnes/hour of Pyrolysis Oil[92].

A.4 Research and Technical Feasibility

Research and testing continue with all technologies. As an example, DynaMotive has completed several tests to confirm applications of its Pyrolysis Oil including:

- Tests in 2006 to replace Heating Oil #2 in a furnace at one of Alcoa's largest aluminum plants in Baie Comeau, Quebec. Alcoa made minor changes to piping and its existing instrumentation system and installed Pyrolysis Oil handling systems. The tests established the potential commercial utilization of Pyrolysis Oil as an alternative to heating oil #2.
- A 4-hour combustion test in 2006 to replace fuel oil #6 (Bunker C) with 2 tonnes of Pyrolysis Oil in a greenhouse application at Great Lakes Greenhouses Inc. in Leamington, Ontario. The fuel demonstrated very good ignition properties, steady flame characteristics, and a low emissions profile. No modifications to the existing burner system were necessary.
- A 2005 test of conversion of Pyrolysis Oil to Syngas via gasification at the research institute Forschungszentrum Karlsruhe (FZK) in Germany. FZK has

[92] ThermalNet newsletter- Feb 2006

developed a new biomass-to-liquid (BTL) process to produce tar-free syngas from a mixture of Pyrolysis Oil and pyrolysis char (slurry). Syngas can be converted into synthetic diesel, methanol and other chemicals. Synthetic diesel, or Syndiesel, is a renewable CO_2 neutral fuel that can replace diesel produced from fossil crude oil, and can be used in diesel engines without modification, including automobiles, trucks, buses and industrial diesel turbines.

As a future application, DynaMotive is researching the emulsification of Pyrolysis Oil and hydrocarbon diesel. The goal is to allow for co-burning of Pyrolysis Oil/diesel mix in stationary engines without significant modification to them. As energy prices reach record levels and environmental concerns take centre stage, Pyrolysis Oil presents a strong potential as a partial fuel alternative.

Appendix 2

Gross Electricity Generation

2003 (in TWh)

	Total	Conventional Thermal	- Coal	- Oil	- Gas	- Other	Nuclear	Pumped Storage	Renewables (*)
EU25	**3121**	1714	960	162	582	10	974	35	*399*
EU15	**2766**	1452	739	150	554	9	898	32	385
BE	**84.6**	34.5	9.6	1.0	23.6	0.3	47.4	1.1	1.7
CZ	**83.2**	55.1	51.0	0.4	3.7	0.0	25.9	0.4	1.9
DK	**46.2**	37.5	25.3	2.3	9.8	0.0	-	-	8.7
DE	**599.5**	382.3	306.5	4.7	65.8	5.4	165.1	5.2	47.2
EE	**10.2**	10.1	9.4	0.0	0.7	-	-	-	0.0
EL	**58.5**	52.1	35.2	8.7	8.0	0.2	-	0.6	5.8
ES	**262.9**	139.4	74.7	24.0	40.6	0.0	61.9	2.8	58.8
FR	**566.9**	55.6	26.3	8.7	20.6	0.1	441.1	5.2	65.1
IE	**25.2**	23.7	8.2	2.5	13.1	-	-	0.4	1.1
IT	**293.9**	239.3	38.8	76.0	122.6	1.9	-	10.5	44.0
CY	**4.0**	4.0	-	4.0	-	-	-	-	0.0
LV	**4.0**	1.6	0.0	0.1	1.5	-	-	-	2.3
LT	**19.5**	3.0	-	0.3	2.5	0.2	15.5	0.7	0.3
LU	**3.6**	2.6	-	-	2.6	0.0	-	0.8	0.2
HU	**34.1**	22.8	9.2	1.6	12.0	-	11.0	-	0.4
MT	**2.2**	2.2	-	2.2	-	-	-	-	0.0
NL	**96.8**	87.5	24.3	2.9	60.0	0.3	4.0	-	5.4
AT	**63.2**	22.7	8.4	1.8	12.2	0.3	-	2.0	38.5
PL	**151.6**	147.8	140.7	2.5	4.4	0.3	-	1.6	2.3
PT	**46.9**	28.4	14.5	6.2	7.7	0.0	-	0.3	18.1
SI	**14.0**	5.5	5.1	0.1	0.4	-	5.2	-	3.3
SK	**31.2**	9.6	6.0	0.7	2.8	0.1	17.9	0.2	3.5
FI	**84.2**	42.1	26.2	0.9	14.5	0.5	22.7	-	19.4
SE	**135.6**	8.7	2.7	3.9	1.8	0.3	67.4	0.1	59.4
UK	**398.6**	296.0	138.2	7.0	150.7	0.0	88.7	2.7	11.2

Source: Eurostat

Note: (*): not including hydro from pumped storage

Appendix 3

Emissions projections for EU-15 Member States, based on existing and additional domestic policies and measures and use of Kyoto mechanisms, compared with their Kyoto targets

	EU burden sharing target (in % of base year emissions)	With existing policies and measures		With additional policies and measures		Gap including use of Kyoto Mechanisms
		Projections for 2010 (in % of base year)	Gap between projections and target (in % of base year)	Projections for 2010 (in % of base year)	Gap between projections and target (in % of base year)	(in % of base year)
Austria	-13.0 %	+8.7 %	+21.7 %	-9.2 %	+3.8 %	-5.2 %
Belgium	-7.5 %	+6.5 %	+14.0 %	-3.3 %	+4.2 %	-1.4 %
Denmark	-21.0 %	+15.7 %	+36.7 %	-	-	+31.3 %
Finland	0.0 %	+16.5 %	+16.5 %	-0.5 %	-0.5 %	-
France	0.0 %	+9.0 %	+9.0 %	-1.7 %	-1.7 %	-
Germany	-21.0 %	-19.7 %	+1.3 %	-	-	-
Greece	+25.0 %	+38.6 %	+13.6 %	+22.4 %	-2.6 %	-
Ireland	+13.0 %	+29.4 %	+16.4 %	+3.6 %	-9.4 %	-16.3 %
Italy	-6.5 %	+3.7 %	+10.2 %	-3.4 %	+3.1 %	-
Luxembourg	-28.0 %	-22.4 %	+5.6 %	-	-	-17.9 %
The Netherlands	-6.0 %	+3.3 %	+9.3 %	-	-	-0.1 %
Portugal	+27.0 %	+53.1 %	+26.1 %	+45.7 %	+18.7 %	-
Spain	+15.0 %	+48.3 %	+33.3 %	+28.0 %	+13.0 %	-
Sweden	+4.0 %	-0.2 %	-4.2 %	-	-	-
United Kingdom	-12.5 %	-13.9 %	-1.4 %	-22.5 %	-10.0 %	-
Total EU-15	**-8.0 %**	**-1.0 %**	**+7.0 %**	**-7.7 %**	**+0.3 %**	**-0.8 %**

Emissions projections for new EU Member States, based on existing and additional domestic policies and measures, compared with their Kyoto targets

	Kyoto target (in % of base year)	With existing policies and measures		With additional policies and measures	
		Projections for	Gap between	Projections for	Gap between

		2010 (in % of base year)	projections and target (in % of base year)	2010 (in % of base year)	projections and target (in % of base year)
Cyprus	-	-	-	-	-
Czech Republic	-8.0 %	-30.0 %	-22.0 %	-	-
Estonia	-8.0 %	-56.6 %	-48.6 %	-60.0 %	-52.0 %
Hungary	-6.0 %	-6.0 %	+0.0 %	-	-
Latvia	-8.0 %	-58.2 %	-50.2 %	-	-
Lithuania	-8.0 %	-43.3 %	-35.3 %	-	-
Malta	-	-	-	-	-
Poland	-6.0 %	-12.1 %	-6.1 %	-	-
Slovakia	-8.0 %	-26.6 %	-18.6 %	-33.5 %	-25.5 %
Slovenia	-8.0 %	+4.0 %	+12.0 %	-3.9 %	+4.1 %

Appendix 4
Torrefied Wood

Torrefaction is a thermal pre-treatment technology to improve the properties of biomass as a fuel. It consists of a slow heating of biomass in an inert atmosphere to a maximum temperature of 300 °C. The treatment yields a solid uniform product with a lower moisture content and a higher energy content than the initial biomass. The process may be called mild pyrolysis, which retains approximately 70% of the initial weight and 90% of the original energy content.

Torrefaction technology is not commercially available yet. The only commercially applied plant, Pechiney, was built in the 1980's in France, and it was operated for a few years. It has a capacity of 12,000 tonnes annually. As the only commercially built process, it is considered state-of-the-art[93]. The investment cost was approximately 2.9 million Euros in 1985, and the production cost was 100€/ton. Process scaling up could reduce the production costs, but the reactor used at Pechiney had poor scaling up properties, implying the need to search for a better process technology.

Torrefied biomass has several advantages over raw biomass[94]:

- It does not regain humidity in storage and therefore unlike wood and charcoal, it is stable and with well defined composition.
- It has a lower moisture content and higher calorific values compared to biomass
- It produces less smoke when burnt.
- It has a higher density and similar mechanical strength compared to the initial biomass

Torrefied wood is suitable for various industrial applications as a fuel, such as combustion and gasification. A major advantage of torrefied wood over raw wood is its uniformity. It is a predictable, flexible fuel with optimum combustion and transport economies. Due to it's low moisture content, the transport cost is lower than for raw biomass and the quality as a fuel better. It is easily packaged and transported, and thus constitutes an efficient fuel.

Torrefied biomass is porous, with a low density. As it is fragile, it is easy to grind, however dust and strength issues, and the expense of transporting a low-density product make densification all but necessary. The mass density of torrefied biomass pellets is 22 MJ/kg while the energy density is 18 GJ/m^3. Although this density is less than coal at 20.4 GJ/m^3, it is 20% higher than wood pellets, which offers transportation advantages.

New co-firing tests for torrefied wood were undertaken in 2003. 20 tonnes of torrefied wood from forest chips were delivered to EPZ's 400 MWe plant at Borssele, Netherlands, operated by Essent Energy Trading BV. The torrefied wood was progressively mixed with coal up to 9% on an energy basis to test the basics of

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[93] Andre Faaij- University of Utrecht, Netherlands
[94] KTH - Kungl. Tekniska Högskolan http://hem.fyristorg.com/zanzi/torrefaction.html

pulverizing and co-firing. The pulverizer did not appear to reach a limit for adding wood, implying that more than 9% could be co-fired. The quantity of torrefied wood was insufficient for duration testing.

For successful marketing, production costs need to be competitive with alternate fuels. Production costs were estimated for a 60,000-tpa plant to be 40-50€/ton[95] not including feedstock, or about 1.8-2.30€/GJ. Bergman used production and transport from South Africa as an example, with delivered cost estimates for torrefied wood in pellet form of 4.5€/GJ. At this price, this product would be competitive with wood pellets, which currently are 7.5€/GJ. However, wood pellet research is now focused on enhanced densification, which would bring costs down. Torrefied pellets would also be competitive against Pyrolysis Oil from some sources, but not others. However, the co-firing limit of torrefied pellets in pulverizers is unknown, while Pyrolysis Oil does not have a co-firing limit. Char can be delivered to Europe at 1.6-3.1€/GJ, considerably lower than torrefied pellets, and char has no co-firing limit.

[95] Torrefaction for Biomass Upgrading- P. Bergman, J. Kiel- 2005

Appendix 5
Greenhouse Gas Impact

Assume 5 million tonnes Pyrolysis Oil is substituted for fossil fuels in 2012; half for coal and half for heavy fuel oil. At 17.8 GJ/tonne, this is approximately 90 million GJ.

Coal:
45 million GJ * 1 tonne coal/30GJ * .8 tonnes C/tonne coal * 44tCO_2e/12 tC= 4.4 million tCO_2e

Heavy Oil:
45 million GJ * m^3/40GJ * 1 tonne/m^3 oil * .8726 t C/tonne oil * 44tCO_2e/12 tC= 3.6 million tCO_2e

Substituting 5 million tonnes Pyrolysis Oil as above would reduce EU GHG emissions by 4.4+3.6 = 8 million tCO_2e.

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