An Information Guide on Pursuing Biomass Energy Opportunities and Technologies in British Columbia

for First Nations, Small Communities, Municipalities and Industry

For

BC Ministry of Energy, Mines and Petroleum Resources
BC Ministry of Forests and Range

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By

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CANADA

January 31, 2008

Acknowledgements:

This Primer has been developed with support and engagement from the following organizations:

BC Ministry of Forests and Range (www.gov.bc.ca/for):

The Ministry of Forests and Range is committed to building a strong and diverse forest sector through revitalization, while maintaining high environmental standards, to help ensure long-term jobs and economic benefits.

BC Ministry of Energy, Mines and Petroleum Resources (www.gov.bc.ca/em):

The Ministry of Energy, Mines and Petroleum Resources is the catalyst and facilitator for developing sustainable and competitive energy and mineral resource sectors for British Columbians.

BIOCAP Canada Foundation (www.biocap.ca):

BIOCAP is committed to providing the scientific insights, technologies and policy options to support Canada's transition to a sustainable bioeconomy. A sustainable bioeconomy is an economic system in which the nation's biological resources (e.g. forests and farmlands) provide renewable energy, chemicals, materials, and environmental values (healthier air, water and soils; greenhouse gas emission reductions).

ENVINT Consulting (www.envint.ca):

ENVINT Consulting provides services in the areas of renewable energy, energy policy, carbon trading and life-cycle analysis, as well as services in facilitation, research and technical consulting. ENVINT is active Canada-wide for clients in the private and public sectors, as well as environmental non-governmental organizations.

Northern Development Initiative Trust (www.nditrust.ca):

The Northern Trust mandate is to be a catalyst for strategic economic development at the local and regional levels to achieve its mission of helping northern BC communities create and sustain world-class industries and diversified economies.

Table of Contents

Purpose of this Primer:

This Primer is designed to assist stakeholders in small communities, aboriginal groups, municipalities and industry in developing and pursuing bioenergy options in the Province of British Columbia. It will help these stakeholders to

- identify bioenergy options and technologies that are suitable for the biomass resource and bioenergy markets available to them;
- identify potential hurdles and requirements related to each of the technologies described;
- learn about ways to finance a bioenergy project;
- understand the steps involved in the development of a project; and
- identify technology providers in Canada.

The Primer is specific to biomass and emphasizes technological and implementation questions. It should therefore be used in conjunction with a number of related information resources that will cover other aspects in more detail, such as:

- *The Renewable Energy Project Development Guide for North America* (forthcoming) by the Commission for Environmental Cooperation in Montreal, which details the project development process for biomass and other renewable energy projects. This Guide is written from a community group perspective and covers technology selection, stakeholder consultation and networking, financing, and permitting. It also contains business plans for renewable energy projects that can be used to assess a project opportunity and to raise funds.
- *The BC Renewable Energy Guide* by the BC Community Energy Association, which briefly outlines biomass energy options from a community perspective.
- *Biodiesel in British Columbia – Feasibility Study Report* by Eco-Literacy Canada (May 2004). This report guides community groups and other interested stakeholders through the process of determining if a biodiesel plant is feasible in a given BC community. http://www.saaep.ca/Biodiesel.pdf
- *Feasibility Study* - *Anaerobic Digester and Gas Processing Facility in the Fraser Valley* (forthcoming) by the BC Bioproducts Association. This report is forthcoming at the end of 2007 and will contain details on economics and favoured technologies to produce energy from agricultural residues in BC.
- *Funding Your Community Energy Initiatives Guide* by the BC Community Energy Association (Oct. 2006). This is a good resource on funding programs in Canada that can be used for bioenergy projects in BC. Chapter 3 of this BC Biomass Energy Primer builds on the funding information included in the BC-CEA 2006 Guide. http://www.communityenergy.bc.ca/documents/2006-CEA_Funding_Guide.pdf

A glossary of terms used throughout this Primer is provided at the end of this document.

1 Bioenergy in BC – An Attractive Energy Option

1.1 Overview

The Province of British Columbia has committed itself to maintain a share of at least 90% of its electricity generation from clean and renewable energy sources, and to mandate that all new facilities will have net zero greenhouse gas emissions. Biomass, as a "carbon neutral" renewable resource, can make a major contribution towards this goal. In addition, biomass can also support energy and greenhouse gas emission reduction goals in the fields of heat and transportation fuels. One tonne of dry biomass (bdt) can displace between 1.5 and 3 barrels of oil, depending on the application, technology and process efficiency applied (see Table 1.1).

Table 1.1 Fossil Energy Displaced by Biomass Resources [Envirochem 2004]

Biomass Pathway	Energy Displaced (barrels of oil equivalents)	Electricity produced
Wood to electricity (large-scale steam)	1.5 bl/bdt	900 kWh/bdt
Wood to electricity and heat (small-scale, non-steam)	3.3 bl/bdt	680 kWh/bdt
Anaerobic digestion	0.5 bl/bdt	310 kWh/bdt
Waste incineration	0.4 bl/bdt	235 kWh/bdt
Corn ethanol	1.4 bl/bdt	n/a
Lignocellulosic ethanol	1.8 bl/bdt	n/a
Yellow grease to biodiesel	2.0 bl/bdt	n/a

A standing offer program to be designed by BC Hydro for projects up to 10 MW in size may provide opportunities for new, local biomass projects to obtain favourable economics. BC's new Innovative Clean Energy Fund may encourage the development and commercialization of new biomass energy technologies, among others, and the Province's new Bioenergy Strategy is aimed at taking advantage of British Columbia's abundant biomass resources, such as beetle-killed timber, wood waste from sawmills and woodwaste landfills, currently unused roadside slash and forest thinnings, and agricultural residues.

Biomass is solar energy captured in plant material through the process of photosynthesis. Sustainably harvested biomass is carbon neutral, because the carbon dioxide released during its combustion is recaptured from the air when the biomass resource is regrown as forests or agricultural crops. There may be an opportunity over the coming two decades to use trees killed by the Mountain Pine Beetle, as well as other residues from forestry operations, for power and heat generation. Harvesting the beetle-killed trees will help restore the forest, enable new growth, and prevent forest fires, and provide a significant energy resource for both domestic use and export. Other important sources of biomass are household waste and the food industry, as well as agricultural residues.

The GLOBE Foundation's 2007 "Endless Energy Project" report assessed BC's biomass resource (biofuels, heat & electricity) to represent 47% of the provinces total remaining renewable energy potential. GLOBE's assessment of BC's bioenergy potential is similar to that prepared by BIOCAP Canada Foundation in 2006, which is summarized in Table 1.2. As this table shows, forest biomass is by far the most important resource (even if current usage is discounted) and could provide almost half the Province's energy consumption of 920 PJ/year. The BIOCAP study indicates that up to 11 million tones of mountain pine beetle wood may be available for energy uses. The actual (or net) recoverable amount, however, is anticipated to be much smaller, for two reasons:

- Not all of the pine is located in stands that will be targeted for harvesting in the next 20 years.
- A lot of pine, about 120 million m³, has been harvested since 2004. In 2006 alone, about 48 million m³ of pine was removed from the inventory.

There are a number of reasons that a major portion of the pine is not being allocated for harvest at this time. These reasons are primarily associated with a desire to conserve other forest values and land use objectives as defined in legislation and land use plans such as

- biodiversity and habitat,
- water quality and quantity,
- visual ascetics and adjacency and
- the protection of mid-term timber supply (e.g. allowing pine harvest on only those stands with greater than 70% pine by volume).

Given the above considerations, the Ministry of Forests and Range estimates that the twenty-year supply of pine for bioenergy is closer to 5 million m³ per year (2.1 million tonnes/year) if pine harvest rates are regulated to suit a 20 year time frame. This number may still be optimistic because it does not account for possible catastrophic losses to fire or wind or for the fact that we are currently removing about 42 million m³ of pine from the inventory each year, about twice the rate the 20-year time frame would allow. At the current rate, the available pine will be harvested by around 2014. The Ministry does, however, anticipate a slowing down of pine harvest for sawlogs over the next few years. Even so, the supply is limited and competition from other markets is expected to increase, so a rigorous approach to assessing fuel supplies is warranted by the bioenergy proponent.

Table 1.2 Bioenergy Potential of British Columbia

Biomass Feedstock	Resource Size (dry t/yr)	Bioenergy potential (PJ/yr)	% of Potential	% of total fossil energy
Municipal Solid Waste				
MSW	**948,450**	**15.2**	**2.9%**	**1.6%**
Sustainable Agriculture				
Crop residues	143,901	2.3	0.4%	0.3%
Livestock manure	388,426	6.1	1.2%	0.7%
Biomass Crops on summerfallow land	147,060	2.4	0.5%	0.3%
Biomass Crops on new /converted land	2,587,118	41.4	8.0%	4.5%
TOTAL SUSTAINABLE AGRICULTURE	**3,266,505**	**52.1**	**10.1%**	**5.7%**
Sustainable Forestry				
Forest residues	11,940,429	191.0	36.9%	20.8%
Enhanced silviculture for traditional forest products	1,194,043	19.1	3.7%	2.1%
Enhanced silviculture for bioenergy plantations	3,980,143	63.7	12.3%	6.9%
TOTAL SUSTAINABLE FORESTRY	**17,114,615**	**273.8**	**52.9%**	**29.8%**
Mountain Pine Beetle: A Temporary (20 yr) Resource				
Residue from increased AAC to harvest dead pine (a)	2,353,882	37.7	7.3%	4.1%
Whole tree harvest of non-recoverable pine (b)	8,660,736	138.6	26.8%	15.1%
TOTAL MPB FOR BIOENERGY	**11,014,618**	**176.2**	**34.1%**	**19.2%**
Total potential	**32,344,188**	**517.4**	**100%**	**56.2%**

NOTE: The current fossil energy demand in the province is 920 PJ/year

(a) *PJ/yr.*calculated as the residue left from the harvest of the recoverable MPB wood (417 Mm^3 or 224 Mt(dry)) assuming that 30% of the harvested biomass is forest residue and 70% of this can be removed sustainably. Finally, it was assumed that the resulting 47 Mt(dry) would be harvested over 20 years, resulting in 2.4 Mt(dry) per year.

(b) Calculated from BC government estimates for excess MPB wood of 358 Mm3 (about 193 Mt(dry)), where 90% of this could be harvested over a 20 year period to give an estimate of 8.7 Mt(dry) per year.

Biomass resources in BC offer meaningful opportunities to create new clean energy facilities: they can help provide cheaper and more sustainable energy to remote communities, support district energy systems and municipal greenhouse gas management plans, create local employment, stimulate the rural BC economy and expand emerging export markets.

BC's road and train systems, as well as its international ports, provide a well-built existing infrastructure to facilitate the use of bioenergy, and transport it across the province or to users outside of BC. While the ability to collect and transport biomass can still be improved, current policy initiatives are creating more advantageous economic circumstances to value the biomass resource in the Province.

The challenges of securing a long-term supply of biomass feedstocks, choosing and implementing appropriate technologies, securing financial investment, and keeping operating and transport costs manageable distinguish biomass projects from other types of renewable energy. This Primer was therefore completed to identify both the challenges and the solutions that can be applied to show that biomass can indeed play a very important role in BC's future energy scenario.

1.2 Local Considerations

On the input side, the choice of bioenergy technology will depend on the type, amount and quality of biomass feedstock available. A feedstock inventory that identifies these parameters, and also describes them on a seasonal, annual and long-term basis, is the main ingredient to a successful bioenergy project. Such an inventory should also look at the spatial and seasonal distribution of biomass, as well as the related infrastructure available for transportation.

On the output side, identifying markets for the end products produced is very important: are the products for an export market (such as wood pellets), for on-site use to generate heat or electricity, or for transportation fuels to help supply domestic markets?

Other considerations will be capital as well as operating costs of the system, its environmental profile in terms of air emissions, residues, etc., and the expertise required to operate the system. For example, a steam turbine will always require a qualified steam engine operator, which may not be available in all locations. Likewise, if your ability to raise capital is limited, then so is your choice of systems. The purpose of the bioenergy project can be either to apply a reliable, commercial technology with private financing or community ownership, or to demonstrate a new process that may be eligible for grants, which may not be available for established technologies.

For any given feedstock, there are multiple finished product options and usually more than one technology option to convert the feedstock to a finished product. Sometimes, different feedstocks can be combined to either enable the use of a favoured technology, to improve the end product, or simply to make sure enough biomass feedstock is available throughout the year to run the bioenergy system at high capacity factors.

Figure 1.1 provides an overview of bioenergy feedstock, technology and product options. Clearly, there are many possible pathways, and the one most suitable will depend on an array of circumstances and objectives. This Primer is written to help stakeholders undertake preliminary evaluations of their assets and potential products, narrow down their technology options and understand financing and the project development process:

- Section 1.3 discusses the main biomass feedstocks in BC and related energy product options.
- Section 1.7, and Figure 1.3 in particular, helps stakeholders quickly understand their technology options.
- Chapter 2 examines in more detail how each technology works and what its requirements are.
- Chapter 3 reviews funding options.
- Chapter 4 describes the BC Hydro electricity procurement process, and Chapter 5 the general biomass project development process.
- Chapter 6 provides insights for finding bioenergy consultants or technology vendors.

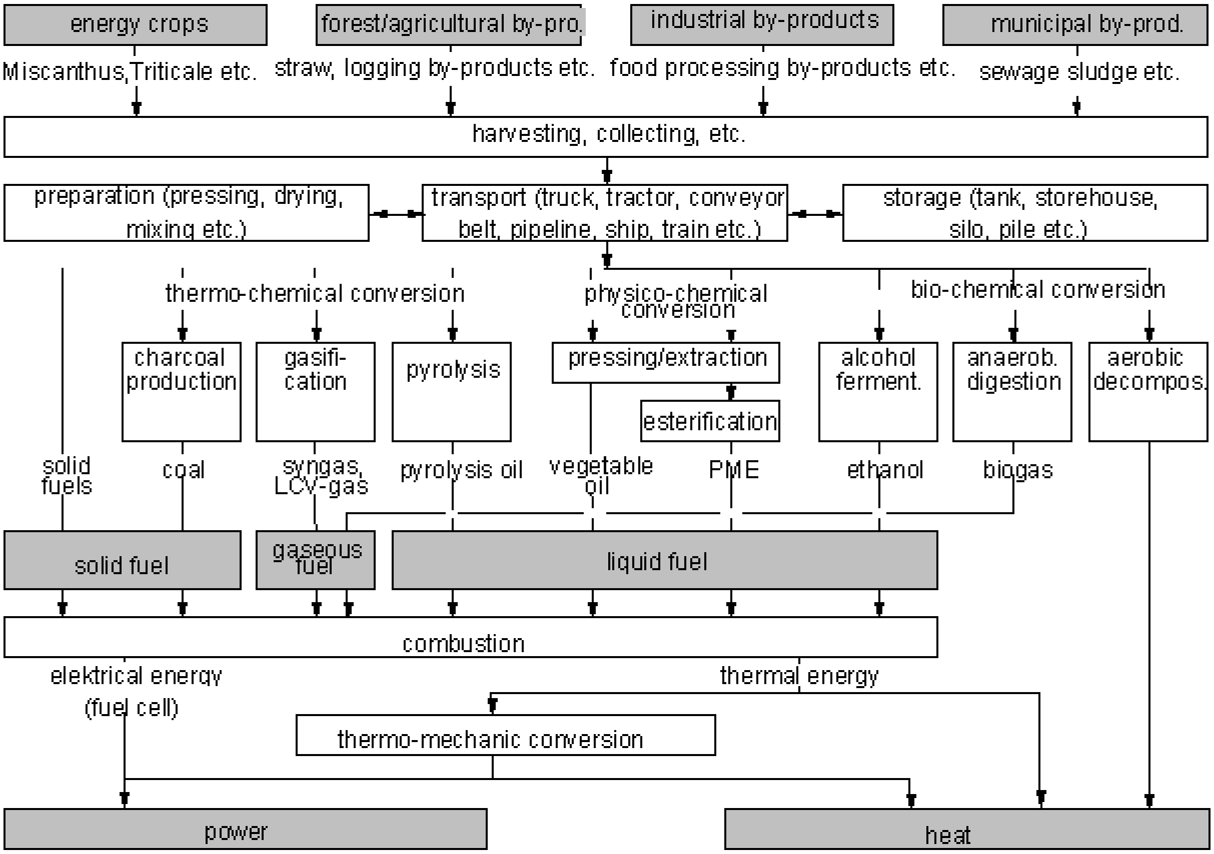


Figure 1.1 **Biomass Energy Conversion Technologies** [FAO 2004]

1.3 Bioenergy Feedstocks: Evaluating Your Assets and Defining Your Product

This section briefly discusses the main feedstocks available for energy uses in BC. The resource is described and the options to process these feedstocks are identified in tables. To learn more about these processes, refer to Chapter 2. Note that not all options are technically mature or appropriate for all situations. The scales and suitability of biomass energy processes are explained and compared later in this chapter.

Biomass feedstocks are rarely available for free. Usually, you need to enter into an agreement with the owner of the biomass resource. The bigger your energy facility, the more important it is to have such agreements in place, at a defined price and for a long duration. Forests in BC are predominantly owned by the Province. Most of the annual allowable cut is already allocated, however not all of the wood is being utilized. So the question is, how can you obtain long-term access to mill and logging residues? There are several options:

- You could negotiate with pulp & paper companies, sawmills or other license holders in order to obtain mill and/or harvesting residues from the logging sites. The City of Revelstoke has done just that with Downie Street Sawmills.
- Or you could secure long term tenure from the Ministry of Forests and Range. As most of the available timber is already under license, this option will present itself only rarely.
- About 15% of the allowable cut can be obtained by bidding on a cutblock through BC Timber Sales. Licenses for these blocks will only cover a duration of one or two years.

The BC Government is investigating new options to enable the utilization of logging residues and standing timber not presently utilized by the existing industry with the intent of having the necessary legal mechanisms in place in 2008.

Agricultural biomass needs to be obtained from farmers or breeders. Municipal biowaste is available from municipalities, either from separate collections or mixed with general household waste. The latter would limit the options available for turning such waste into energy. Wastewood from construction and demolition operations can either be collected directly at the site, or can be obtained from landfills or waste sort centers. Whenever a biomass residue is a waste that causes the owner disposal costs, you can expect to source this biomass for free, or even charge a small fee for its removal. Make sure, however, that everything is laid down in contracts as what is a (free) waste today may become a priced resource as soon as a use for it can be found.

Wood: Wood is the largest bioenergy feedstock resources in British Columbia. As a result of the pine beetle infestation, a large amount of low-value wood is available from the forest: local mill residues will increase over the next two decades because the harvested beetlewood is of lower quality and less of it will meet the quality standards for traditional wood products.

Wood from construction and demolition waste can be separated and untreated wood can then be used for energy generation, after separating out impurities and metal, and chipping the wood. The amounts collected are usually small, however, such that a facility of several megawatts can only be fed in large communities if this is the only feedstock. An average annual amount of 35 bdt per 1,000 inhabitants can be assumed as a first approximation. To feed a 1 MW power plant only from clean construction and demolition wood, a community must then have at least 180,000 inhabitants. Construction and demolition wood will therefore only provide for a small portion of the wood required for an energy system. Alternatively, such wood might instead be used to heat local buildings. A few calls to the local landfill and waste sort centres will usually be enough to establish how much construction and demolition wood is available in the area.

Table 1.2 Energy Products from Woody Feedstocks

Biomass Feedstocks	Energy Products
• Wood (hardwood, softwood) • Sawmill residues • Bark • Construction and demolition waste • Wood from plantations (poplar, willow, etc.)	Electricity
	Heat
	Ethanol
	Pellets (for export)
	Synthetic natural gas
	Bio-oil
	Cellulignin
	Methanol
	Biodiesel (Fischer-Tropsch)

Forest residue is the single largest resource in BC (37% of the total biomass energy potential). The most readily available portion of this biomass is found as residues from paper and sawmills. A typical large BC sawmill (1 million m^3 of wood processed per year) will produce about 70,000 bdt of sawdust and 40,000 bdt of bark. While sawdust is often used either inside the mill or sold to the rapidly expanding pellet industry, bark is usually available from most forest products operations. Bark has higher ash content than white wood, and is therefore not the preferred material for pellets.

A very significant resource of 100 million m^3 of pine beetle wood (40 million bdt) may be available for energy uses over the coming two decades. Challenges with this resource include longer term availability (decay and utilization assumptions), acquisition rights, and harvesting costs which can exceed $100/bdt (including road construction, replanting, etc). The use of roadside slash and other non-merchantable wood, as well as co-harvesting some higher-end quality stems, can be used to reduce average harvesting costs. About 20-50% (on average, roughly 25% in mountain pine beetle areas) of trees harvested is usually left on-site and much of this could be recovered for energy purposes. From 2004-2006, the average annual pine harvest (total volume cut) in BC has been about 42 million m³ per year. This level of harvest will exhaust the available pine within ten years.

Recent studies have examined the economics of using pine beetle wood [Envirochem 2006; BIOCAP 2005], and innovative solutions can address the challenges of recovering these residues. Accounting for transport and processing costs, electricity produced from pine beetle wood will probably cost more than that from other renewable energy sources. However, current government policy seems to favour all technologies, including biomass-based systems. It is unclear how the pine beetle infestation will progress and how this will affect the availability of such wood. It is expected that most of the pine beetle wood will have decayed by the year 2020 and that older tree stands that are vulnerable to the beetle infestation will have disappeared. Long-term resource planning should therefore include other wood resources, such as hog fuel, tree limbs from on-going harvesting operations or other non-merchantable wood that is currently still left in the forest and often burned there. Wood may also be available from heritage piles (hog fuel in landfills or piles next to existing or closed mills), from forest thinning operations (fire protection) or from local logging due to oil and gas exploration in BC (seismic lines). Small amounts may also be available from

- BC Hydro from power line clearing;
- Highway construction and maintenance operations;
- Urban-interface fire hazard mitigation projects and;
- Industrial / private land clearing.

Although BC has a very large wood resource, securing wood and woodwaste for bioenergy systems is not always easy. The BC Utilities Commission is the regulator of energy prices and will therefore play a pivotal role in shaping the wood-fuelled electrical energy sector in B.C. At this time, existing forest tenure holders and mill owners hold the majority of long-term logging rights. In addition to rights to harvest, they also hold the responsibility to mitigate fire hazard and reforest areas as well as manage road maintenance and safety issues. While the BC Government is assessing what opportunities exist under the current regulatory regime, interested parties should contact forest tenure holders and mill owners in their area to explore possible business arrangements. BC Hydro is also assessing how best to proceed with a future power contract process and with the BC Utilities Commission and Government. For more detailed information about bioenergy opportunities from wood fibre, visit the following web sites:

http://www.for.gov.bc.ca/hts/bioenergy/index.htm or
http://www.bchydro.com/news/2007/mar/release51407.html

It is also possible to grow trees specifically for use in energy generation facilities. While this has been tested using fast-growing trees, such as poplar or willow, the cost is still fairly high and the economics of such operations may not currently be favourable in BC. Employing locals might help reduce such costs, and may present energy opportunities especially in remote communities that are not grid-connected. At a wood yield of between 15 and 25 bdt/ha and year, between 250 and 420 hectares of land are required to provide enough feedstock for each MW of electric generation facility run on wood.

Wood can be processed into a number of energy carriers or products. Pellets are usually used to either export the wood to Europe or Asia, where the pellets are ground up again and the wood powder is then used for co-firing in coal plants or in biomass power plants. Bio-oil can be produced through a pyrolysis process, which concentrates the energy in a liquid. The oil has low commercial value but the extraction of specialty chemicals could increase the economic viability of the process. A different technology that is still pre-commercial gasifies the wood and then uses the syngas to form long-chain paraffin molecules, which combine into a biomass-based biodiesel. Wood can be treated with enzymes to produce ethanol, or can be gasified and then turned into methanol or synthetic natural gas. These processes, however, are at best at pilot or pre-commercial stages. Another process is cellulignin production (see Envirochem 2006), which turns the wood into a pre-treated powder that burns quickly and cleanly and is currently being used in turbines in Brazil.

Black liquor: Some 12 million tonnes of black liquor are generated annually in Canada in the pulp & paper sector. It is a pulping process residue, mainly containing lignin, water and chemicals**,** that remains after removal of the cellulose for papermaking. Black liquor is usually combusted in recovery boilers in order to recover the pulping chemicals and to produce energy. Efforts are underway to gasify the liquor prior to combustion in order to reduce air emissions and increase process efficiencies, possibly even in combination with gas turbines or fuel cells. Black liquor can also be gasified to create a syngas, which is then conditioned and made to form methanol over a catalyst. This is a feedstock that is used within the pulp & paper industry, and is typically not available to other users.

Table 1.3 Energy Products from Black Liquor

Biomass Feedstock	Energy Products
• Black liquor	Electricity
	Heat
	Methanol

Agricultural waste: Though a less abundant biomass resource in BC, there is a variety of agricultural wastes, such as crop residues, and liquid and solid animal wastes, that can be used for energy purposes. Dry crop residues, straw etc. can be burned (or gasified) to drive a steam turbine or other process. Animal waste is usually either composted without energy recovery (composting will actually consume quite a lot of energy due to the need to move the material) or processed in an anaerobic digester, which produces a mixture of methane and carbon dioxide that can then be combusted to produce heat and electricity. Other energy uses are less common, but the gas can also be purified and fed into the public natural gas network, sold as a transportation fuel for natural gas vehicles, or converted to methanol. The digester residue can be used as a fertilizer, animal bedding or even a fodder additive, depending on the specific feedstocks used.

Municipal biowaste and landfill gas: Like animal waste, separately collected municipal biowaste (“green bin”) can be processed in anaerobic digesters to form a methane-containing gas. The same process also works inside a landfill, only more slowly. Landfill gas can be captured in a pipe system and can then be combusted in an engine to produce electricity, or it can be used in an industrial process to replace natural gas, or even used to make methanol or hydrogen. The 2007 BC Energy Plan envisages requiring landfills above a certain size to capture the gas in order to reduce greenhouse gas emissions. Municipal waste can also be combusted without separating out the biowaste fraction in order to produce energy. This process is fairly expensive and requires sophisticated and expensive flue gas cleaning equipment due to the many noxious substances that can be found in household waste. A new process presently being demonstrated in Ottawa (plasma arc gasification) may be an alternative to current waste treatment options. The economics of scale for waste combustion facilities are usually such that they require larger municipalities (300,000 inhabitants or more). For waste digesters, a municipality still needs to have a population of at least 1,000 people in order to collect enough biowaste to run a very small digester (35 kW). Most digesters in Europe today are larger (about 300 kW). If the local municipal biowaste is too small for a digester, other sources of biomass such as food waste or agricultural waste could be added.

About 1,000 tonnes of waste are required to produce enough landfill gas to produce 1 kWh of electricity. This means that a landfill that has been in operation for 20 years should have a service area of about 300,000 people to produce enough gas for the operation of a 1 MW engine.

Food waste: If collected separately, the same options as for municipal biowaste are also open for using food waste for energy production. Often the combination of different biomass feedstocks will deliver a more optimized process or fertilizer product, or will enable the operation of a bigger unit offering better economies of scale.

Table 1.4 Energy Products from Municipal and Agricultural Feedstocks

Biomass Feedstock	Energy Products
• Municipal biowaste • Food waste • Agricultural residues (straw, manure)	Electricity
	Heat
	Synthetic natural gas or hydrogen
	Methanol

Plant and animal fat: So-called yellow grease (used vegetable oil from restaurants) and, of course, virgin oil (mainly canola or soy oil) can be used to produce biodiesel by mixing it with methanol and filtering off glycerin as a by-product (1 litre of oil and 0.1 litres of methanol will produce 1 litre of biodiesel and some glycerin). This is a fairly simple process that can virtually be carried out "in the backyard" but is often implemented at an industrial scale. Likewise, animal fat from animal rendering can be processed in a similar way. Biodiesel has a higher viscosity (is thicker) than normal diesel, which may cause problems when starting a cold engine during winter time. It is therefore often mixed 20:80 with petroleum-based diesel. This mixture will reduce overall greenhouse gas emissions, but may slightly increase NOx emissions as compared to normal diesel fuel. Note that the amount of yellow grease available even from a large community will usually not suffice to provide enough fuel to replace the local consumption of petrodiesel. It can, however, replace all or most of the diesel consumption of a select group of vehicles, such as that of a particular company or a municipal department. Vegetable and animal fats can also be added to other feedstocks and treated in an anaerobic digester to produce methane, instead of making biodiesel.

Table 1.5 Energy Products from Oils and Fats

Biomass Feedstock	Energy Products
• Yellow grease • Vegetable oil (canola, soy) • Animal fat	Electricity
	Heat
	Synthetic natural gas or hydrogen
	Methanol
	Biodiesel

Energy crops: In addition to wood from coppice plantations, grasses like switchgrass or elephant grass are being tested as energy sources worldwide. These grasses can provide fairly high yields (10-30 bdt/ha) without large fertilizer inputs. Their ash content is higher than that of wood, and their land requirements are very similar to that of wood plantations. The potential for such energy crop plantations in BC is limited due to current uses of agricultural lands. However, it has been suggested to replace a portion of the dead pine beetle stands with fast-growing trees for energy production. Growing algae in special ponds may be another way of creating biomass for energy purposes.

1.4 Transport

Raw biomass always contains water, which is not desirable for energy uses. Green trees have a moisture content of 45-55%; for dead trees that may be reduced to 20-25%. The moisture content of straw can be as low as 15%, whereas municipal biowaste or food waste may have moisture contents as high as 60%. The moisture content increases the weight to be transported as compared to fossil fuels, which usually have very low moisture contents. Table 1.6 summarizes moisture content by feedstock and compares the amount of biomass required to deliver an equivalent energy content as one metric tonne of coal. For some processes, pre-drying is required to bring the biomass to an acceptable moisture content. For example, pellet production usually requires a moisture content of 10%.

Table 1.6 Comparison of Weight and Volume for Biomass and Fossil Fuels

Resource	Moisture content	Mass equivalent to the energy in 1 t of coal	Corresponding Volume
Heating oil/diesel	<2%	0.8 t	1.0 m^3
Coal (anthracite)	2%	1.0 t	1.1 m^3
Coal (lignite)	2%	1.9 t	2.5 m^3
Hardwood (stems)	50%	4.1 t	5.9 m^3
Softwood (stems)	50%	4.1 t	10.8 m^3
Dead pine wood	25%	3.0 t	10.8 m^3
Sawmill dust	30%	2.8 t	9.3 m^3
Wood pellets	8%	2.0 t	2.8 m^3
Wheat straw	10%	1.9 t	24.0 m^3
Biowaste	60%	5.6 t	8.0 m^3

In comparison to fossil fuels, transporting and storing biofuels can require an order of magnitude more space, and also significantly higher transport costs. These disadvantages must be taken into account when planning for a biomass energy facility. Figure 1.2 below illustrates the differences between the densities of a massive piece of wood, stacked wood, and chunks of wood stored in bulk. Decentralized processing (e.g. converting wood to bio-oil) concentrates the energy and reduces the transport cost. However, processing in smaller, decentralized units is often less efficient and a detailed analysis must therefore be carried out to determine the most cost-effective setup for each given situation.

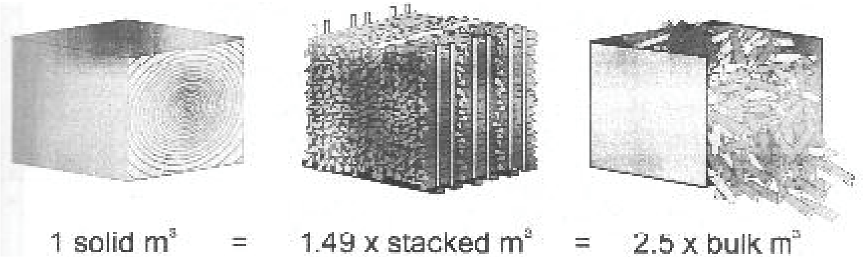


Figure 1.2 Density of Wood

Transport costs of biomass will also vary with the type of contract (one-off job or long-term, regular supplies), as well as with the quality of roads: a carrier may have to carry out more maintenance, and drive more slowly, if a large part of the distance consists of logging roads. Difficult road access to the biomass, for example in the forest, may also exclude some of the more efficient vehicle types, such as chip trucks. Special side dump chip trucks with containers mounted on a logging truck drive train are then required. Data on transport costs for pine beetle wood can be found in FERIC 2006.

1.5 Comparison

The above overview provides some general rules of thumb to assess biomass resources and technology options. Note that all numbers provided are “ballpark numbers” and that a more detailed resource assessment should be carried out whenever a resource in the same order of magnitude as indicated here can be found. The table below summarizes some key values once more. Note that the combination of several biomass resources is possible and often desirable.

Table 1.7 Overview of Biomass Technologies and Resources Required for 1 MW

Resource	Resource required for each MW of electric generating capacity
Wood	10,000-15,000 tonnes (about 25,000-35,000 m³) per year
Construction/demolition waste	Community of 180,000 people (this means it will rarely be the only biomass resource used)
Agricultural waste (anaerobic digestion)	Biowaste from 30,000 inhabitants or from other sources (food/agricultural waste)
Landfill gas	Landfill for mid-sized city (300,000 people)
Energy crops (grass, wood)	250 – 420 hectares

Some of the processes and technologies mentioned above require an industrial-scale installation. Whereas biodiesel can be made in a small-scale installation, it is usually also produced commercially in a larger facility. Making ethanol, synthetic natural gas, methanol or even hydrogen from solid feedstocks through gasification will always require a larger facility. Some smaller systems are available to convert landfill gas or digester gas. Bio-oil systems exist as mid-sized versions of a few megawatts. Pellet plants will usually be fairly large; typical plants in BC process between 100,000 and 200,000 tonnes of wood per year. Chapter 2 in this Primer will discuss these processes in more detail, and will point out their relative strengths and weaknesses. Many of these technologies are still at the pilot or demonstration stage and are therefore still investments with a larger technology risk. This situation is evolving quickly, however, and should be evaluated for each case.

Hydrogen fuel cells are an emerging technology and are not discussed in detail in this report. They are, similar to a cogeneration engine, an energy conversion technology, but don’t actually qualify by themselves as renewable energy systems. They are more efficient than internal combustion engines, but the technology is not yet as reliable and is very expensive. Fuel cells are currently being used in some places in conjunction with municipal biosolids digesters in the U.S. and elsewhere. They are usually small, but are available in sizes up to 1 MW.

Table 1.8 System Size Ranges of Biomass Energy Technologies

Technology	Electric Capacity Range
Anaerobic Digesters with cogeneration unit	35 kW – 2 MW
Steam Turbines (Rankine cycle)	10 MW – 300 MW
Entropic cycle	250 kW – 5 MW
Gasifiers with steam engine	80-350 kW (downdraft) 500 kW – 4 MW (updraft) 2-100 MW (fluidized bed)
Pyrolysis with turbine	100 kW – 10 MW (modular)
Plasma Arc with combined cycle turbine	12 MW

Table 1.8 shows the size ranges of the various biomass technologies discussed in this report. It becomes obvious that the amount of biomass available also dictates the technology to be used, among other factors. On the other hand, if a certain size of system is required, certain feedstocks will be unsuitable. It may be necessary to complement biomass with fossil fuels if insufficient amounts of biomass can be sourced to run the system at high capacity factors. Table 1.9 compares the technologies to produce liquid biofuels for transportation. Note that only the biodiesel through esterification pathway offers the full size range from a small “backyard system” to a full, industrial-size plant.

Table 1.9 System Size Ranges of Liquid Biofuel Technologies (Transportation Fuels)

Technology	Annual Plant Output
Biodiesel (Transesterification)	2,000 – 50 million litres
Biodiesel (Gasification/Fischer-Tropsch)	30 million litres
Lignocellulosic ethanol	10 – 50 million litres

1.6 Potential Applications

The following overview provides some perspective as to how and where biomass could be used for energy purposes. Other applications are possible and these are just a few examples which may help inspire a project in BC.

Heat-only applications: Such technologies can be very small (starting with residential pellet stoves) or larger, such as wood heaters for hospitals, industrial units, churches, municipal buildings, universities, schools and colleges. It is also possible to construct a district heating plant to heat homes. This should especially be considered for new housing developments. The technology is cheaper and simpler than those for producing electricity, and is therefore especially suited for remote and small communities. Heat-only applications should be considered where the amount of biomass is insufficient to generate electricity cost-effectively. Dryer feedstocks like wood and straw are most suitable for heat production. Municipal biowaste should first be treated in a digester, and the resulting gas can then be used for heating purposes.

2 $\mathbf{MW_{el}}$ and smaller: This includes most landfill gas and anaerobic digester units. Likewise, smaller cogeneration units fall into this category. A 2 MW plant will use about 30,000 tonnes of biomass per year (two tandem trailer truckloads per day), and can provide electricity and heating needs for some 1,500 homes. Most communities will be able to source enough biomass for units of this size within a radius of 50-100 km at the most.

2-10 $\mathbf{MW_{el}}$: These are small-sized units that may benefit from a fixed per-kWh tariff to be introduced by the BC Government in the near future. They can make use of steam or non-steam technologies, and can produce electricity, as well as heat. They may be suitable for larger remote communities and other BC communities or industries that want to reduce their carbon footprint and create local employment and increased energy autonomy. A 10 MW unit will use up to 100,000 tonnes of biomass per year. Such amounts can usually only be found near industrial activities that produce large quantities of waste biomass.

Larger than 10 $\mathbf{MW_{el}}$: These are industrial units that will supply electricity to the power grid. Such large units will be sited either next to a biomass user, such as a saw or paper mill, or in a location removed from any residential areas, due to industrial character and emissions of such and installation, and the increased traffic incurred by feedstock transport. They may, in some cases, produce industrial heat where a suitable user is available but are most likely to be power-only systems. These units are more difficult to site and finance as they require large investments and long-term contracts for biomass deliveries which cannot be found in all parts of BC. Biomass may have to be sourced from several suppliers, including potential backup sources if any of them should become unavailable in the future.

1.7 Before You Read the Next Chapter

Considerations for selecting a biomass energy technology not only include what you want to produce, but also the amount of your feedstock and the size of system that you can finance. A small community will not build a full-scale ethanol production plant. A large paper mill may want to invest in a steam cycle, rather than using a smaller-scale system. Figure 1.3 illustrates which technologies could apply to you, depending on what your resources are. This streamlines your research and means that you don't have to read up on the technologies that you already know are not suitable for your situation. The cogeneration option is discussed for several energy systems, but requires that you find a user for the heat. In a remote area, or even at a distance of a few km from an urban agglomeration, selling the heat may not be an option because the cost of transporting it is too high. Cogeneration should, however, be considered for all electricity projects since it significantly improves efficiencies and emission reductions from a biomass system but it cannot be applied in all circumstances.

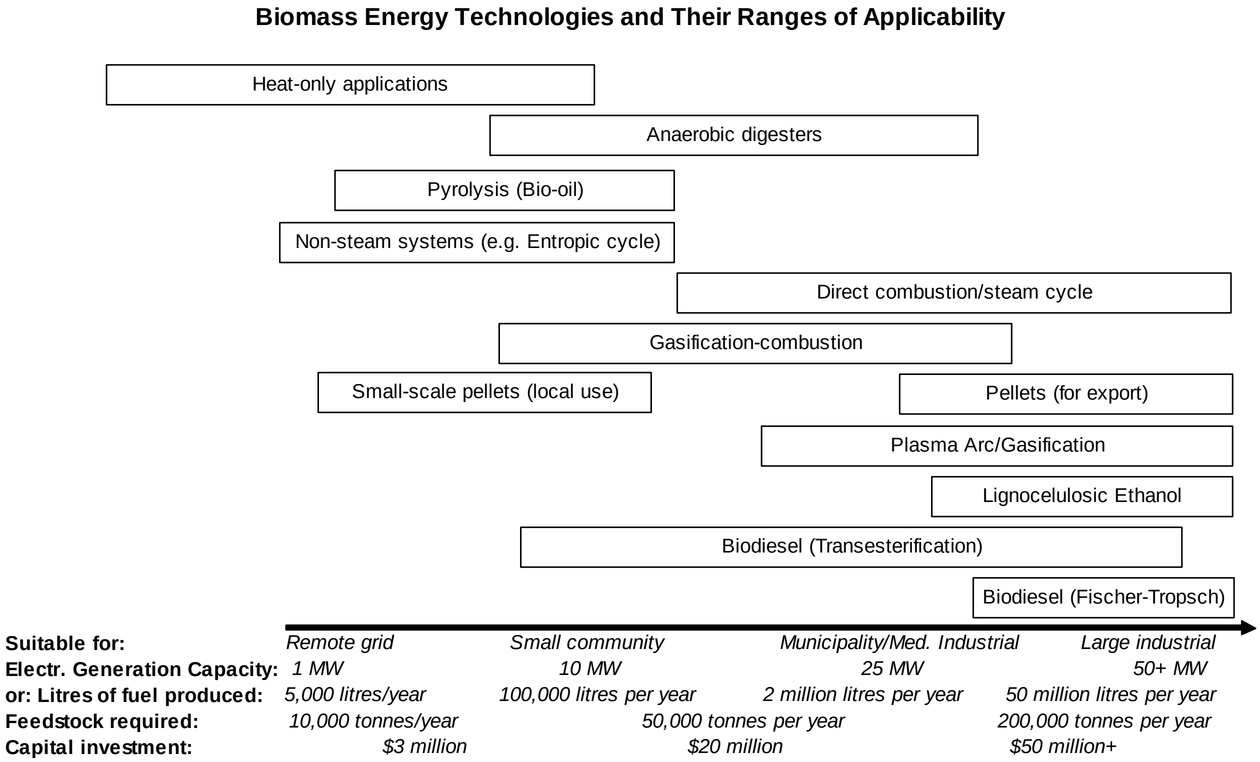


Figure 1.3 Applicability of Biomass Energy Systems to Potential Audiences of this Primer

2 Technology Review and Comparison

2.1 Introduction

This chapter reviews how different bioenergy technologies work and what their system requirements are. The Primer profiles the following bioenergy technologies:

1) anaerobic digestion,
2) direct combustion,
3) gasification-combustion,
4) pyrolysis,
5) pelletization of wood (large and small-scale),
6) high-temperature gasification of MSW and biomass,
7) lignocellulosic ethanol,
8) biodiesel (transesterification of fats and gasification of biomass).

Within each technology section, the Primer provides overviews and details on the following topics that will be of high interest to stakeholders:

1) Technology
2) Feedstocks and Products
3) Air Emissions
4) Market Readiness
5) Capital Costs
6) Scale of Process
7) Decision Matrix to Select an Appropriate Technology

Care was taken to provide enough detail to understand how each technology works and what its limitations and advantages are while trying to reduce information to the most essential elements to the Primer remains readable for the layman. Please note that there may be some topics or statements that experts will disagree on, and that this Primer can only reflect the situation at the time of writing. Since new technologies are coming to market all the time, some of the suggested decision pathways or limitations of the technologies discussed may become outdated. It is therefore prudent to examine a particular situation in more detail in order to make the best decision on which biomass energy technology should be used, with the most recent information available at that time.

2.2 Anaerobic Digestion

Technology

A biological digester mimics the processes occurring inside a landfill, but accelerates these reactions and produces a useful residue. The digestive process is a bacterial process that runs under anaerobic conditions, i.e. without oxygen or in an oxygen-poor environment. Organic material is decomposed inside the digester, which is really a large reaction vessel. The process produces a gas, which is a mixture of about 60% methane (CH_4), 35% carbon dioxide (CO_2) and 5% other gases. The production of gas is controlled by maintaining the required process temperature and the addition of fresh organic material. This biogas can be used in internal combustion engines, generating heat and electricity. It is also used as a transportation fuel after scrubbing out most of the carbon dioxide.

The main advantages of digestion over other waste treatment options will be illustrated in the following example. Removal (stabilization) of 70 kg of organic pollutants (i.e. organic biomass such as hog manure) in the anaerobic digester will yield enough biogas to produce roughly 75 kWh of electrical energy and a similar amount of heat, if an internal combustion engine is used. Conversely, if one uses an aerobic process to treat that same biomass (e.g. aeration of a hog manure lagoon until stable odour-reduced product is obtained), one needs to put in about 100 kWh of energy for aeration. An anaerobic digestion generates two products: a stable, albeit still a little odourous solid product, which may require some aerobic curing, and biogas. If long digestion times are used or if the temperature is controlled at higher than the body temperature (i.e. in the thermophilic range of 55°C) the product will have significantly reduced pathogen levels and can be safely distributed for land application. The anaerobic process, in contrast to the aerobic process, fully contains all emissions, thus giving the operator complete control over greenhouse gas and odour emissions, removes carbon but leaves the nitrogen and phosphorus intact, thus improving the fertilizer value of the final product. Aerobic processes lose significant amounts of ammonia due to volatilization and nitrification/denitrification reactions. Volume and weight of the biomass feedstock are cut in half by the digestion process.

The product of the digestion process is usually dewatered if it is in a slurry form. Anaerobically digested solids can be further "cured" (composted for two to four weeks to eliminate the residual odours and to firm up the material) inside a building with a biofilter to eliminate odour, and sold as soil conditioner. The liquid fraction is often recycled when water is required to make the incoming material more liquid (such as in case of some processes digesting municipal biowaste), is discarded as wastewater or used as liquid manure on nearby agricultural land.

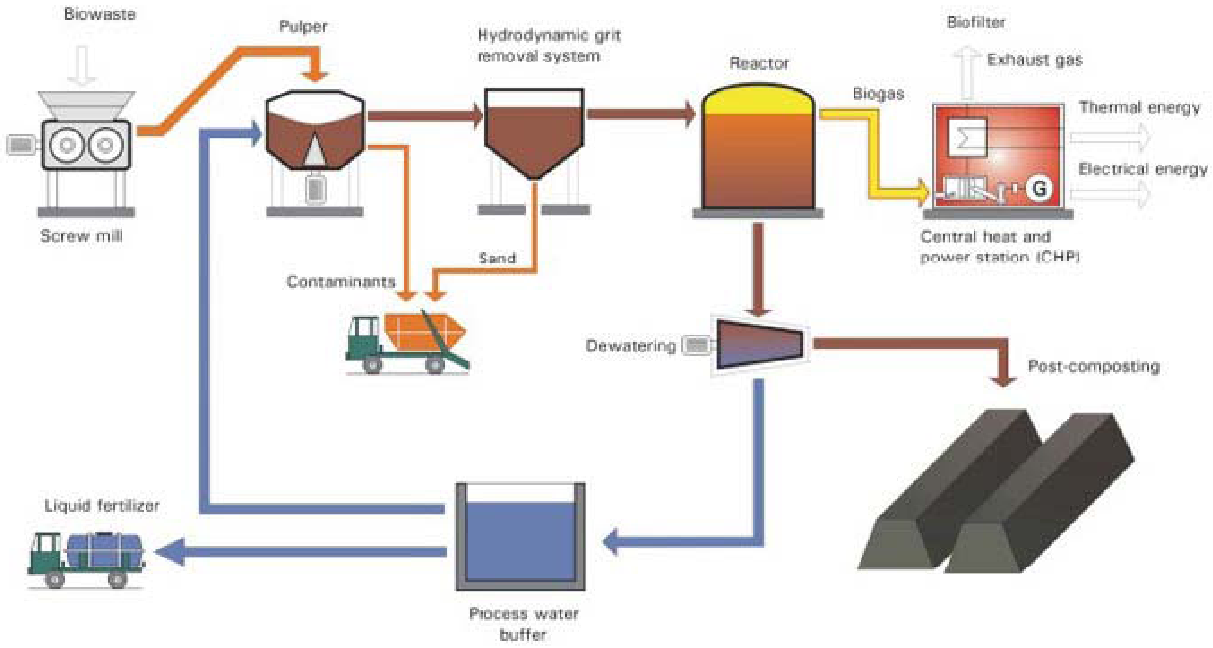


Figure 2.2.1 An example of an anaerobic digestion process where solid waste (such as organic fraction of municipal solid waste or solid manure with bedding) is converted to liquid slurry before the digestion. The digestate, after dewatering, is further cured (composted) to a final solid product (single-stage digester, courtesy Canada Composting, Inc.)

Types of digesters: Digesters can use batch, continuous or semi-continuous processes. In the batch process, the feedstock is fed into the reactor and left to be digested, after which the reactor is emptied. Retention times are 30-60 days, and process efficiencies and gas production are lower because the feedstock in batch reactors is usually not mixed. In the continuous process, fresh material continuously enters the tank and an equal amount of digested material is continuously removed. Because mixing is usually performed in these reactors, they can be kept smaller and work more efficiently, with fairly constant gas production and shorter retention times of 10-20 days. This is particularly true if the digesters are uniformly heated and stirred.

Another common operation is the semi-continuous process. If higher temperatures are used (e.g. thermophilic at 55^{o}C) the process can facilitate gas production and pathogen inactivation. Here the feedstock is batch-fed to the digester and then left for 24 hours, before the next withdrawal and feed cycle, allowing time for adequate pathogen inactivation, without the fresh input of raw material.

The simplest and least efficient reactors are plug flow reactors (usually in the shape of a long trench or "lagoon"). Plug flow reactors are typically used for thicker substrates with higher dry matter content, whereas liquid manures etc. are usually treated in a completely mixed digester (usually a cylindrical design). A lagoon is less expensive, but since it is typically not well insulated and covered, gas production is a secondary goal when lagoons are applied. The exception is a commercially available, heated well-covered deep lagoon which is used in a number of cold-climate locations to treat food industry wastewater such as potato processing; slaughterhouse and vegetable oil wastes in Manitoba or Ontario.

Feedstock concentration: Digestion can be done as "dry digestion," with a typical dry solids content of 25-35% (that is moisture or water content of 75-65%) and as "wet digestion," with a dry solids content of less than 15%. Dry digestion is typically applied to the organic fraction of municipal solid waste in a process where moisture levels are adjusted with for example manure or municipal biosolids, to e.g. 65% (35% solids). Mixing of the solid mass is done by an auger. A number of commercial processes exist using such feedstocks.

Liquid manure slurry and liquid agricultural residues can be treated in stirred digesters. Figure 2.1.1 illustrates an example of municipal biowaste digestion, where water is added to decrease the concentration of solids to form a slurry which is then digested in a conventional stirred tank digester. The diversity of digester designs corresponds to the diversity of feedstocks and treatment goals.

Process temperature: The process can be run at a body temperature of 35-37 °C (mesophilic) or around 55°C (thermophilic). The latter process is faster and removes pathogens more efficiently, but requires better process control and uses more energy to maintain the higher temperature. In general, the increased energy yield in thermophilic mode does not compensate for the need for a larger energy input for heating the digester in cold climate. Thermophilic digesters are mainly used in larger operations when pathogen inactivation is important. The smaller digesters will be run in the mesophilic mode since start-up and tolerance against changing process parameters is larger. Low-temperature digesters (psychrophilic) are currently in operation in Manitoba and Quebec and run at temperatures between 15 and 25 °C. The biogas yield from these digesters is not as reliable and much less gas is obtained per kg of material fed.

Feedstocks & Products

In theory, anything that is organic can be used as a feedstock in a digester. However, different feedstocks have different biodegradability. The biological process in the digester works best if the substrate is easily biodegradable. Thus liquid hog manure will digest faster than municipal biowaste or straw bedding-laden broiler manure. On the other end of spectrum, wastewater from a vegetable processing facility or fruit juice manufacture will digest much faster than any manure. Although digesters are tolerant of low nitrogen and phosphorus in the feed the optimum carbon/nitrogen ratio for a digester is about 25. The current trend is to combine several feedstocks to achieve optimum biodegradability, thus maximizing gas production. In Denmark, a number of such central digester operations exist where farmers and growers bring their waste residuals and take in return digested compost-like material for land application. The feedstocks are chosen such that an optimum digestibility mix is generated.

Municipal biowaste: The high solids content of this waste will require pre-treatment before it is introduced into the digester. This treatment will reduce the particle size and separate glass, metal and sand fractions from the material. Some digesters function with the organic fraction from mixed household waste that is separated in a waste sorting center. However, separation at the source and biowaste collection will lead to far lower contamination and better compost quality.

Manure: Manure is high in nitrogen and cow manure is well suited for treatment in digesters. Hog and especially poultry manure is more difficult to treat by itself due to its high fine solids content, and requires larger digester volumes than other manure.
Food waste: Meat and slaughterhouse waste, residues from bakeries, dairy process waste, brewery waste, fruits, vegetables and other such organic residues are all potential feedstocks for a digester. Likewise, vegetable and animal fats, oils and greases can be used; although more difficult to digest, their overall biogas yield is higher.
Biosolids: Sludge from municipal wastewater purification plants is termed "biosolids" and is often treated in anaerobic digesters to reduce organic content, inactivate pathogens and generate some energy that is then used to operate equipment on-site.
Paper & cardboard: Proteins such as meats are high in nitrogen while paper products contribute relatively more carbon. Generally, paper digests less easily and is better suited for recycling, but may be used to achieve a desired carbon/nitrogen balance.
Wood: Wood has high lignin content and is not easily accessible for biological degradation. It may be added to achieve a desirable texture of the compost produced from the aerobic curing phase.

The digestive process will produce a liquid from the dewatering process which can either be recycled and used to increase the water content of incoming feedstocks (mainly recommended for solid wastes, such as food scraps), eliminated as wastewater, or used as a liquid fertilizer. The remaining solid digested material is cured in an aerobic process and then also used as fertilizer and soil conditioner. Sometimes it is also used as animal bedding.

Air Emissions

The main problem with digesters, as with composting, is odour control. Usually, the digestate is cured/composted after it leaves the anaerobic digester to stabilize it and reduce odour. This process needs to be housed and exhaust air must flow through a biofilter to remove any odourous components.

Other air emissions are created from the gas combustion process. These emissions either occur at the digester's cogeneration engine, microturbine, fuel cell, or wherever else the gas is used. For example, the gas could be purified and fed into the natural gas grid, or used to heat greenhouses or provide heat for an industrial process.

Table 2.2.1 Emissions from Biogas-Energy Conversion

	Cogeneration engine	Fuel cell	Microturbine
NOx	26 g/kWh	0.0006 g/kWh	0.2-2.3 g/kWh
SOx	3 g/kWh	0.03 g/kWh*	3 g/kWh
Dust	~0 g/kWh	~0 g/kWh	~0 g/kWh
Methane	50 g/kWh	1-4 g/kWh	lower than engine
Source	*UoM 2006*	*UoM 2006*	*ETSU 2002*

* with pressure swing absorber to remove most of the H_2S in the biogas

Depending on the process (internal combustion, combustion in a boiler, etc.), emissions may vary slightly. A scrubber is often used to remove sulfur emissions (hydrogen sulfide can be 1-2% of the gas produced). Table 2.2.1 shows air emissions for a cogeneration unit that uses an internal combustion process, a microturbine and a fuel cell. Note that the carbon contained in biomass is usually considered part of a regeneration cycle and processes using biomass can therefore be considered carbon neutral. However, any methane emissions should be avoided as they would otherwise constitute GHG emissions. Methane emissions can occur during curing of the material, but can be partly eliminated by the biofilter. The anaerobic digestion process will generate GHG credits through avoided emissions in the field or from open lagoons, as well as from the electricity or natural gas displaced when using the digester gas for energy purposes.

The fuel cell has much lower emissions, especially in terms of criteria air emissions – although the low SOx emissions are mainly due to a scrubbing process required to protect the fuel cell from corrosive sulfur in the biogas, which could also be applied to the engine. Note that some of the methane will remain uncombusted. In the case of the engine, 50 grams per kWh may still be emitted, which is equivalent to GHG emissions from a coal power plant on a per-MWh basis (a microturbine would emit less). However, the system needs to be seen on a life-cycle basis and combusting the gas in an engine will still reduce total emissions from biomass as opposed to the case where it can digest in the open. This disadvantage is a lot smaller for fuel cells than for internal combustion engines.

Market Readiness

Anaerobic digesters are an established technology and several designs are available from European and U.S. providers. Today there are over 600 digesters in Europe, 370 in the U.S., and Canada has about a dozen. There are also Canadian designs, such as Bio-Terre, IMUS and Clear-Green Environmental Inc. Note that the Canadian concepts are still pre-commercial. More information on technologies and providers can be found in the Appendix.

There are several different designs and features that distinguish digesters from the various manufacturers. It is necessary to conceptualize digesters around the feedstock used. For example, chicken manure requires much larger designs due to its high solids content. Also, municipal biowaste may be better used in a dry digestion process, whereas pig or cow manure yields itself to wet digestion. It is therefore not possible to buy digesters “off the shelf” without first analyzing the particular needs of the process envisaged.

Additional considerations apply to annexed equipment, such as cogeneration engines. Combustion engines are readily available, as well as the related heat exchangers to recover the waste heat produced. Likewise, microturbines are market-ready equipment. Fuel cells are operating on digester gas in several places, but fuel cell technology itself is less developed. Units are still very expensive and manufacturers usually only warrant some 2,000 hours of running time.

Biogas purification to pipeline standards is being done in Europe, and planned in the U.S. This technology requires the removal of CO_2 such that the gas becomes almost pure methane. Technologies like water scrubbing, membrane separation or absorption are commercial and already applied in the field.

Capital Cost

Table 2.2.2 shows the cost of the elements of a digester. Note that the size of the digester may vary, and that these costs are only indicative because manufacturers offer systems with different degrees of sophistication. Costs are shown in 2007 Canadian dollars and include the heat exchanger for cogeneration applications, but not any remote heat transport pipelines that would lead off-site.

Table 2.2.2 Capital Costs of Digester and Energy Conversion Equipment

Component	Capital cost per MW of electric capacity	Electric conversion efficiency
Digester vessel and equipment	$2,500,000	-
Cogeneration engine	$1,000,000	18-25%
Microturbine	$3,000,000[1]	27%
Fuel cell	$5,000,000	40%

Clearly, since a fuel cell costs five times as much as the cogeneration engine, it can usually not be justified economically. The electrical efficiency of a fuel cell is higher, which in turn means that less heat is produced. A combustion engine will usually produce 1.5 times as much heat as electrical energy. Operational costs are of course an important factor in the technology choice. Life-cycle costs for a digester will be determined not only by maintenance and energy consumption, but also by transport costs for both feedstocks and products. At the time this Primer was written, the BC Bioproducts Association was undertaking a detailed study of the economics and feasibility of digester technology in the Lower Fraser Valley. Readers are encouraged to refer to this study for further information on technologies, payback and related information.

Scale of Process

Digesters are available in smaller sizes (35 kW) for small farms and large sizes up to several MW, for industrial applications. Annual capacities for feedstock throughput range from 3,000 to 100,000 tonnes. Note that the optimum location for a digester not only depends on the distance over which feedstocks have to be transported, but also on the distance to potential users of the compost and other products coming out of the process.

The literature indicates that biogas production for generating cost effective electricity requires manure from at least 200 cows or 1,000 pigs, and the animal population should not vary by more than 20% throughout the year. In BC, larger systems may be required due to fairly low electricity prices (2,000 cows or 10,000 pigs). Alternatively, biowaste from 5,000-10,000 inhabitants or an equivalent amount of feedstock from other sources would have to be available. Feedstock should be collected daily or every second day, and some storage should be provided. Emission control systems will increase system costs and may demand a larger overall system size in order to reach the desired economies of scale.

The decision matrix (Figure 2.2.2) shows the selection process to determine which type of reactor is most suitable for the feedstock at hand. In some cases where pathogen inactivation is necessary and biowaste production is small or not continuous, one may opt for a batch thermophilic process or choose a very long anaerobic storage (several years) at ambient temperature. In case of small feedstock amounts from a single source, combining several waste streams to arrive at the economically critical total mass, and thermophilically digesting in one central location could be the right choice.

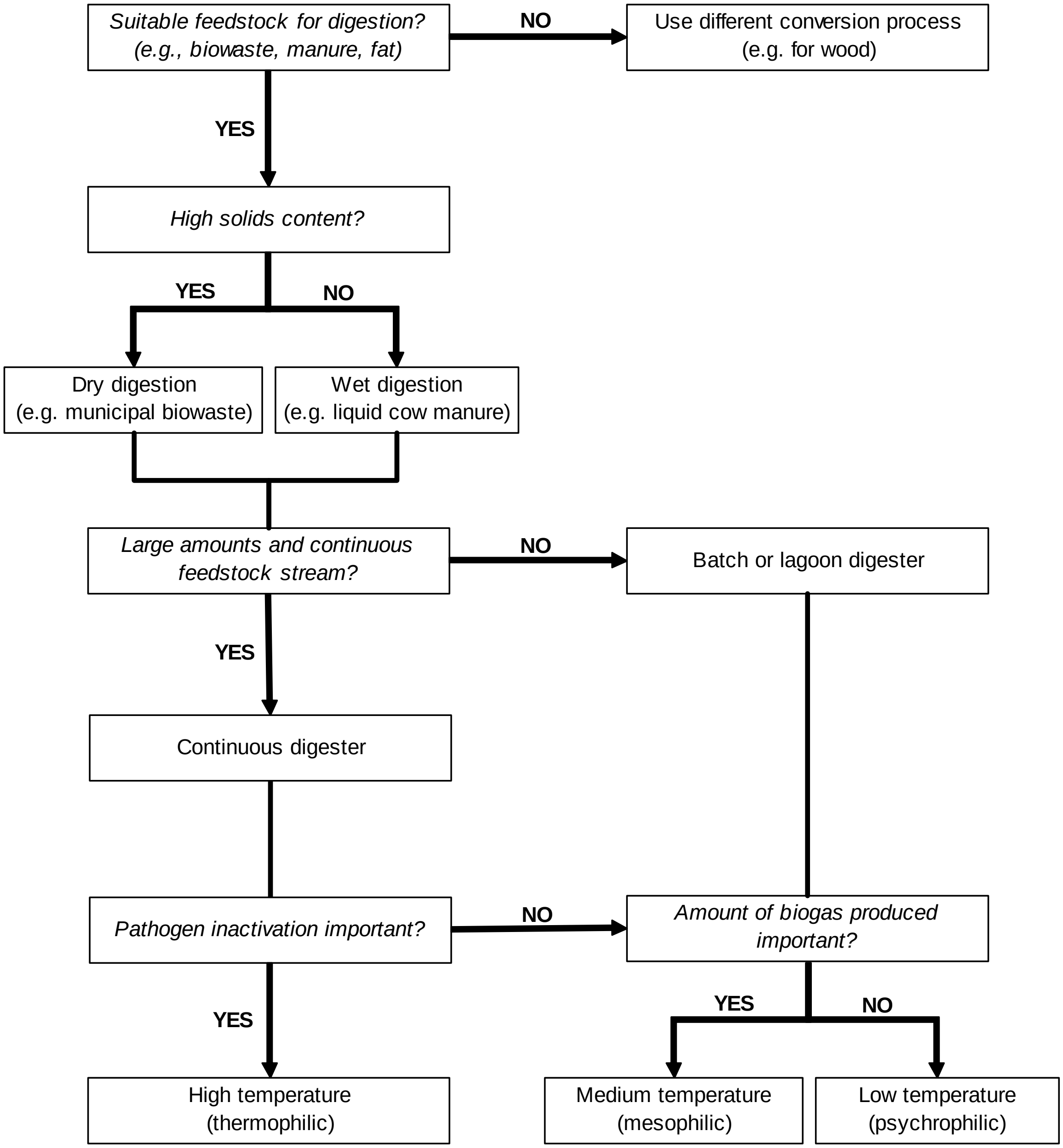


Figure 2.2.2 Decision Matrix for Selecting Anaerobic Digester Technology

2.3 Combustion, Gasification and Pyrolysis

Technology

Combustion: This process is most commonly used today in power generation. Usually based on fossil fuels like coal, oil or natural gas, it vaporizes water and the steam is then used to drive a turbine, which in turn generates electricity. It is possible to use the waste heat generated by this process for industrial purposes or for district heat. That makes such a system a cogeneration plant with a much improved overall system efficiency, although the electric conversion efficiency is slightly reduced as compared to a plant that only generates electricity.

The Rankine cycle is the basis of steam systems for power generation. The Williams Lake Generating Station is a well-known example of a stand-alone biomass power generating facility based on the Rankine cycle. It was commissioned in 1993 at Williams Lake, B.C. at a cost of $150 million. It has a rated capacity of 60 MW, a capability of 67-69 MW and achieves an overall electric efficiency of about 30%. 550,000 green tons of wood waste is supplied annually from five sawmills, all located within 5 km of the plant, and includes pulp quality chips as there is no paper mill in the vicinity. This relatively high quality fuel varies in moisture content from 37% in the summer to 50% in the winter. This plant is claimed to be “the most efficient stand-alone wood fired power plant in North America” and thus could be viewed as the upper limit of power production efficiency expected from large steam Rankine systems. It should also be noted that this facility operates at or beyond its rated capacity.

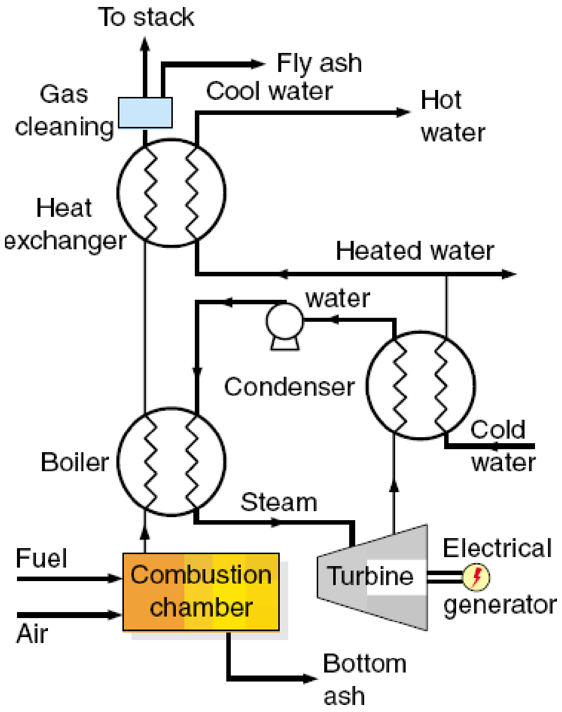


Figure 2.3.1 Steam Cycle with Turbine to Generate Electricity

Source: ROYAL COMMISSION ON ENVIRONMENTAL POLLUTION – BIOMASS AS A RENEWABLE ENERGY SOURCE

Cogeneration: Every energy conversion system wastes a portion of its input energy. For biomass to electricity conversion systems, 50% or more of the energy input can be lost - even up to 90% for some small-scale and alternative technologies. However, the energy rejected from a conversion system can often be used productively for industrial or residential heating purposes in place of burning fuels separately for that purpose. When this is done the overall efficiency can jump to 75-80%. Most systems must reduce their electricity production somewhat to make cogeneration feasible.

Entropic cycle: The so-called entropic power cycle is a Canadian invention most suitable for small-scale applications. This technology is similar to the steam cycle, but uses a proprietary non-steam working fluid in a closed loop system. The fluid is non-flammable and safe to use directly in a flue gas heater. Moreover, the entropic power cycle permits the use of simple equipment, is compact, increases efficiencies over other systems and uses a high-temperature coolant. The coolant enters the system hot (50°-60°C) and leaves at a higher temperature (85°-95°C), which makes it ideal for district or other heating purposes. No cooling tower, cooling pond or external cooling water is required. The system does not have the safety concerns of a steam boiler and therefore does not require a steam qualified or regulated operator.

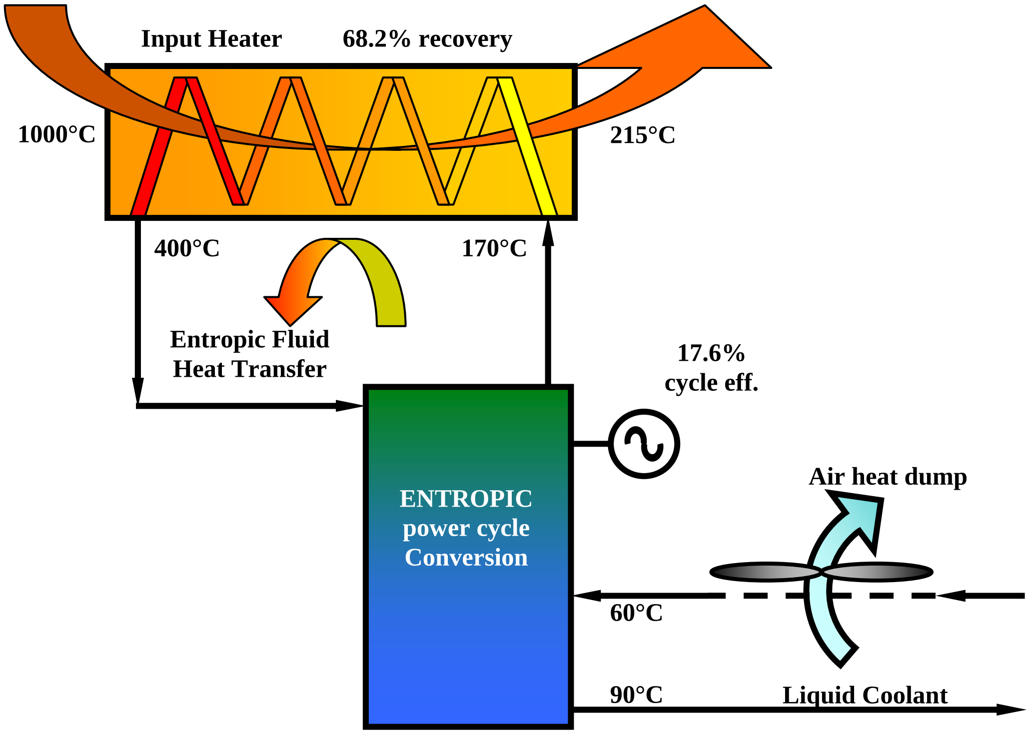


Figure 2.3.2 Entropic Power Cycle System

Gasification-Combustion: Gasification is the conversion of biomass into ash and volatile, gaseous compounds at high temperatures with the controlled restriction of oxygen. This creates a flammable producer gas ready to combust, but with a much lower heating value than natural gas (10-20%). Using pure oxygen instead of air can increase the energetic value to about 50% of that of natural gas, but is more costly. The process works at high temperatures (800-1,400°C) and therefore uses part of the energy in the feedstock for the gasification step. The gas is either combusted in a steam or other power cycle, or can instead be combusted in place of fossil fuels in drying or other industrial processes requiring a heat source. The calorific value of the gas is lower than that of natural gas, making it difficult to produce high temperatures, which may limit its usefulness in some applications, such as lime kilns, or can require modifications to the installation.

Some feedstocks may also require pre-drying before gasification can take place. Various gasifiers feed some kinds of biomass materials more easily than others, so the ability to switch between different feedstocks may be limited or may require modifications to the system. The composition of the gas also varies with the feedstock entering the gasifier. The ash may be developed into a soil amendment or plant fertilizer.

Gasification-Syngas: The process described above does not clean up the syngas produced by the gasification process. Attempts to produce a syngas close to the quality of natural gas have been made, but this requires cooling to remove water vapour, which is a significant energy loss, as well as filtering to remove tar and other components in the gas that would damage subsequent equipment, such as a gas turbine. These steps pose difficult technical problems, such that few commercial systems exist today. Sections 2.5 and 2.7 discuss some emerging technologies in this area.

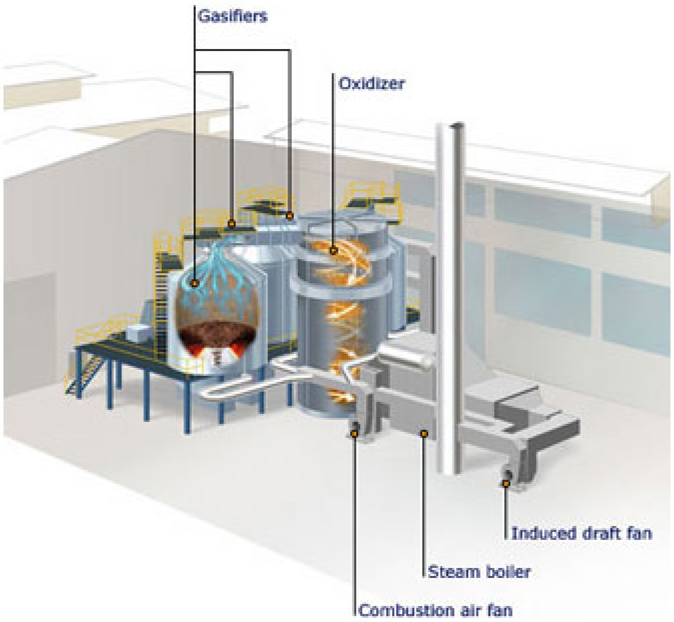


Figure 2.3.3 Nexterra Gasifier

Nexterra is a Vancouver based gasification company. The image shows a cogeneration application at the University of South Carolina. Three gasifiers convert wood biomass to combustible syngas, which is burned in the oxidizer. The hot flue gas is directed through a heat recovery steam generator to produce steam. The steam is sent to a back pressure turbine to produce electricity. The turbine exhaust provides heat to the campus heating system. The 1.4 MW_{el} plant burns sawmill residues from a nearby mill.

Pyrolysis: In pyrolysis systems, biomass is heated up to a temperature of 400-600°C in the absence of oxygen to vaporize a portion of the material, leaving a char behind. Bio-oil is produced by condensing part of the gases formed by the process. Generally it is the large, carbon based molecules that will condense. Further it has been found that these molecules will tend to break down to smaller non-condensable molecules if they are maintained at high temperature. Recognizing this, several groups have developed “fast pyrolysis” systems in which the pyrolysis gases are cooled and condensed quickly (<2 seconds), soon after being formed. Fast pyrolysis will maximize the yield of bio-oil (60-80%) and maintain complex constituent molecules as compared to slow pyrolysis. About 20-25% of the biomass will end up as char, and another 10-20% will be available as non-condensable gases. This chapter will only concentrate on fast pyrolysis technologies as they appear to be more promising than slow pyrolysis systems.

Biomass must be dried to 10% water content before entering the pyrolysis unit, in order to keep the moisture content of the bio-oil low. The chemical mix of bio-oil varies with the feedstock used and the conversion process employed. Some promotion of bio-oil has focused on extracting high-value chemicals before using the remainder for energy, possibly resulting in a “biomass refinery” that yields several useful products. However, it has been difficult to extract such chemicals and to find stable markets for them; this chapter therefore focuses on bio-oil as an energy product from pyrolysis.

Bio-oil has a higher energy content than the raw biomass, reducing transportation costs per unit of energy. However, only about 60% of the initial feedstock energy will be available as bio-oil. It is proposed for use in internal combustion engines, combustion turbines (such as the Canadian Orenda turbine) and Stirling engines. Engines designed to work on petroleum fuels must usually be modified, or can be unsuitable to burn the lower-energy bio-oil. Alternatively, co-firing of bio-oil in coal power plants or natural gas-fired units has been tested. Container materials for storage and transport must consider its acidic nature. The production plants for bio-oil require operator expertise, quality control, power input and often other material supports such as makeup sand and nitrogen.

The Ensyn and Dynamotive processes use fluid bed systems and require nitrogen and sand supplies, which are significant financial inputs and implicit energy consumers. Operating power for these systems is also notable at 220-450 kWh/t. This equates to 3.9%-7.9% of the original energy content of the biomass feed and is in the form of electricity. Some other companies, such as Advanced Biorefinery Inc., are working on prototypes that are energy self-sufficient and could be used as mobile units in the forest. Figure 2.3.4 shows a flow diagram of the pyrolysis process. Note that there are several competing technologies that use slightly different temperatures and heating processes. Drying may happen after grinding since it is easier to dry smaller particles.

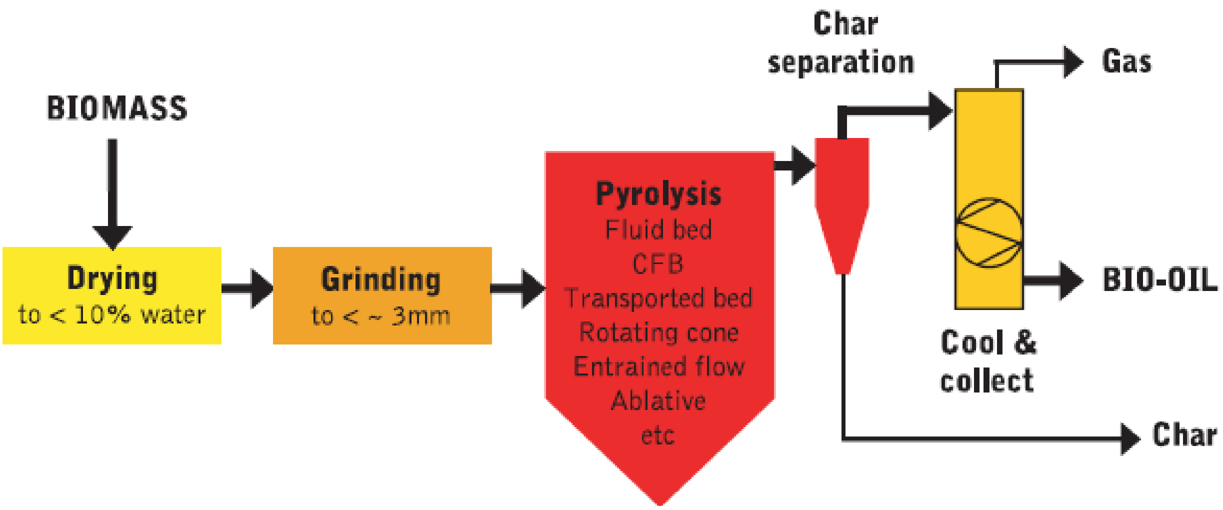


Figure 2.3.4 Schematic of a Generic Pyrolysis Process [IEA 2007]

Whereas pyrolysis does reduce biomass transport costs by concentrating the energy, the conversion of pine beetle wood to bio-oil was found to have no real cost advantage in BC [Envirochem 2006]. Bio-oil becomes interesting in situation where it can be produced in decentralized, local facilities and the user is more than 100 km away, as this can reduce transport costs per unit of energy delivered considerably. The decision to build such a unit is also influenced by other factors, including possible uses for bio-oil as opposed to other energy products, available subsidies for different technologies, and research interests. However, a more detailed cost analysis for the feedstocks and specific location is required to confirm the actual circumstances to make an informed decision.

Feedstocks & Products

Combustion works best with fairly dry feedstocks. For efficient, fast and complete combustion, it is generally necessary to size the feedstock, i.e. wood needs to be ground or chipped. Wet feedstocks, such as municipal biowaste, are less suitable for combustion due to their high moisture content. They are combusted in municipal waste incinerators, but having plastics in the waste together with the biowaste facilitates the process by adding extra heat, which is not the case in dedicated biomass power plants.

For fast pyrolysis, biomass needs to be dried to less than 10% moisture and sized to less than 2 mm. Depending on the initial moisture content, this can use up some 20% of the energy contained in the biomass feedstock. Drying is done using either the char residue or external energy sources, such as natural gas. Equivalent to 10% of the energy in biomass will be required for sizing, and this energy is usually in the form of grid electricity. Char or the non-condensable gases can also be used to provide the energy to heat up the biomass in the pyrolysis process (about 8% of the energy in the feedstock).

Biomass has a lower energy density than most fossil fuels, such as black coal (anthracite), oil and natural gas. However, dry biomass can have a heat content equal to brown coal (lignite), but contains significantly less sulfur than coal.

Wood: Green wood usually has a moisture content of around 50%. Dead pine beetle wood will have lower moisture content (probably 20-25%). Wood from energy crops (such as poplar or coppice) can be used but is often expensive to procure. Lower-end wood, such as branches and underwood removed for

fuel source reduction (forest fire prevention) can be used for combustion if ways are found to cost-effectively collect and deliver it.
Bark: The bark is usually discarded in pulp & paper, sawmills and even in pellet production. Whereas bark has higher ash content (3% vs. about 0.5% in white wood), it also has a higher heating value and is therefore a good fuel.
Construction and demolition waste: Clean wood residues from construction and demolition can be used. Treated wood is generally not desirable because paint and varnishes can cause toxic emissions during the combustion process, which would require more sophisticated and expensive flue gas treatment.
Paper: Paper and cardboard can be easily combusted. However, the ash content is high and it may be that paper recycling is a better option. Sizing paper (such as brochures or phone books) for complete combustion may present difficulties.
Straw: Straw and hay can be used in combustion and usually has low moisture content (10-15%). Note that it also has a low energy value and high ash content, leading to higher ash disposal costs. Straw and switchgrass will also contain high concentrations of alkali materials and chlorine, which can foul and corrode the boiler during combustion.

Table 2.3.1 Suitability of Feedstocks for Energy Conversion Systems

Feedstock	Steam	Entropic	Gasification	Pyrolysis
Max. moisture content	55%	55%	55%	20%
Wood/bark	YES	YES	YES	YES
Construction wood	YES	YES	YES	YES
Paper	YES	YES	YES	YES
Straw/hay	YES	YES	YES	YES
Biowaste	NO	NO	NO	NO
Chicken litter	NO	NO	YES	YES
Fuel sized to	≤3 inches	≤3 inches	≤3 inches	≤2 mm*

* Some systems can process larger particle sizes [IEA 2007]

Syngas: The gas produced by gasifiers can be used in several applications. Apart from creating steam, it can also be used directly in industrial processes. Gasification can be used in sawmills, plywood mills, veneer plants, pulp and paper mills that convert boilers, kilns and dryers from natural gas to syngas made from gasifying wood residue. Gasification systems can also be used at universities, hospitals and government institutions.

Bio-oil: Yields of bio-oil will vary with different technology systems and different fuel feeds. The resulting bio-oil will have a moisture content of 20-25%, and is very acidic. This means it can only be used in special engines and turbines that are able to run on low-energy fuels (about 16 to 18.5 MJ/kg, HHV) with a low pH of about 2.5. The lower heating value of bio-oil is about 40% that of diesel fuel. The bio-oil will also contain some ash, further reducing the possible range of applications. It does not mix with petroleum fuels, but can substitute for conventional fuels in many stationary applications such as boilers, furnaces, engines, and turbines. Bio-oil has been be stored for several years in normal storage conditions in steel and plastic drums without any deterioration that would prevent its use as a fuel. However, there is a gradual increase in viscosity over time and in extreme cases of wide temperature fluctuation, phase separation can occur.

Air Emissions

Combustion processes vary a great deal and, as such, so do their particulate emission. Wildfires are the worst particulate emitters followed closely by slash pile, beehive and silo burning. Industrial combustion reduces particulate emission substantially but still constitutes a significant source of pollution. Large grate boilers produce significant emissions in the form of ash, carbon and unburned particles. New large fluidized bed boilers have reduced overall emissions due to the complete burning of the biomass fuel and burnout of the carbon. However, all the ash that doesn't form clinkers as well as silica particles, worn from the sand bed, exits with the flue gas. Flue gas cleaning to remove particulate is required to bring large combustors into regulatory compliance. Moreover, the volume of flue gas limits the practical choices of cleaning technology that can be employed. Electrostatic precipitators are currently the most common and most effective flue gas cleaning technology available for large biomass combustion systems.

For smaller combustion systems there are more effective approaches for minimizing particulate emission. High temperature combustors will use a refractory-lined chamber to achieve a very complete burnout of the biomass and prevent the emission of unburned particles or carbon. Sedate fuel feed and grate systems reduce the amount of ash being carried into the flue gas. However, these systems still cannot meet regulatory emission requirements without post cleaning of the flue gas. This holds true for gasification systems as well, such that the gas cleanup system determines the emissions coming out of the stack, rather than the specific combustion technology.

The smaller sized combustion system has the advantage of greater choice in flue gas cleaning technology. Electrostatic precipitators, scrubbers and baghouses can all be employed since the flow volumes are not excessive. Dry baghouses are the most effective for particulate removal. Baghouses have the specific limitation of flue gas temperature. Excessive temperature requires special bag material and "sparklers" in the flue gas can cause fires. Baghouses can be used when the flow volume is reasonable, the flue gas temperature is below about 230°C and "sparklers" are prevented or with a suitable spark detection/extinguishing system.

Table 2.3.2 Emissions from Steam Engines (Biomass and Fossil Feedstocks), per kWh$_{el}$ produced

	Wood (gasification)	**Coal**	**Natural Gas**
NOx	0.1-0.5 g/kWh	0.4-0.75 g/kWh	0.08-0.75 g/kWh
SO_2	~0 g/kWh	0.6-1.5 g/kWh*	0.002 g/kWh
Dust (PM_{10})	<0.01 g/kWh	<0.1-0.3 g/kWh	~0 g/kWh
VOC	like natural gas	0.016 g/kWh	0.0003 g/kWh
CO_2	0 g/kWh**	800-1,000 g/kWh	380-450 g/kWh
Source	*BioCost 1998*	*CEA 2006*	*CEA 2006*

* with pressure swing absorber to remove most of the H_2S in the biogas

** Note that life-cycle emissions will be higher due to fertilizer inputs, machinery use and transport. It is estimated that bioelectricity from forest residues results in CO_2 equivalent emissions of about 8 to 16 g/kWh and bioelectricity from short rotation coppice in CO_2 equivalent emissions of about 44 to 109 g/kWh. This may have to be taken into account when calculating potential carbon credits from a biomass project.

It is obvious that biomass emissions can be kept very low. Note, however, that these are based on a gasification-combustion system, not on direct combustion, which would increase dust emissions. Biomass contains very little sulfur and SO_2 emissions are therefore negligible. Life-cycle GHG emissions will be higher than those shown here, but including upstream emissions will also increase those of fossil fuels. Several technologies can be used to control dust emissions in larger bioenergy systems. Table 2.3.3 compares these technologies and their scale and application. Cyclones are very simple devices that separate the larger dust particles out of the flue gas using inertia and gravity, but are ineffective for fine dust. They are sometimes only used as a precollector in front of a more efficient device. An electrostatic precipitator uses electricity to ionize dust particles, which then precipitate on the positively charged electrode. Such systems are expensive to buy but fairly inexpensive to operate. They are usually only used in larger facilities, such as coal plants. Electrostatic gravel filters (filter beds) are making inroads into the bioenergy field, and represent a technology that is said to be somewhat cheaper than precipitators, but delivers similar performance. Instead of metal, the positive electrode is gravel, which has a large surface and effectively collects dust. These systems are still fairly expensive and also have high operating costs. A bag house (made of fabric) will be the technology of choice for most bioenergy systems and is likewise a very efficient dust removal mechanism. However, the flue gas must be cool enough for the bag house, whereas it can be hotter for the electrostatic precipitator or filter bed. Also, the pressure drop necessary to operate the bag house consumes energy and thus causes higher operating costs than alternative systems. Wet scrubbers spray water into the flue gas to remove dust; they are mainly used when gas adsorption is necessary in combination with dust removal, and can have high maintenance cost.

Table 2.3.3 Comparison of Dust Removal Technologies

Technology	**Electrostatic precipitator**	**Electrostatic Gravel Filters**	**Bag house**	**Wet scrubbers**	**Cyclone**
Scale	>10 MW	>10 MW	>0.2 MW	>1 MW	<1 MW
Dust removal efficiency	90-99.5%	80-99%	99.5%	50-99%	50-87%
Cost	high	high	medium	high	low

Market Readiness

Combustion: Biomass combustion systems are in commercial use around the world, using different boiler technologies that can burn a wide range of biomass fuels. The most common boiler types are: pile burners, stoker-fired boilers, suspension fired boilers and fluidised bed boilers. The latter are rapidly becoming the preferred technology for plants >10 MW_{el} because of their clean and efficient combustion characteristics. Plants are typically below 100 MW_{el}, significantly smaller compared with conventional large-scale fossil, e.g. coal, plants that are generally >500 MW_{el}.

Around 1,000 wood-fired plants are in operation in the US and over 100 fluid bed boilers are operating or planned for operation. Most European examples of biomass fuelled stoker-fired, suspension and fluidised bed boilers are situated in Austria, the Netherlands, Denmark, Sweden and Finland. Most plants use wood fuel or agricultural residues, though there are many examples of plants operating on a variety of other fuels – including poultry litter. Co-combustion of biomass and fossil fuels such as coal is also an option that is employed in some countries such as the USA, Australia, Finland and Germany.

In B.C. there are numerous potential sites that would be suitable for small systems with capacities ranging from 1 to 5 MW. These could include sawmills and other forest operations that are too far away from larger generation facilities to make it economical to transport the wood residue there.

Gasification: Hundreds of small-scale fixed bed gasifiers are in operation around the world, in particular in developing countries. Recent gasification activities, mainly in industrialised countries, have focused on fluidised bed systems, including circulating fluidised bed systems. Gasification before combustion is becoming the preferred technology in many biomass applications due to reduced flue gas cleaning needs as compared to direct combustion systems. Larger systems coupling combined cycle gas and steam turbines to gasifiers (biomass integrated gasification combined cycle, BIG/CC) are at the demonstration stage. BIG/CC systems could lead to electrical efficiencies of about 50%.

Pyrolysis: Some companies have developed pyrolysis to a market-ready technology. Dynamotive has installed a facility in West Lorne, Ontario, Canada, designed as a 100 tonnes per day dry biomass feed demonstration plant, with plans for further plants up to 400 tonnes per day. A 2.5 MW_{el} gas turbine is also provided on site for generation of power for local use and for export to the grid. Ensyn is operating plants in Renfrew and in Wisconsin. There are research units at universities and research institutions around the world including State University of Iowa, USA, RTI Canada, IWC Germany, Aston University UK, VTT Finland, and the National Renewable Energy Laboratory (NREL), USA. Whereas bio-oil plants are functioning in several locations, their economics are not always favourable and will depend on local circumstances or subsidies.

Capital Cost

Large steam systems usually have the least unit cost, due to their economies of scale. Smaller systems of a few MW or less will cost more, and suggest the use of cogeneration because their electrical conversion efficiency is lower than that of large steam engines. Virtually any system can be built as a cogeneration unit by capturing the waste heat, but this can increase overall system costs considerably, especially if a long heat loop is required for district heating. Pyrolysis is still very expensive in comparison to other systems. Note that the system efficiencies in Table 2.3.2 take electricity use for the process itself into account; turbine or engine efficiencies may be higher, but these are net output numbers.

Prior to purchasing a gasifier, a test burn of the intended feedstock would need to be conducted in most cases to ensure efficient design of the new gasifier. The test burn costs about $70,000-$100,000, depending on test protocol requirements.

Table 2.3.2 Capital Costs of Digester and Energy Conversion Equipment

Component	Capital cost per MW of electric capacity	Overall system electric conversion efficiency
Direct combustion (steam cycle)	$2.5 million	25-30% (large-scale) 20-25% (small-scale)
Cogeneration (steam cycle)	$4 million*	20-25% (large-scale)
Cogeneration (Entropic cycle)	$2.8 million*	14%
Gasification-combustion	$3.0 million	20-25%
Pyrolysis-to-turbine	$3-5.6 million	12%

* without the heat distribution system. Unless the heat is sold to an industrial user next to the plant, a heat distribution system (such as for district heat) can cost several million dollars.

There are a number of practical barriers to large scale biomass systems that have minimized their implementation. Operating a large steam Rankine system requires large facilities including storage and handling areas. Such facilities are normally sited at a large distance from local users, far from populous areas and city centers. It is therefore often difficult to find a user for the waste heat produced, such that they are more often built as stand-alone electric power plants, rather than as cogeneration facilities. The boiler also presents a safety issue that is addressed by government regulated qualifications of both systems and operators. There is clearly an economy of scale required to justify the application of steam systems.

The quantity of biomass required is significant and there are limited locations where such quantities exist. The logistics and cost of biomass transport to central facilities are not insignificant. Although the unit cost of new large biomass systems is minimized due to the scale, the total investment is high due to the large overall size. This requires large companies or consortiums as investors who often still require subsidies for economic justification. Biomass power is a secondary venture for forest companies and such investment receives limited corporate support. Institutional investors require long-term fuel supply guarantees, which may be difficult to obtain. The amount of biomass that can be contractually sourced over a long period of time will therefore often determine the actual size of the system to be envisaged.

Scale of Process

The steam cycle is suitable for mid- and large-size systems between 10 and 100 MW or more. Most current biomass facilities have sizes between 25 and 50 MW, although larger plants have been built, such as Stockholm’s 100 MW plant and a 240 MW facility in Finland (which does not, however, run only on biomass). An even larger system has been proposed for BC [BIOCAP 2005]. For smaller sizes than 10 MW, the process becomes fairly inefficient as it is normally not cost-effective to apply the efficiency-enhancing features that require better economies of scale. Also, the requirement to employ certified steam engine operators will usually prohibit the use of the Rankine cycle in small applications.

Large steam Rankine systems can be used effectively whenever sufficient amounts of biomass are available. This situation can be found in integrated pulp mills and special regions that are centrally located for forest product operations. Within pulp mills the large steam Rankine systems are used for process steam and often co-generation with electricity. Such is generally the highest value application of biomass energy recovery. There are opportunities within many pulp mills to upgrade existing biomass systems to produce electricity or additional electricity and these should be pursued. Generally in these situations the upgrades will involve only electricity production as process steam production already exists, thus the implementation is effectively a power-only option.

In applications smaller than 5 MW, the Entropic cycle becomes more attractive. Despite its low electric conversion efficiency, it is more suitable to these system sizes than the traditional steam engine, also due to its advantage of a much lower operational cost.

Gasifiers are available in a great range of sizes, but biomass gasifiers are currently mainly sold into the smaller-scale market of kW size to a few MW. BC company Nexterra, for example, envisages sizes between 10 and 15 MW. Large-scale systems, such as pressurized entrained flow gasifiers used for coal, are not suitable to biomass due to its higher moisture content and its tendency towards slagging. Modular systems such as Nexterra can be used to combine several gasifiers into a larger system.

The Dynamotive and Ensyn pyrolysis processes are currently available as small units, in the 2-3 MW range. Commercial fluidized bed gasifiers can operate in the 10-20 MW range. The decision to use pyrolysis is currently mainly dictated by transport cost: since the energy is concentrated in the bio-oil (transporting fresh wood usually means that one needs to carry 1 tonne of water for each dry tonne of wood). The rule of thumb says that whenever the energy user is situated more than 100 km away from the wood resource, local conversion to bio-oil becomes an attractive option.

The decision matrix below discusses systems that generate electric power. Biomass may also be used to create heat or steam for district heating or industrial processes. This would be the initial question to be answered before following the decision pathways in the matrix. Heat can be produced in fairly small units, which means a system can be purchased without having any long-term contracts for biomass deliveries in place. Heat can be produced through direct combustion, which will be the main option for small units for single buildings. Gasification may be suitable for larger units, or for industrial applications. The reasons for using gasification over direct combustion will be the same as described in the matrix, i.e. cost, suitability for the task at hand, reliability and other technical questions.

Apart from the questions in the matrix, a host of other considerations will find its way into the decision-making process. The matrix is therefore just a simplified first take on the matter. You may want to ask yourself and the manufacturer questions such as:

- Which technology handles the fuel best?
- Which technology completes the fuel combustion best?
- Which technology is easiest to operate?
- Which technology is the most robust?
- How much capital can be raised for a project, and does this exclude any of the technologies?
- Do I have the personnel to operate the technology (numbers and qualifications)?
- Is the infrastructure in place to support the plant (power lines, rail or waterways for transportation of feedstocks and products)?

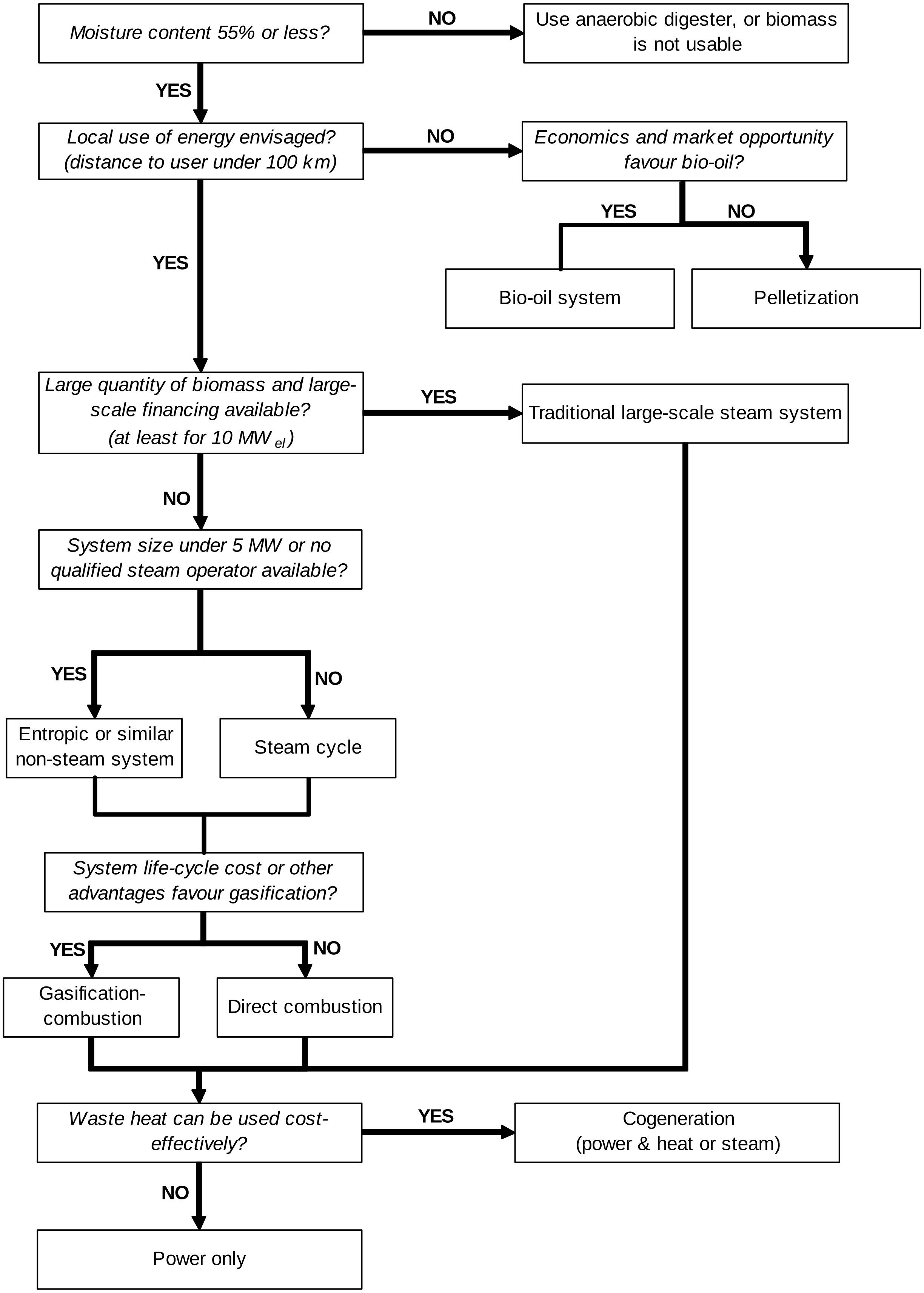


Figure 2.3.4 **Decision Matrix for Selecting a Thermal Conversion Technology to Produce Electricity from Biomass**

2.4 Pelletization of Wood

Pelletization serves two purposes: the concentration of energy in the biomass feedstock, reducing transport costs – and the shaping of the wood or other feedstock so it can be burnt in combustors designed for pellet use, providing a low-moisture fuel with good burning characteristics and a defined, constant quality. Depending on the application the pellets are burned as is, crushed to granules or ground to fine wood powder.

Making pellets out of wood from residue such as saw dust and shavings is a well established industry in BC. The production in 2006 was approximately 700,000 metric tonnes. The names of the producers are found at the www.pellet.org Pellets are used as a fuel or as animal bedding. The pellets are sold in large bulk, 1 tonne jumbo bags or in small 40 lbs bags. Most of the pellets have so far been exported to Europe and are transported in large ocean vessels in volumes of 7,000 to 20,000 tonne lots. Pellets may also be transported in bulk containers, railcars or tank trucks and are the most transportable bio-fuel available today.

Technology

Manufacturing of pellets starts with size reduction and extraction of contaminants such as pieces of metal and sand. The material is thereafter dried in a tumbler dryer or conveyor dryer. Wood shavings may not need to be dried. The dried material is hammer milled down to a specified fractional size in accordance with specifications, typically 95% less than 2 mm. This material is extruded in a pelletizer and going through a final screening and cooling before being shipped in bulk or packaged. The following figure illustrates the process of making pellets.

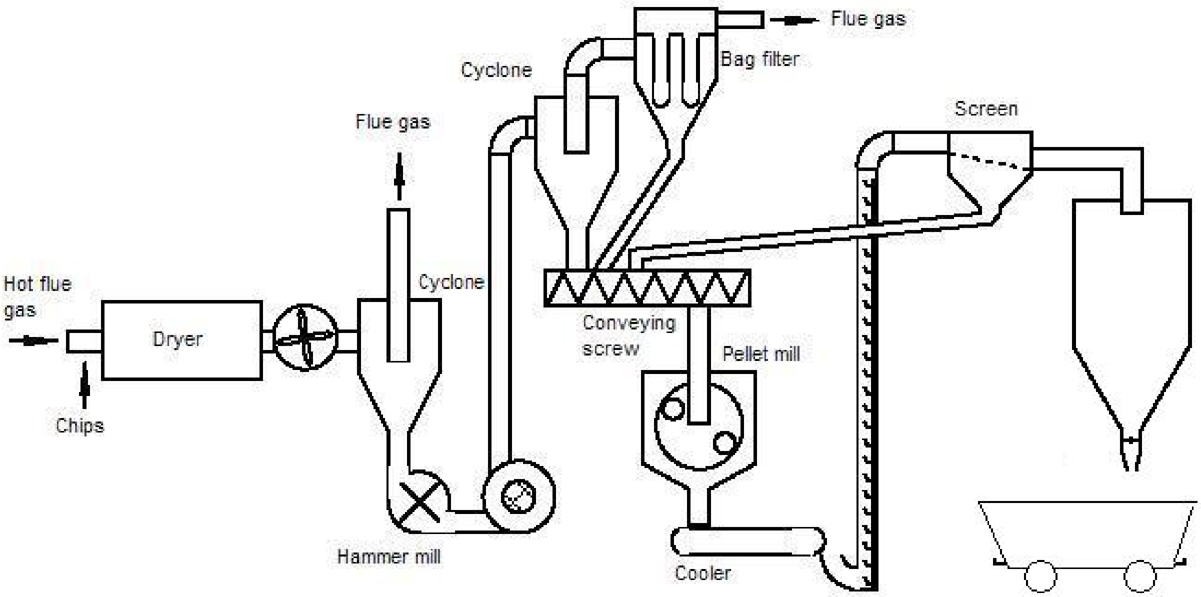


Figure 2.4.1 Pellet Plant [Envirochem 2006]

The ground material passes a roller which presses the wood through a die. Under high pressure, the wood temperature reaches temperatures above +150°C, which makes the lignin in the wood plasticize and act like a glue that provides for cohesion of the pellets. Pellets are stored in silos before they are filled into a pellet truck or into train cars.

At a bulk density of 650 to 750 kg/m³, the energy content of pellets is roughly twice as large as that of roundwood loaded on a truck. Pellets from BC have a typical moisture content of 5% and an energy density of 18 GJ/metric tonne compared to 8 GJ/tonne for hog fuel with 50% moisture.

Feedstocks and Products

Most of the pellets are made from white softwood or hardwood which results in a high quality pellet with low ash content and high ash melting temperature. Bark can also be used but produces a pellet with somewhat higher ash content. The white pellet is suitable for residential heating; industrial users use both types. Most of the pellets produced in BC today are coming from residue from pine beetle infested wood. Experimentation is underway to enable the use of wood harvesting and agricultural residues.

White wood: Whitewood pellets have an ash content of less than 0.5% and an ash melting temperature of more than 1,300°C. These pellets have the highest market value.
Bark (hog fuel): Bark pellets have an ash content of 2–5%, depending on species and amount of contamination from residual soil. The ash melting temperature is typically higher than 1,200°C. Bark tends to have a somewhat higher heat value than whitewood but is a dirtier fuel, i.e. a bit more difficult to handle.
Beetle wood: Harvesting dead pine trees is currently not practiced in BC as it poses serious economic difficulties. Harvesting and chipping whole trees will add another dimension to pelletizing in BC, requiring a larger effort in order to store, grind and possibly dry the trees.
Demolition wood: This material is often contaminated but may in some cases be usable for making pellets but requires a binder to produce a mechanically stable product.
Straw, grass and corn stover: Pellets made of herbaceous material have much higher ash content (2.5 to 13%) and lower energy content and substantially lower ash melting temperature (850 to 1,100°C) as compared to wood.

Currently, pellets are exported from BC to Europe, where governments have been providing subsidies for use of sustainable fuels such as pellets or penalties for using coal, oil and fossil (natural) gas for the last 15–20 years. Incentives are now under consideration in Canada and could potentially mean increased domestic use of pellets for the production of heat and electricity.

Co-firing in coal plants: Pellets are increasingly substituting coal in large coal burning electric utilities in Europe. The substitution has been gradual and in some cases replaced coal completely. Comparatively small modifications are needed for the co-combustion of pellets, primarily in the fuel storage and preparation areas. Depending on the combustion technology used in coal plants, the pellets can either be used directly or need to be ground or pulverized before they are burned. Co-firing of pellets in Alberta or Ontario coal burning plants is being studied but is probably only feasible in cases were power plants have direct rail access.
Industrial heat applications: In BC, many pulp and paper mills require heat sources. The total heat output from industrial energy generated from biomass in BC equals the energy output from BC Hydro and is a very important component is the energy portfolio. With recent increases in fossil fuels the biomass can compete in the local market provided the biomass does not have to be transported too far. Pellets have a higher energy density than raw biomass, which allows for longer transportation distances.
Pellet stoves: Pellet stoves are clean-burning, automated systems that require minimal maintenance (mainly ash removal) as they can acquire pellets from a reservoir using an auger. They are used in residential and institutional settings, including hospitals and schools. Municipal by-laws in some BC communities may prohibit the use of wood heaters due to air pollution concerns, but pellet stoves do usually not fall under these restrictions. There is a role for municipalities to discourage the use of oil, coal and fossil (natural) gas in their jurisdictions and promote the use of clean burning fuels such as high quality pellets from local resources, which are being vigorously pursued by governments in Europe.

Air Emissions

The ash component of wood is generating particulates when converted to energy. The lower the ash content, the less particulates are generated. Flue gas cleaning devices can be installed in larger installations and practically bring down the emissions of particulates to the same level as when using fossil gas or even less with the latest technology. Even regular (non-pellet) biomass can be burned as cleanly with the right flue gas treatment and such installations are in operation in BC (see Section 2.3). Table 2.4.1 compares pellet stove emissions with those of an oil-fired heating application. Wood clearly has advantages in terms of greenhouse gas and smog-forming emissions.

Table 2.4.1 Emissions of Pellet Stoves and Oil Furnaces

Emissions	Pellet stove	Oil furnace
CO_2	11 g/kWh_{th}*	295 g/kWh_{th}
NOx	1.49 g/kWh_{th}	3.6 g/kWh_{th}
SO_2	0.043 g/kWh_{th}	0.1 g/kWh_{th}
Dust	0.45 g/kWh_{th} (PM_{10})	0.09 g/kWh_{th}

* minimal indirect emissions from electricity for auger and fan in forced air system

There are considerable dust emissions related to the pellet production itself. While not required at present beyond simple cyclones, it may be necessary to apply dust retention systems and baghouses to reduce those emissions in the future.

Market Readiness

Pellet production is a solid, growing industry in BC. Under current energy and environmental policies the market in Canada is limited, but market development overseas is extremely dynamic. As environmental regulations support more sustainable energy sources the demand for pellets will increase also in Canada and USA. This process is already underway and is likely to speed up as the general public as well as government becomes more aware of the environmental impact of the continued use of fossil fuels such as coal, oil and natural gas.

Coal plants can usually co-fire wood in quantities of several percent without any major modifications, which opens up a significant market worldwide. Industrial markets exist in Canada where pellets can replace fossil gas or oil in heating applications, such as for greenhouses. Likewise, the residential and institutional sectors can use pellets for space heating. Modern pellet stoves (see Figure 2.4.2) are easy to use and require little maintenance. Pellet stoves can replace an entire oil or natural gas-based heating system, including hot water production. Where electric baseboard heaters are used, a transition towards a pellet stove would require the installation of air ducts, unless the stove is only used to heat one room.

Figure 2.4.2 illustrates an example of a hot air space heating unit and Figure 2.4.3 illustrates a larger, modular prefab heating unit with built-in pellet storage and automatic refill control system connected to the Internet. The installation of such a system, from 100 kW_{th} to 3 MW_{th}, for hot air or hot water production can be accomplished in a day or two, even in remote locations.

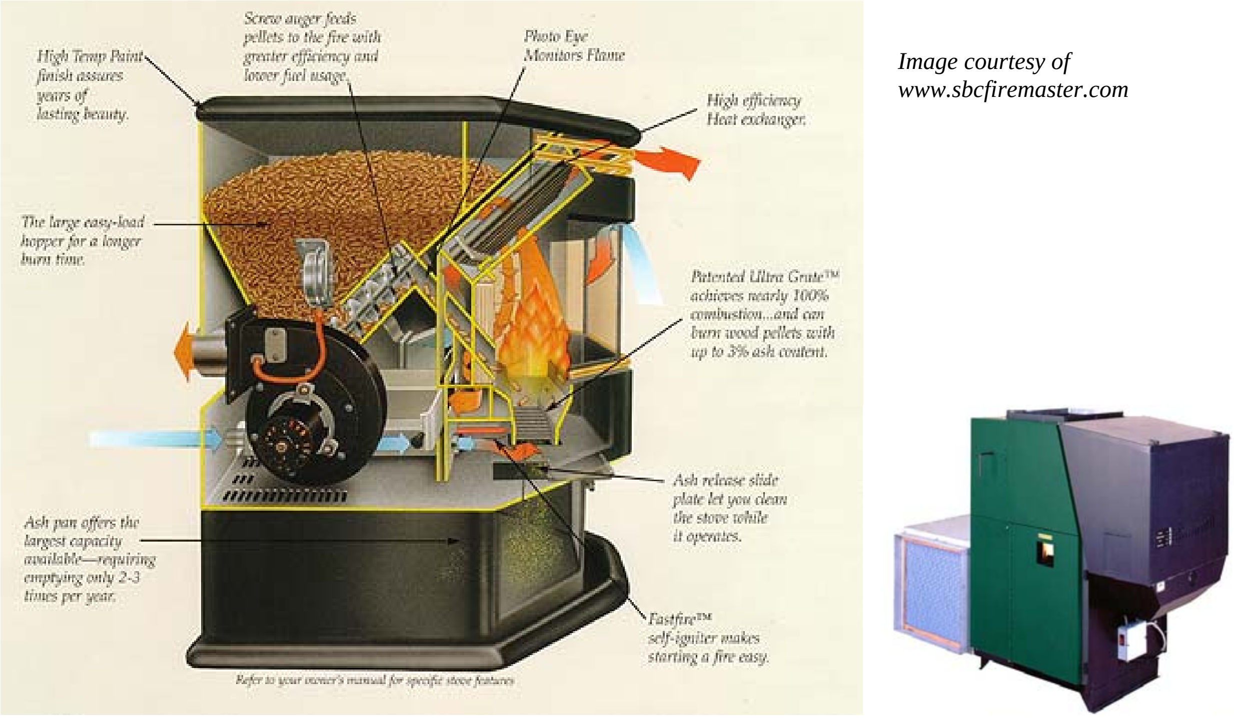
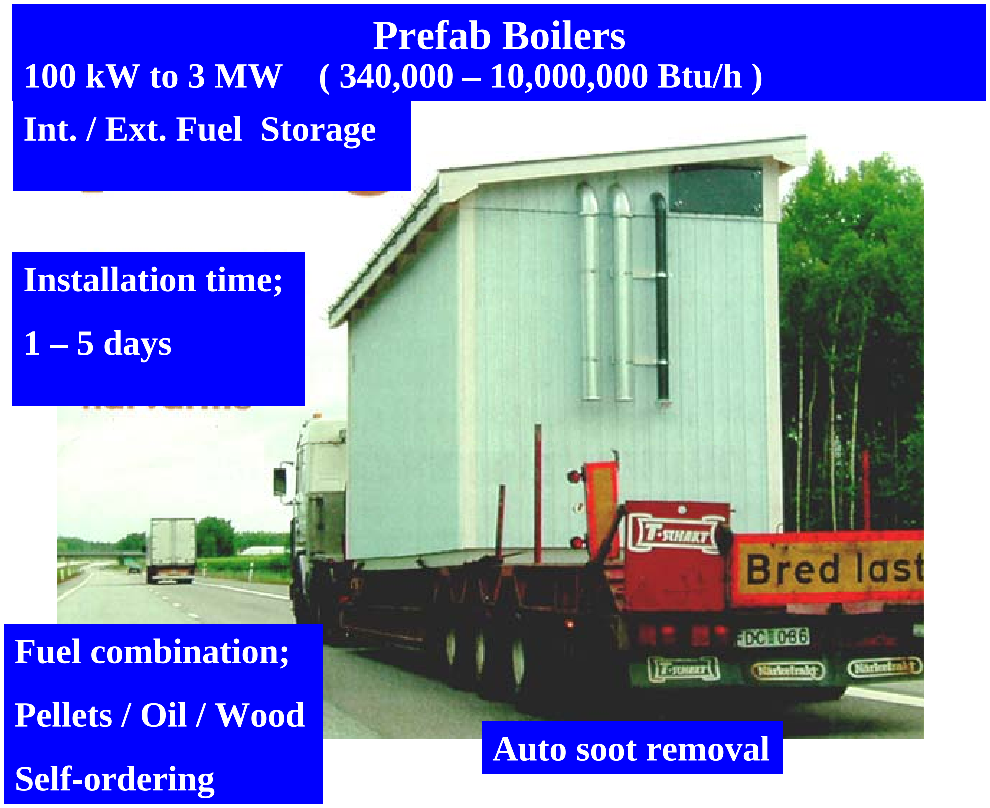


Image courtesy of www.sbcfiremaster.com

Figure 2.4.2 Pellet Stoves: living room unit (left) and central heating unit (right)



Prefab Boilers

100 kW to 3 MW (340,000 – 10,000,000 Btu/h)

Int. / Ext. Fuel Storage

Installation time;

1 – 5 days

Fuel combination;

Pellets / Oil / Wood

Self-ordering

Auto soot removal

Figure 2.4.3 Modular Pellet Heating Unit for Space Heating and Hot Water

There is no universal Canadian standard defining the quality of pellets and each manufacturer has their own data sheet. In USA a quasi-standard exists based on self-declaration of a few significant parameters. The Europeans have traditionally had several national standards with specific ranges or groupings of most of the significant parameters and definitions of testing standards. As of 2005 a new CEN Standard has been introduced in Europe for biomass classification, including pellets and briquettes, with very detailed product quality definitions as well as quality assurance standards. The CEN Standard is likely to become a world standard over time and replace all national standards currently used. More information about the CEN Standard can be obtained from the Wood Pellet Association of Canada.

The requirement for environmental certification of pellets is growing and is likely to become mandatory in international trade in order to qualify as a renewable fuel and traded for carbon credits. The certification requirement starts with the tree in the forest and follows the material all the way to the conversion to energy. More information regarding product certification can be obtained from the Wood Pellet Association of Canada.

Torrefied wood pellets are an emerging technology developed in the Netherlands. Their energy content is about 23 kJ/kg, compared with 19.3 kJ/kg for conventional pine wood pellets. Such pellets have an energy density of about 18 GJ/m^3. Although this is less than coal (29 GJ/m3), it is 20% higher than commercial wood pellets. In addition, less than half as much electricity is consumed making torrefied pellets. The first demonstration plants of this technology are planned for the near future, but the technology is still considered a few years away from commercialization.

The University of British Columbia (UBC) has established a Biomass & Bioenergy Research Group at the Department of Chemical and Biological Engineering and includes close to 20 researchers and high level students as of the end of 2006. This group is working on the leading edge of feedstock engineering, including the next generation of pellets as well as safety aspects of pellets and other densified products. The new generation of pellets will be a high-tech product capable of competing with any other fuel product in terms of heat density and clean conversion to energy. UBC has also developed an extensive network with researchers in Europe.

Capital Cost

Several European manufacturers make small portable pellet mills which can be set up on two 6’ x 8’ frames. The largest unit costs about $240,000 and can produce 1 tonne of pellets per hour. To set up a complete system which will handle wet chips and bag the pellets will probably cost in the range of $600,000 -$800,000, and produces pellets at a cost of around $100 per tonne (BC pricing for pellets was about $150 per tonne in 2006).

The investment cost for a commercial-size pellet plant is about $1 million for every 10,000 tonnes of capacity. As mentioned above, electricity is required to operate the machinery, as well as spare parts to replace worn knives, dies and rollers. Transport costs are an important cost consideration when pricing the product. It is expected that the pellet industry in BC will continue to grow over the coming decade.

Scale of Process

Small pellet mills are currently in use by some New Brunswick farmers and are also being introduced in BC. A small-scale, mobile pelletizing plant may operate near logging operations in order to process non-merchantable stems or roadside slash. Development is currently under way to eliminate the need for diesel fuel for running such units.

Generally, the minimum size of a pellet plant in BC is 20,000 metric tonnes per year in order to capture the required economies of scale. Because of the existing competition from large-scale plants in BC it is likely that the pellet plants to be built will mostly have a production capacity of more than 100,000 tonnes per year. Such plants require up to eight people per shift, plus one supervisor and administrative personnel. Long-term contracts for the sale of biomass feedstock must be in place to build such a plant and are the determining factor for the location of the plant. All future plants will require direct rail access to be successful.

Prices for wood pellets are gradually climbing and so is the cost for transportation. The market in North America is bag oriented (for heating) which means it is highly seasonal, whereas the European market is active year-round with comparatively small seasonal variations. Long-term year-round sales contracts are essential for success since the BC producers cannot operate in the fast incidental spot market due to the transportation distance to the market. Figure 2.4.4 illustrates a selection matrix for evaluating the feasibility of building a pellet plant.

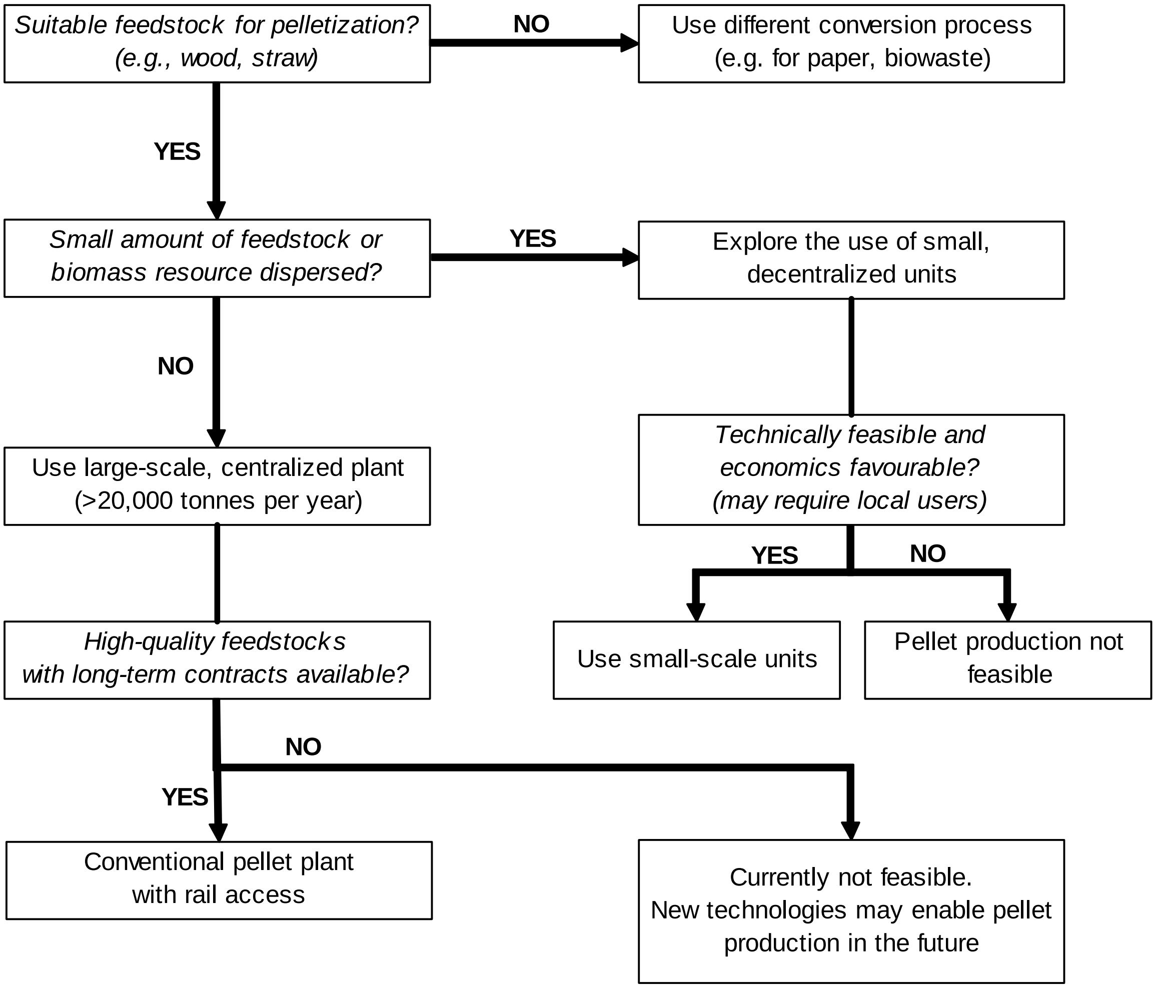


Figure 2.4.4 Decision Matrix for Selecting a Pelletizing Technology

2.5 High-Temperature Gasification of MSW and Biomass

Technology

Traditionally, the gasification of biomass and the subsequent direct use of the resulting syngas in a turbine has not been possible due to the impurities (tars) contained in the syngas. Some companies now claim their second-generation technologies can master this problem. Plasco's "Plasma Arc" gasification technology first gasifies the feedstock and then uses an electric arc to heat the resulting syngas to 5,000°C. This process destroys all long-chain molecules such as tars, such that only gaseous, non-condensible particles remain, which can then be burned directly in a gas turbine. Other gasification systems that work at lower temperatures need to clean up the gas to be able to use it directly – so far a non-commercial technology. This was the reason why this option was omitted from chapter 2.2. They system is promoted for mixed municipal solid waste (MSW), but could also be envisaged for biomass. Figure 2.5.1 shows the setup of the Ottawa demonstration facility. It is a 4 MW system, able to process up to 85 tonnes of waste per day.

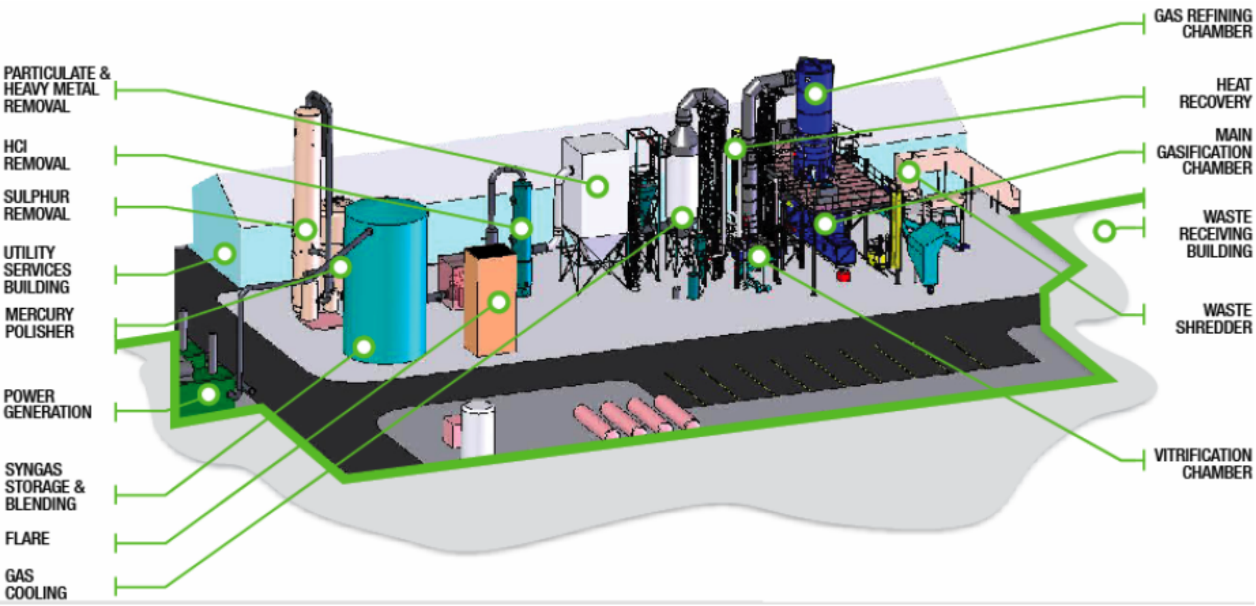


Figure 2.5.1 Plasco's Ottawa Demonstration Facility

Electricity is produced from gas engines or turbines that use the syngas rich in carbon monoxide and hydrogen. The hot exhaust gas is then used to create steam, which drives a steam turbine, i.e. the system is envisaged as a combined cycle, which is more efficient than single cycle systems that produce electricity. The current demonstration site uses single-cycle gas engines.

A three-step system by Choren in Germany first pyrolyses and then completely gasifies biomass at over 1,400°C, then reintroduces the ground char from the pyrolysis step into the process. The resulting syngas is cleaned from dust and further cleaned in a scrubber. The cleaned gas can then be used directly in a combined cycle gas turbine or in a cogeneration setup.

Feedstocks & Products

The plasma arc technology is suitable for high-carbon feedstocks, such as biomass and plastics. The feedstock moisture content the demonstration plant functions with is around 30%. Whether biomass would have to be dried to be used in this process is not yet fully understood.

Municipal solid waste: Commercial and residential waste that cannot be recycled, including biomass, green waste, plastics and paper, can be used. Metals and glass should be removed as much as possible as they will reduce the heating value of the waste. Choren does not advertise that it can use municipal waste.

Biomass: Wood, including treated (with paints or varnish) wood, and straw, is expected to be suitable for Plasco's technology. Choren's system is laid out specifically for biomass use.

Other waste: The plasma arc process is expected to be able to process a number of other waste types, which can be combined with biomass. Tires, municipal sewage sludge, industrial waste sludges, paper mill waste and others have been successfully treated in this process.

The Plasco process produces electricity very efficiently in a combined cycle, but no useful heat. Only 1-2% of the feedstock ends up in landfills. The process produces an inert slag (150 kg per tonne of feedstock), which can be used in road construction and related industries. It also generates 5 kg of sulfur per tonne of feedstock, which can be sold for industrial purposes, as well as 1 kg of residuals (mainly heavy metals) that need to be disposed of in special approved facilities. Please note that these figures relate to municipal solid waste and can be expected to be somewhat different for biomass feedstocks, i.e. sulfur and other residuals are likely to be less or zero.

Choren's technology produces a fully vitrified slag that can be used in road construction, for example.

Air Emissions

The plasma arc process atomizes organic compounds and thus destroys toxic chemicals formed during the gasification step. Plasco foresees emission reduction technologies to control NOx emissions, which is reflected in the table value. Emissions for a commercial-size Plasma Arc system are consistently lower than emissions from a conventional waste incinerator. For dust, the concentration is given per raw cubic metre for the Plasma Arc process, which means that the concentration per Nm³ (norm cubic metre) will be somewhat higher, in the same range as for an incinerator. The Choren process would have emissions similar to any other biomass energy system in Section 2.3.

Table 2.5.1 Emissions of a Waste Incinerator Compared to the Plasma Arc Process

Emissions	Waste Incineration	Plasma Arc
NOx	160-350 mg/Nm³	38 mg/Nm³
SO_2	40-200 mg/Nm³	10.6 mg/Nm³
Dust	5-30 mg/Nm³	2.5 mg/Rm³
Source	*www.wasteonline.org.uk*	*Plasco Energy Group*

ppmv: parts per million, volume-based

Market Readiness

The Plasma Arc system has been demonstrated at a small scale in Spain and is now being demonstrated as a 4 MW system in Ottawa. The system is therefore almost commercial, but operational experience at the Ottawa site will have to be observed for a year or two before investors will be confident to fund such a system elsewhere. Plasco is currently not ready to use biomass other than with municipal solid waste, but is exploring this area fore the coming years. The current design used at the Ottawa demonstration site would likely have to be modified to suit a different feedstock, such as biomass.

The Choren process has been demonstrated but has not seen a full-scale commercial application.

Capital Cost

The Plasco demonstration project in Ottawa will cost $32 million, or $8 million per MW of electric generation capacity, a somewhat larger level of investment than is required for conventional waste incinerators. Since the Ottawa plant is a 4 MW demonstration unit, it can be expected that costs can be reduced further for future larger, commercial systems. This current capital cost estimate is also far higher than other biomass conversion systems. The company claims that it can treat waste cost-effectively if the combined revenue from tipping fees and electricity sales is $175 per tonne. This may cause problems with biomass, since it requires a payment to source biomass for the plant.

The conversion efficiency of the Plasco system, even for a small 4 MW single cycle system, is expected fairly high (25%) in comparison to other small-scale options, which may have efficiencies between 10 and 14%. A combined cycle system would be 30% efficient. Whether this outweighs the disadvantage of higher capital cost will depend on the price of electricity sold to the grid, as well as the interest rates at which capital can be procured. See Chapter 2.3 for more information on capital costs for other thermal biomass energy conversion systems. Note that Plasco wants to own and operate its technology, i.e. the capital cost will not be relevant for a community, as long as the company's revenue can be achieved.

Table 2.5.2 Capital Costs of Conventional Incinerators and the Plasco System

Component	Capital cost per MW of electric capacity	Overall system electric conversion efficiency
Waste incineration with steam cycle	$4.6 to 6.2 million	10%
Plasma Arc gasification	$8 million or less	25%* (single cycle)
Choren Carbo-V technology	$3-4 million	33%* (combined cycle)

* according to company claims

Scale of Process

Demonstration plants have been set up in Europe and now in Ottawa in the 2-4 MW range (40-80 tonnes per day or 15,000-30,000 tonnes per year). Commercial plants are envisaged at feedstock input rates of 200 tonnes per day or more (68,000 tonnes per year), producing 12 MW of power. Note that this company information is based on municipal waste with a moisture content of 30% and energy content of 16.5 GJ/tonne, but a feedstock like pine beetle wood may have very similar characteristics.

The Plasco system therefore has clear advantages over conventional waste incinerators, i.e. it can be built on a smaller scale (waste incinerators are usually built for larger cities, burning 200,000 to 400,000 tonnes of waste per year), produces a lot more electricity and has much lower emissions. However, other biomass conversion systems have far lower investment costs, although lower conversion efficiencies at this scale (12 MW). A biomass conversion system could also be designed as a combined cycle system, but this does not usually represent a large enough cost advantage for small systems.

A large constraint of the current technology is its high cooling water demand. The Ottawa plant will use 7,600 litres of mains water per hour, and will discharge over 8,400 litres. Plasco is working on developing an alternative cooling system that operates without mains water.

The Plasco process will require adequate technical personnel, including a steam engine operator. The Ottawa facility will requires 20-25 full-time equivalent full time positions. A minimum sized facility processing 200 tonnes per day will require about 35 people.

Choren is extending its design for cogeneration applications up to 160 MW gasification power, resulting in medium-scale applications of up to 55 MW_{el}, using a combined cycle or a single cycle combined with heat use.

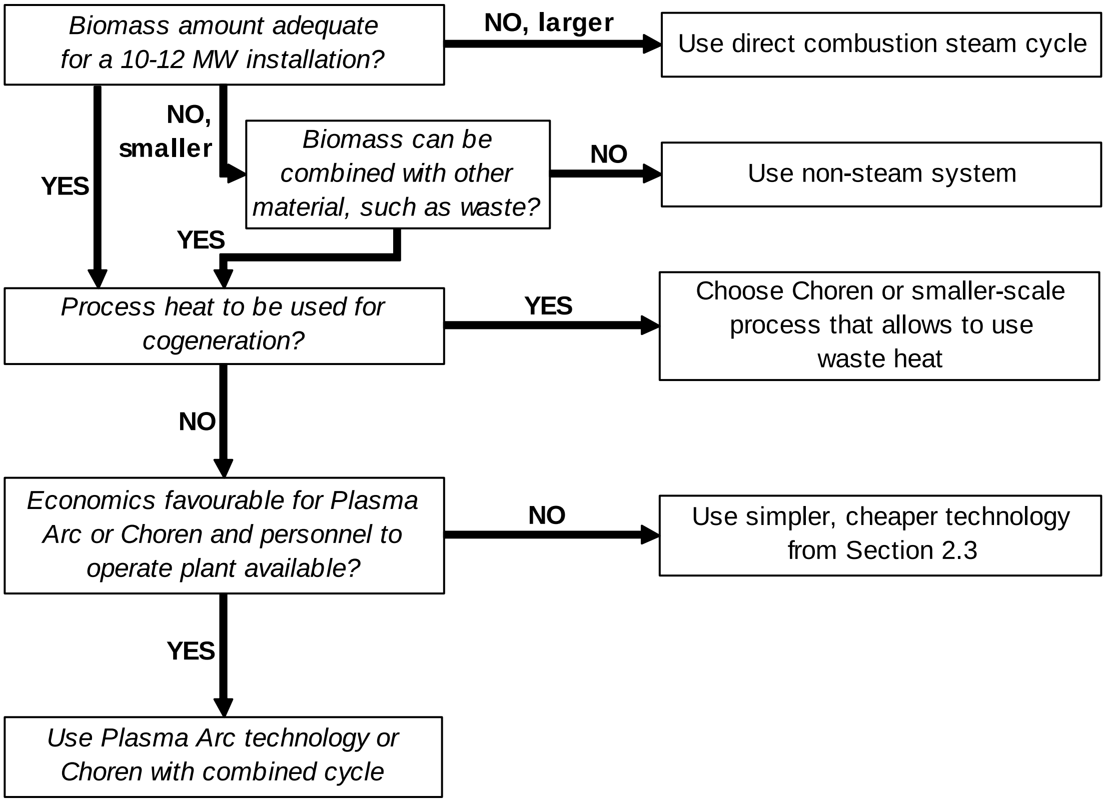


Figure 2.5.2 Decision Matrix for Selecting Second-Generation Biomass Gasification Processes

Figure 2.5.2 describes the decisions to be made when considering Plasma Arc as an option for biomass. The system is a combined cycle and the emphasis is clearly on electricity production. If this is the focus of the operation and not cogeneration, the process can be advantageous because it is small, yet has fairly high electric conversion efficiency.

2.6 Lignocellulosic Ethanol

In North America, ethanol is usually made from starch contained in grain and corn. Investments are taking place in the Prairie Provinces and elsewhere to build commercial, large-scale ethanol production plants using these feedstocks. In BC, no sufficient agricultural basis exists to support such an industry.

Some emerging technologies offer the chance to process other feedstocks, such as agricultural residues or wood, into ethanol. One such process is the Iogen process which is able to make ethanol from hardwood, straw, and corn stover. Another such process is the Lignol process which can process softwood. Since softwood is the largest resource in BC and is especially abundant due to the pine beetle crisis, the Lignol process seems to be better adapted to the local resource. Another process that would work for all biomass feedstocks is gasification. It is not possible at this point to predict which of the competing technologies will capture the lignocellulosic ethanol market in the future, or if several of them might prove to be viable. Figure 2.6.1 shows the Lignol process, which uses enzymatic hydrolysis and results in a large number of products, including lignin, ethanol, xylose, and furfural.

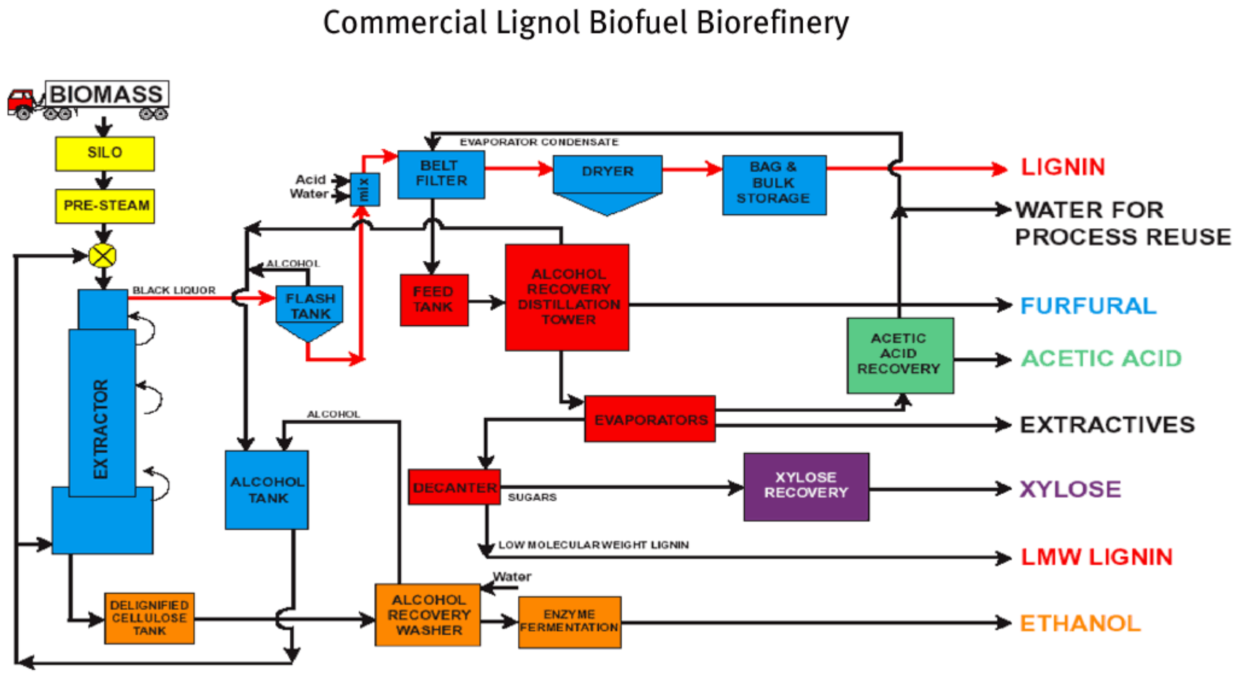


Figure 2.6.1 Lignol Process Diagram [courtesy Lignol Innovations]

Incoming wood is first de-barked and chipped. The wood is then treated with a 50:50 blend of ethanol and water at approximately 200°C and 27 bar (400 psi) pressure. This process generates black liquor that is then sequentially processed to recover a series of chemical by-products. The remaining cellulose fibre is sufficiently delignified to be more readily converted to ethanol. While the extraction process is a batch process in the pilot plant, solvent and by-products recovery is operated continuously. Lignin is recovered by "flashing" the high pressure black liquor to atmospheric pressure, followed by rapid dilution with water. Subsequently, lignin precipitates readily and is dried to a fine powder. The remaining solution contains numerous valuable materials such as ethanol, furfural, extractives and dissolved sugars. This liquid stream is fed to a distillation tower for ethanol recovery while the resulting ethanol-free stream, or stillage, is processed in various systems to isolate and purify the high value by-products, which contribute significantly to the revenue from such a plant.

This type of ethanol plant uses large amounts of fresh water and produces large amounts of nutrient rich wastewater. There may be odour problems close to ethanol plants, and ethanol causes aldehyde and alcohol emissions, which are carcinogens.

Feedstocks & Products

For lignocellulosic ethanol production, the range of possible feedstocks depends very much on the technology used. For example, Iogen (based on a process called enzymatic hydrolysis) uses mainly agricultural residues; a Lignol plant, based on the Organosolv process, is designed to use softwood, and a gasification plant (not described here) could use all types of biomass.

Hardwood: Can be used by all processes.

Softwood: Can be used by the Lignol process and in gasification. This is the largest resource in BC.

Corn stover: Can be used by Iogen and in gasification.

Straw, hay and switchgrass: Can be used by Iogen and in gasification.

Ethanol is used as a transportation fuel and is usually mixed in with gasoline. The BC Energy Plan requires 5% share of ethanol in gasoline by 2010. The Lignol process produces ethanol and several by-products, some of which may have significant market value. Using a gasification route to make ethanol would not produce these by-products. The Iogen process will also produce a lignin residue, but the lignin is of lower quality and may simply be used to produce heat for the process. The other products of the Lignol process are:

Organosolv lignin has several market applications including antioxidants (greases, lubricating oils), resin replacements for waferboard or Oriented Strand Board production, animal feed supplements, additives (brake linings, rubber products, concrete) and advanced light weight materials.

Acetic acid is sold commercially in several grades, depending on its purity. It is the basis for manufacturing acetic anhydride used in the production of cellulose acetate fibres and membranes. It is also used in the production of vinyl acetate, a basic raw material used to manufacture latex paint and paper coatings.

Xylose is a five-carbon sugar widely present in fruit and root vegetables. It is readily converted into a specialty polyol (xylitol) that has about 60% of the sweetness of sucrose and is suitable for diabetics to consume without the need for insulin. However, no xylose can be extracted from softwood feedstocks.

Furfural can be used to produce polytetramethylene ether glycol for the production of Lycra® and spandex. It is also used to produce lubricants, coatings, adhesives, plastics and foundry resins for cores and moulds to cast metal components.

Wood extractives include various chemical compounds and are raw materials for a substantial chemicals industry including printing inks, flavours and fragrances. BC companies lead the way in studying one component — phytosterols — recovered from the extractives fraction of softwoods such as spruce or pine. Phytosterols are increasingly in demand for the manufacture of cholesterol-lowering margarines and spreads.

Air Emissions

Ethanol use can reduce particulate emissions from motor vehicles, but was also found to increase hydrocarbon emissions. Ethanol displaces the uses of toxic gasoline components such as benzene - a carcinogen. Ethanol production itself is an industrial-scale process that is regulated by environmental laws concerning emission levels. A detailed comparison in table format is omitted here as emissions are unlikely to influence the decision whether or not to use a particular process.

Market Readiness

Lignocellulosic ethanol production is not yet a commercial technology. The first Lignol demonstration plant is planned to be completed by 2007, and successful testing could result in commercialization of the process in the coming decade, when the bugwood resource is at its peak. Iogen has built a demonstration plant in Ontario and is further refining its technology. Several other ethanol production technologies are being developed in the U.S. and Europe. Convergence Ethanol, a U.S. company, is planning to build a gasification plant in Hearst, Ontario by 2010, using low-cost forest residues.

Capital Cost

The capital cost for a commercial Lignol plant is estimated at $36 million (for an annual feedstock amount of 35,000 bdt), and the operating cost at $10.4 million per year; actual numbers have to be confirmed once the demonstration plant has been built. Other technologies will likely cost more, since they will process even larger amounts of biomass.

Ethanol from starch feedstocks (corn, wheat) can already compete with high gasoline prices (above 50 cents a litre, before tax). If feedstocks can be sourced more cheaply than starch, lignocellulosic ethanol could be produced at very similar prices. The situation in BC, however, is not likely to provide such feedstocks at very low prices since there are many competing uses. Because 5% ethanol content in gasoline has been mandated, market conditions may allow for higher lignocellulosic ethanol production cost if there is a lack of ethanol made from other sources.

Scale of Process

Lignol's plant design envisages a 35,000 tonnes per year (wood feedstock) plant size generating an output equivalent to 10 million litres per year. The Iogen technology is laid out for plant sizes of 200 million litres per year and more. Likewise, the Convergence Ethanol plant would produce some 200 million litres or more by gasifying woodwaste. Smaller-scale ethanol production could be technically feasible, but would likely be less efficient, and overall economics would then be less favourable. There are research efforts, notably in the U.S., to develop small-scale ethanol production technologies, so the situation should be monitored as these may become available in the coming years.

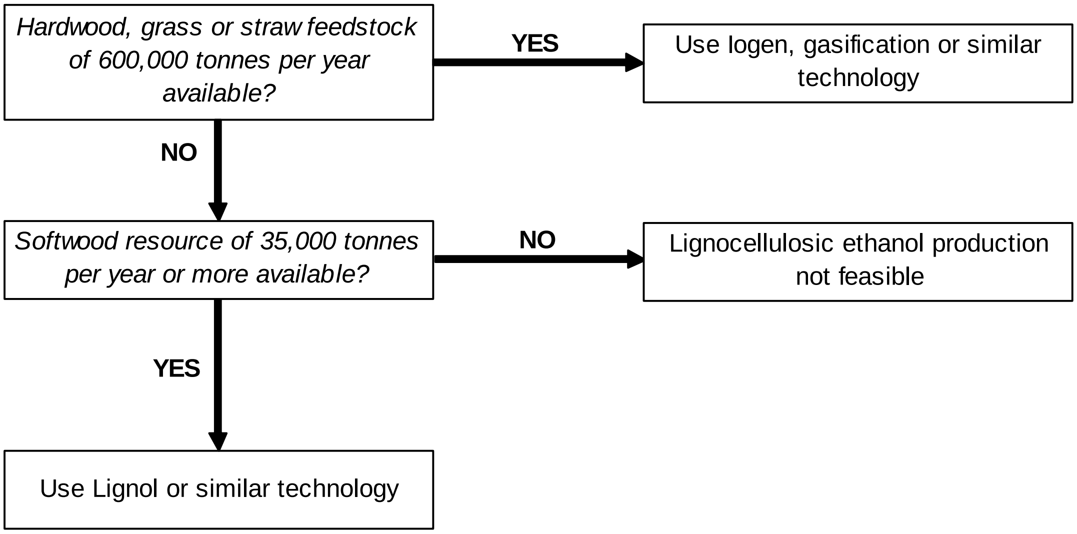


Figure 2.6.2 Decision Matrix for Selecting a Lignocellulosic Ethanol Technology

2.7 Biodiesel or SunDiesel

Technology

This section discusses and compares two pathways to produce biodiesel: transesterification and a Fischer-Tropsch process. The former is the technology used to make biodiesel today. The latter is an emerging technology that is currently being pursued by companies like Volkswagen in Europe to achieve higher yields of biofuels from agricultural land, using gasification linked to a Fischer-Tropsch process.

Transesterification: The common technology to produce biodiesel is the transesterification of plant and animal fats by adding methanol. This is simply a chemical transformation to turn the oil into a more fluid liquid that can be used in conventional diesel engines. 100 kg of oil react with 10 kg of methanol to produce 100 kg of diesel and 10 kg of glycerine. This process is fairly simple to accomplish, and is sometimes done in small, "back yard" facilities, for farm or other local uses. However, to obtain a stable, defined product quality, capture economies of scale and achieve high performance in cleaning used vegetable oils, most biodiesel is made in large industrial facilities. Figure 2.7.1 shows a general biodiesel process diagram. The chemical designation of biodiesel is methyl ester.

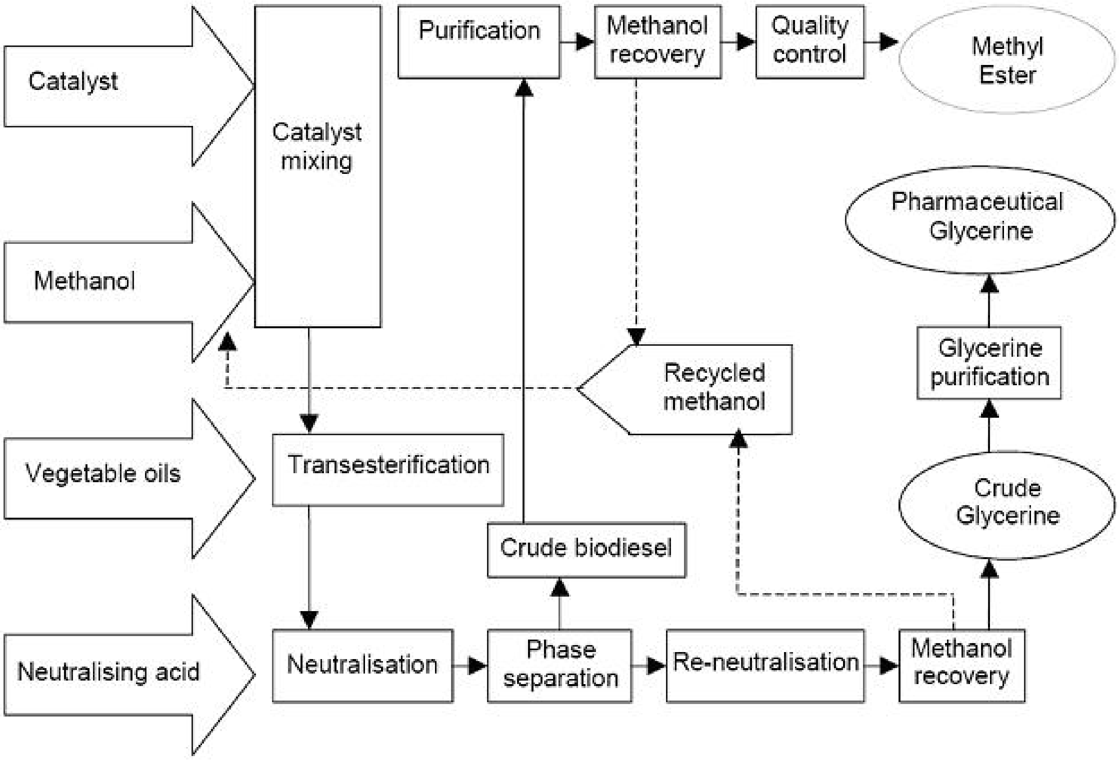


Figure 2.7.1 General Biodiesel Process Diagram (www.biodiesel.org)

Fischer-Tropsch diesel: This process uses different feedstocks and is entirely distinct from the transesterification process. It produces paraffins, not methyl ester, and the product is not called biodiesel but "SunDiesel", a synthetic biofuel. It is an emerging, industrial-size process that uses gasification and subsequent steps to obtain an energy-rich, distillable liquid from several types of biomass, including wood.

Biomass is gasified in one or more steps and the resulting syngas is then purified and cleaned. Using a catalyst (usually iron or cobalt), the carbon monoxide and hydrogen molecules in the syngas are recombined to form longer chains (paraffin liquids and waxes). The resulting fuel is then upgraded to diesel quality using a process called hydrocracking.

The fuel composition depends on the process temperature and pressure, the catalyst and the reactor type. Typical process conditions for Fischer-Tropsch synthesis when aiming for long-chain products (waxes) are temperatures of 200-250ºC and pressures of 25-60 bar. If the process is operated at higher temperatures, it mainly produces lighter hydrocarbons, which can be refined to petrol and diesel, solvents and olefins. To optimize the yield of Fischer-Tropsch diesel, the process is usually modified such that a maximum of waxes are formed, followed by selective hydrocracking. The direct production of diesel fractions from synthesis gas would yield less diesel fuel.

The unconverted off-gas remaining after the synthesis can be recycled and fed to the synthesis reactor again to maximise the production of liquids. In a simplified system, a so-called 'oncethrough' Fischer-Tropsch synthesis, the gaseous by-products are utilised for electricity and heat generation. A favourable aspect of the latter system is that investments are lower due to elimination of gas recycling and the accompanying synthesis gas production.

Feedstocks and Products (Transesterification)

Using all of BC's plant and animal fat feedstocks for biodiesel production could deliver a 5% blend as it is required by law for the year 2010. Note that West Coast Reduction in Vancouver already collects some of these feedstocks and sells them into Asian markets. The level of pre-processing required for each feedstock depends on its free fatty acid (FFA) content. The following feedstocks can be used for the conventional esterification process:

Virgin vegetable oil: Made mainly from canola and soy in Canada, virgin (unused) vegetable oils are a good feedstock for biodiesel that does not require purification before it is used. They have an FFA content of less than 1.5%. However, these oils are fairly expensive and would have to be sourced from outside BC, since most canola and soy is cultivated in the Prairies and Eastern Canada. Lower-quality crops from bad harvests may be available more cheaply, but their supply depends on weather and other parameters, meaning they are not always available in large quantities.

Used vegetable oil (yellow grease): Like virgin canola oil, used canola and other vegetable oils can also be purified and then transformed into biodiesel, by the same transesterification process. Their FFA content is 5% or more, which requires additional pre-processing. These feedstocks can be collected from restaurants and animal rendering operations. Note that locally collected waste fats and oils can usually only sustain fairly small-scale biodiesel production, e.g. to fuel a small fleet of cars or trucks. An industrial-size plant would have to source waste oils from a large perimeter. The potential supply of waste yellow grease from B.C.'s restaurants and food service establishments is estimated at 21.4 million litres a year.

Fish oil and animal fat: Fats from rendering (beef tallow and pork lard) and fish industries can likewise be used to make biodiesel. The FFA content of animal fats is up to 20%, which requires extensive pre-processing.

Products: Biodiesel can be used directly to replace diesel, but is usually mixed with conventional diesel (20% biodiesel, 80% conventional diesel). This is done partly to reduce problems with biodiesel in the winter, when it can become too thick at low temperatures for a normal engine to start. The BC Energy Plan foresees that diesel fuel must contain at least 5% biodiesel by 2010.

Glycerine is another by-product of biodiesel production and will be produced in 1/10 the quantity of biodiesel produced. Currently, the total Canadian market for glycerine equals approximately 6,000 tonnes annually. Since a single commercial-size biodiesel plant (60 million litres per year) can produce this same amount of glycerine per year, the increased supply can be expected to reduce market prices for glycerine significantly, but export markets exist. The demand for glycerine is rising as new uses are found and the economies of developing countries grow. Otherwise, glycerine can be combusted for process heat, or can be composted.

To avoid the glycerine by-product, unprocessed vegetable oils can be used in modified diesel engines. Such engines are in limited production and are therefore more expensive, although their numbers are increasing in Europe. This direct usage of vegetable oils would reduce energy use and emissions from biodiesel production and would not produce any glycerine as a by-product.

Feedstocks and Products (Fischer-Tropsch Diesel)

Fischer-Tropsch liquids can be produced from virtually all types of biomass that can be gasified (see section 2.3). Most biomass has to be dried to achieve a moisture content of 15-20%. The production of one tonne of Fischer-Tropsch diesel requires about 7.5 tonnes of wood or similar amounts of other biomass feedstocks. Fischer-Tropsch diesel is similar to fossil diesel with regard to its energy content, density, viscosity and flash point. It is also in liquid phase at ambient conditions.

Fischer-Tropsch diesel is a very suitable transportation fuel. Fischer-Tropsch liquids in general can also be used as an energy carrier, for storage purposes and for electricity and/or heat generation. Petrol components produced by the Fischer-Tropsch process cannot be applied in the existing spark ignition engines. In contrast to petroleum-derived petrol that contains aromatics, Fischer-Tropsch petrol consists of straight hydrocarbon chains and its octane number is too low for application in current engines. Therefore, straight-chain Fischer-Tropsch petrol can only be used in these engines in a mixture with fossil petrol, up to 15%.

The Choren process also produces naphta, a solvent used in the oil and other industries. About 45% of the feedstock energy is contained in the SunDiesel, and including the naphta, 53% of the original feedstock energy is turned into useful products. The remaining energy is used to power the process such that it is energy autonomous.

Air Emissions

Compared to regular diesel, pure biodiesel (B100) can make a significant contribution to the reduction of air emissions. It can deliver upwards of 73% reduction in lifecycle GHG emissions depending on the feedstock used, a 67% reduction in unburned hydrocarbons (although some sources report an increase in this category), a 48% reduction in carbon monoxide, a 47% reduction in particulate matter, a 100% reduction in sulphur oxide emissions, and an 80% reduction in polycyclic aromatic hydrocarbons, which can cause cancer and emphysema. On the other hand, biodiesel will increase nitrogen oxide emissions by about 10%.

Fischer-Tropsch diesel offers even more significant contributions to the reduction of air emissions. It has a very low aromatic content, which leads to cleaner combustion. This means that the particle and NOx exhaust emissions are lower. Furthermore, sulphur emissions are avoided, because Fischer-Tropsch diesel is sulphur free. It can be blended with regular diesel fuel in the same way as conventional biodiesel. The production process is a large-scale industrial process that will have air emissions similar to other biomass energy systems. Plants will have to comply with their air emission permits, and emissions will be similar to other biomass or fossil fuel systems. A detailed comparison in table format is omitted here as emissions are unlikely to influence the decision whether or not to use a particular process.

Market Readiness

Biodiesel production by transesterification is a fully commercial process. Installations to produce biodiesel can be purchased from several technology providers. New technologies, such as the Canadian BIOX process, may still be at the demonstration stage.

So far, commercial large-scale Fischer-Tropsch conversion installations only use fossil fuels for the production of synthesis gas. The use of biomass as input for Fischer-Tropsch processes is still in the development phase. The integration of biomass gasification and Fischer-Tropsch synthesis has not yet been demonstrated, but a pilot plant is being constructed in Germany by Choren Industries (2007). Current research and development activities are focused on cleaning and conditioning of synthesis gas, development of several types of catalysts, reducing the amount of inert components in the feed gas, and the utilisation of by-products such as electricity, heat and steam.

Capital Cost

Production costs for biodiesel are estimated $0.32 for the BIOX process, but can be almost twice as much for other biodiesel processes. The capital cost for plants with annual biodiesel production of 60 million litres is approximately $0.04 per litre of annual production ($0.03 for the BIOX process). Feedstock costs can be assumed to be $0.37 per litre for animal fats and used oils, but are higher (above $0.50) for virgin vegetable oils. Transportation costs are additional, as well as the cost of methanol, which is around 50 cents per litre. Glycerine may fetch about $0.10 per litre of biodiesel produced. Biodiesel usually sells for the same price as regular diesel, but is exempt from federal and provincial excise taxes. Companies like Rothsay are already successfully producing and selling biodiesel in Eastern Canada.

A biodiesel facility using the Fischer-Tropsch process (based on abundant biomass feedstocks like wood) is expected to cost about four to five times as much per litre of production capacity as a conventional biodiesel plant which uses vegetable and animal fats. Volkswagen assumes that the production costs are at about $0.70 per litre even for a very large-scale facility, which is also confirmed by Choren. This may be lower if cheap biomass feedstocks can be used.

Scale of Process

Transesterification: This is a fairly low-tech process and can be accomplished at almost any scale, starting from a small “farm size” system. Industrial facilities that function in a continuous mode, 24 hours a day, would produce 10-60 million litres per year, but a smaller production capacity of around 2 million litres per year (likely in a batch system) may be more adequate for a community-based production plant. The question whether to use a continuous or batch system mainly depends on system size and feedstock quality: if the type of feedstock varies a lot, a batch system can be better adapted to the specific cleaning and processing needs of different feedstock types.

There is a tendency towards using hybrid systems that utilize a batch acid esterification preprocess for low to high FFA content feedstocks (5-30%). This creates a consistent feedstock that can then be fed into a continuous transesterification system

Wastewater is generated from water separated from yellow grease, as well as washwater to remove salts and other impurities in the biodiesel. The selection of the best production technology will thus depend on the waste products and the ability to dispose of them, the types of feedstocks to be processed, the ability to expand plant capacities (if desired), and product quality and yields.

Fischer-Tropsch diesel: This is an industrial-scale process (200,000 tonnes of fuel per year or more) that will require large amounts of biomass and investment, as well as the necessary personnel and skills to operate such a plant, in three shifts. A plant site would have to be larger than 10 hectares, and should be located near rail access and possibly in the vicinity of other petrochemical installations. Experience with this process exists in the petroleum industry, but not yet for biomass as a feedstock, at the time this Primer is written.

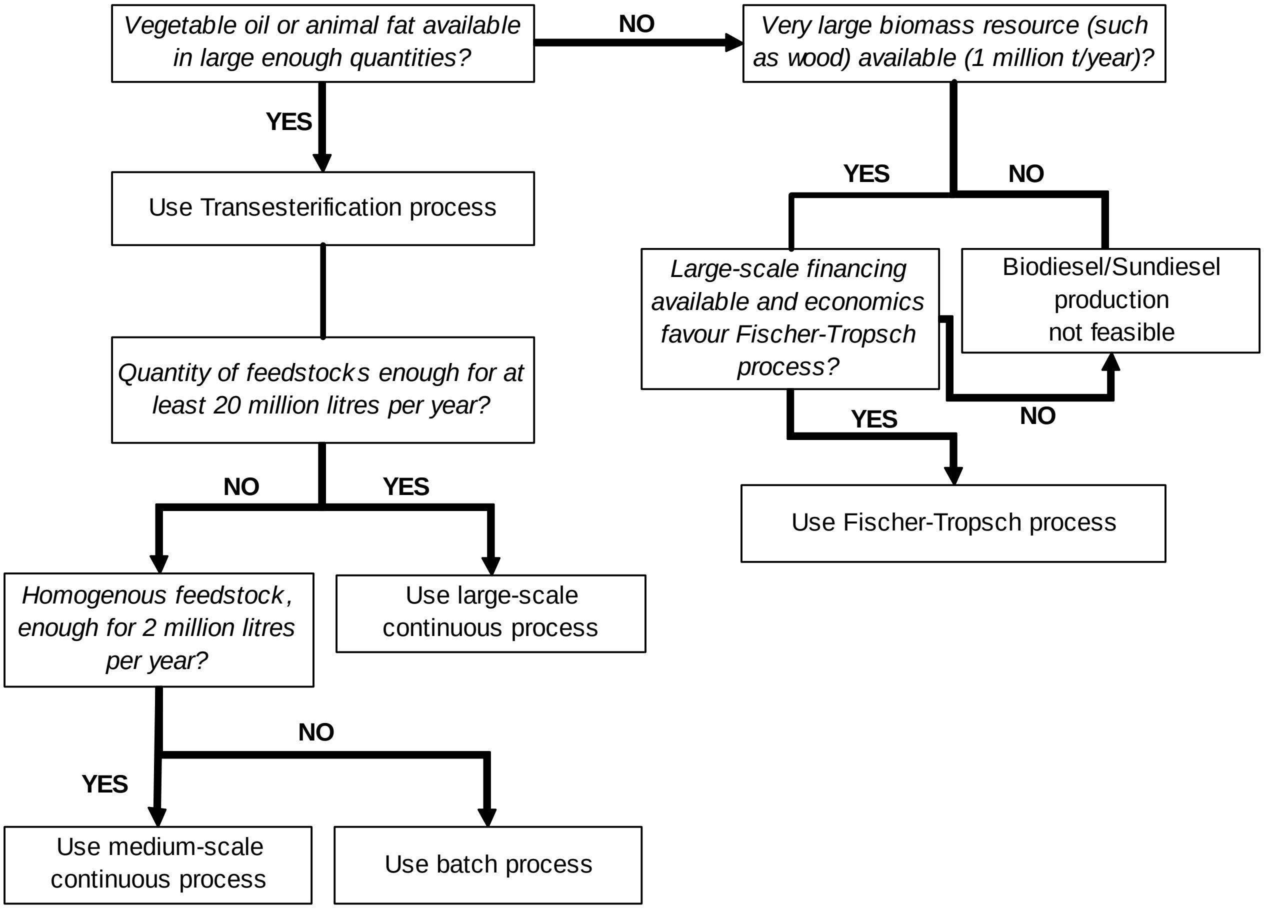


Figure 2.7.2 Decision Matrix for Selecting a Biodiesel Production Technology

3 Funding Sources

3.1 Introduction

Your main source of income will of course be the sales of electricity and/or heat. This expected income will enable you to get funding for your project. For heat sales, you need to find a contractor, which will either be a company like a pulp mill, or individual customers for district heating. Talk to your municipality and heat utility if you can sell your heat to them. If you cannot sell your heat directly to the municipality or another company, you may consider setting up a separate organization that deals with the individual contracts with small heat users. See Section 4.3 for options to sell electricity.

Project funding can be obtained in many different ways and from a variety of sources. Private funding will usually be the main source, sometimes the only one. In addition, there are several governmental programs that support biomass energy projects with grants. Note that grants are usually only given to projects that either demonstrate:

- a new technology that is not yet commercial in Canada, or
- an existing technology in a new application or context, or
- the use of technologies by communities that enjoy access to targeted funding programs.

Specific mechanisms like emissions trading or green power sales can also be used to leverage extra income, which may in some cases bring a project over a profitability threshold that is needed to attract the required investment.

The list of funding mechanisms in this Primer represents a snapshot of funding sources at the time of writing. You should investigate if there are additional programs that are not listed here but which might apply to either your project or to you as the project initiator (e.g., remote communities, First Nations). The sources explained below are therefore only a starting point when considering financing options. Please consult the *Funding Your Community Energy Initiatives* guide from the BC Community Energy Association (see “Purpose of this Primer” above) for contact details on most of the funding mechanisms listed here. The Association will update their funding guide on its website to include new information. Another source of funding information is *Environment Canada Green Source*, a website which lists and explains public and private sector funding sources (see www.ec.gc.ca/ecoaction/grnsrc/index_e.cfm), as well as the *Canadian Environmental Grants Database* (see www.cegn.org/grantmaking/publicintro.html).

3.2 Private Financing

Bank loans: Most of the funding for a commercial project will usually come from bank financing. Bank loans carry a fairly low-interest rate compared with other sources and will generally cover around 50% of the financing required. The loans are lower cost because the Banks are risk averse and will only take on a relatively low level of risk. For example Banks will require that their loan is secured with the primary or first charge on the equipment purchased. They may also want further assurances from other stakeholders which could be in the form of guarantees or capital contributions. They will also require other parties, such as risk capital providers or the community through equity, to co-finance the project. These other funding sources will be expected to take a position behind the banks i.e. in the event of a problem the banks get paid first and other parties will be only paid if there are any funds left over.

Risk capital: There are many technology investors and venture funds available to potentially provide “risk capital” for projects. As these sources of funds take a higher level of risk this funding is more expensive than a bank loan. Risk capital investors will want to see returns on their investment of 15-20%. They may also want to refinance their exposure after some initial years. This is often undertaken: once the facility has run successfully for a period of time and other funding sources will be more willing to replace the risk capital on a proven/operating project.

Investment funds: Companies like Creststreet, the Clean Power Income Fund or Algonquin Power Income Fund have investors that want to specifically profit from the renewable energy market. Their investment may come from tax deductible savings and investment plans. They will come with the perspective that they will want to own all or part of a facility, and may even want to operate them directly. Each investment firm is different and any proposals received will reflect the preferences of their investors.

Renewable energy companies: Several renewable energy development companies exist in Canada. They will approach a community or business with a plan to develop, own and operate the renewable energy project. These companies generally have good experience in the field and will bring their own funding. Many of the benefits of a project will then flow outside the community, but this option is less complicated for locals and does not require a lot of local expertise or dedication to the operational aspects of a bioenergy project. There would be some negotiation but in its simplest form the community would assess the complete package and make a decision to proceed or not.

Community ownership: Community ownership is the option that keeps most benefits of a renewable energy project inside the local community. It can foster support for a project by involving local skilled personnel, and provides income for members of the community who can become co-owners of the facility through shares. Note that community ownership may allow you to do avoid using risk capital, which is very expensive. The return on investment for your project can also be lower (under 10%) for community ownership, whereas such rates do not usually attract any risk capital. The rationale for the lower rate is that the community is often getting many more benefits from the project than simply its output. Community ownership will require a lot of extra work during the development phase of a project, but usually results in a much higher level of support among local stakeholders, which will help the project move ahead much more easily. More detail on community ownership and on how to develop a community project can be found in the *Renewable Energy Project Development Guide for North America* by the Commission for Environmental Cooperation.

3.3 Grants

Many biomass technologies are at the pilot or pre-commercial stage, or have only been used in other countries. Private investors are therefore often not prepared to bear the full technology risk. The most common way to get over this objection is to secure additional funding sources that will stand in front of the private investors to reduce the private investor risk. This is where several government programs or private foundations may be able to assist. Substantial amounts of funding may be provided with funds from those sources (sometimes 30% or even the full cost). On the other hand, the administrative burden will be increased through reporting requirements, and you may be required to modify the scope of your project to fit specific conditions to make you eligible for such funding. You may also have to team up with other groups, such as research organizations or local interest groups, in order to qualify for grants. Note that grant applications can often only be submitted at specific dates each year, and expect that approvals will take several months to process. Make sure you do not apply for grants too early in the development of your project as grant approvals may only be valid for a limited time and could be revoked if your project does not go ahead as planned. In some cases, the project may cover several areas of interest and you may be able to obtain grants from more than one organization.

When applying for grants, be creative and think about how you can “sell” your project: grant programs usually have a well-defined scope which may not fit your project 100%. By emphasizing specific features, involving particular groups or possibly adding on new aspects to your project, it may turn out to be eligible. If you do not have the necessary in-house experience, it may be worthwhile to involve a consultant to find the right funding partner and fill in the application forms, or get help from organizations in the field, such as the BC Sustainable Energy Association, the BC Community Energy Association or a group similar to yours that has already successfully developed a renewable energy project.

Each program has its own mandate and they will often focus on different areas. For example, some programs do not provide funding to assist with project capital costs, but will assist with work preceding the actual investment, such as feasibility studies, developing a business concept/plan, etc. It is important to look at all potential sources and utilize the ones that will assist your project to the greatest degree.

Federal Funding Sources

- *Sustainable Development Technology Canada* (SDTC, www.sdtc.ca) provides grants for up to one-third of the capital cost of pre-commercial technology projects. SDTC requires that applicants join with partners to form a consortium (consult the SDTC website for more information). SDTC funds up to one-third of the capital cost of demonstration projects, including the cost of feasibility studies.
- *Technology Early Action Measures* (TEAM, www.team.gc.ca) is a federal program supporting technologies that tackle the problem of climate change. TEAM requires that (private or community) project proponents team up financially with the provincial governments or municipalities, or each other. TEAM will only fund part of a project, and additional funds should come from a different federal program. Funding is provided as equity investment, but repayment can be negotiated in certain cases. TEAM funds new technologies that are to be demonstrated.
- The *Canadian Biomass Innovation Network* (CBIN, see www.cbin.gc.ca) funds research and development of biomass technologies. It fills the space between basic research and demonstration/ pre-commercialization. All projects must have a Federal Government lead and partners (industry, academia, provincial or municipal governments, NGOs, etc.). Eligible projects will have to have an important research component.
- Natural Resources Canada's *ecoENERGY Technology Initiative* (http://www2.nrcan.gc.ca/ES/OERD/English/View.asp?x=1603) provides funding for biomass energy projects at the demonstration stage. The first call for proposals is planned to be issued in the fall of 2007; no detailed information on the program was available when this Primer was completed.
- *Canada Strategic Infrastructure Fund* (www.infrastructure.gc.ca) requires partnerships between provincial and municipal governments and the private sector. Funding from this program is only available for large-scale projects with costs of over $75 million.
- *Western Economic Diversification* (www.wd.gc.ca) provides funding for economic development in Western Canada.
- *Northern Development Initiative Trust* (www.nditrust.ca) funding is available for local governments, not-for-profit societies, and First Nations. The Trust's funding mandate covers the pine beetle problem.
- *Aboriginal and Northern Community Action Program* (ANCAP, http://www.ainc-inac.gc.ca/clc/prg/index_e.html) supported communities in identifying climate change related opportunities and assessing their energy options. Previous funding by this program has ended. New funding and program details were not available at the time this Primer was completed.
- *EcoAction Community Funding Program* (Pacific and Yukon Region, http://www.pyr.ec.gc.ca/ecoaction/index_e.htm) provides funds for community groups. 50% of costs are funded for greenhouse gas emission reduction projects (up to $100,000, but mostly around $25,000).
- *Moving on Sustainable Transportation* (MOST, http://www.tc.gc.ca/programs/environment/most/applyingtomost.htm) is a government program that may apply to biofuels projects in BC. Funding is provided up to a limit of $100,000, but no funding was available when this Primer was completed.

- In the coming years, the federal government intends to set up a *Technology Fund*, based on contributions from industry in compliance with greenhouse gas emission regulations. The fund will be used primarily to finance investments in technology and infrastructure deployment that have a high likelihood of reducing greenhouse gas emissions in the near term. It was not known how this fund would specifically support biomass energy projects in BC when this Primer was completed.

Funding for Municipalities and First Nations

The following Trust organizations provide funding in the form of grants and loans for communities, local government, joint public-private enterprises, first nations, authorities, and non-profit organizations for a broad range of economic development and diversification projects that may include bioenergy projects. These projects must demonstrate direct job creation, increased export sales, increased property tax base and funding requests must be leveraged with financial contributions from other sources. First Nations should also consider the New Relationship Trust www.newrelationshiptrust.ca. For more information on available programs see the websites below:

- BC *Local Government Infrastructure Planning Grant Program* (http://www.cserv.gov.bc.ca/lgd/infra/infrastructure_grants.htm) provides up to $10,000 for local governments that can be used for community energy planning and feasibility studies.
- BC's *Municipal Rural Infrastructure Fund* (http://www.canadabcmrif.ca/en/guide.htm) is specifically geared towards local governments of communities under 250,000 inhabitants. Renewable energy projects are one of the categories qualifying for grants to cover part of the capital costs of a project. Infrastructure projects of First Nations communities are funded separately and administered by Indian and Northern Affairs Canada (INAC, http://www.ainc-inac.gc.ca/).
- Under the federal-provincial-municipal Gas Tax Agreement, the *Innovations Fund & Strategic Priorities Fund* provides grants for community energy projects and planning (up to 100% of project costs). Local governments can apply through the Union of BC Municipalities (http://www.civicnet.bc.ca/siteengine/ActivePage.asp?PageID=294#gas%20tax).
- *Green Municipal Funds* (http://www.sustainablecommunities.fcm.ca/GMF/) is administered by the Canadian Federation of Municipalities. Grants for 50% of the cost of energy planning and feasibility studies are available, as well as low-interest loans towards the capital cost of energy projects (15-25% of total cost). Only municipalities are eligible.
- *Municipal Finance Authority of BC* (www.mfa.bc.ca) provides low-interest loans (under 5% annual interest rate at the time this Primer was completed) to BC municipalities, Regional Districts and Hospital Districts. Applications are approved at meetings during spring and fall each year.
- *Towns for Tomorrow* (www.townsfortomorrow.gov.bc.ca) is a BC government program that may cover 80% of energy project costs, to a maximum of $400,000. Only governments of small communities (under 5,000 people) are eligible.
- BC Hydro administers the *Remote Community Electrification Program* (RCE), which aims at providing electricity to remote communities by extending the power grid or with alternative energy in order to replace diesel generation. No program website was available when this Primer was completed.
- The *Northern Development Initiative Trust* (www.nditrust.ca) is an economic development funding corporation for central and northern British Columbia. It provides the funding and ability for local government and First Nations to identify and pursue new opportunities for stimulating economic growth and job creation. The trust offers both grants and loans, and has a program specific to the pine beetle problem. It will assist with up to 28% of the capital cost of projects. The Northern Trust covers approximately 70% of the Province; see the *Southern Interior Development*

Initiative Trust (www.sidit-bc.ca) and *Island Coastal Economic Trust* (www.islandcoastaltrust.ca) for the remaining areas.

- BC Hydro's *First Nation and Remote Community Clean Energy* Program supports BC First Nations in the implementation of their Community Energy Planning action plans. The program also provides financial incentives (totaling $3.8 million) to ten First Nation communities who develop and implement zero-emission electricity supply projects and demand-side efficiency and management options. The incentives will be applied to the communities' clean energy project capital costs and local training in the field of alternative energy and energy efficiency (to a maximum of 20 per cent of eligible costs), leading to increased employment opportunities. (http://www2.news.gov.bc.ca/news_releases_2005-2009/2007EMPR0014-000354.htm)
- Other grant programs applicable to local government can be found at *Civic Info BC* (http://www.civicinfo.bc.ca/18.asp).

Other BC Programs and Initiatives

- The BC Energy Plan mentions the creation of a $25 million *Innovative Clean Energy Fund* and the creation of a *BC Bioenergy Strategy*. The Fund, which will be administered by the Ministry of Energy, Mines and Petroleum Resources, will support pre-commercial energy technology or commercial technologies not currently used in British Columbia. No details on these initiatives were known at the time this Primer was completed.
- In March 2007, BC Hydro issued a call for expressions of interest to be followed by a call for proposals for electricity from sawmill residues, logging debris and beetle-killed timber to help mitigate impacts from the provincial mountain pine beetle infestation (see http://www.bchydro.com/news/2007/mar/release51407.html).

Non-Governmental Funding Sources

Whereas the above are either directly or indirectly government-funded programs, there are also a number of private sources for grants, as well as foundations that may support bioenergy development in BC. These organizations may require charitable status from the applicants (this can usually be fulfilled by involving either local governments or a registered charitable group). Applicants must often be non-profit organizations, and applications must likely include significant community involvement or broad community benefits to be considered for funding. Applications from smaller communities with fewer resources available to them may be more likely to be accepted. The following list is only a small subset of potential funding partners:

- The *Encana Environmental Innovation Fund* (http://www.encana.com/responsibility/eif/index.htm) invests in new energy technologies.
- *Suncor Energy Foundation* (http://www.suncor.com/default.aspx?ID=2729) provides grants for communities in Northeastern BC (only not-for-profit entities are eligible). Funding covers community projects and environmental initiatives.
- *Terasen Energy Services* is investing in alternative energy projects including biomass for thermal energy. The company will want to own and operate the energy assets and provides all conventional utility services including maintenance, customer support and emergency response. For information about district energy or large scale heat projects contact Kristen Mucha (604 293 8642, kristen.mucha@terasen.com).
- The *Vancouver Foundation* (www.vancouverfoundation.bc.ca) may assist charities in implementing resource management elements of local sustainable development plans, as well as climate change and energy projects. The *Victoria Foundation* (www.victoriafoundation.bc.ca) has similar goals on Vancouver Island.
- The *Bullitt Foundation* (www.bullitt.org) provides funding to non-profit groups for education, climate change, forests and other environmental projects ($25,000 to $100,000).

- The *Endswell Foundation* (www.endswell.org) financially supports charitable groups that want to improve the environment, create educational programs in BC, or want to enhance the local economy and employment.
- Please consult the *Canadian Directory of Foundations and Grants* for more complete information at www.ccp.ca.

3.4 Additional Income and Incentives

In addition to the above funding sources, which are primarily directed to the capital costs, the following can provide additional revenue or lower costs, thereby increasing the return to stakeholders. Furthermore, some of these sources can generate revenue at the outset of a project, in advance of it being operational, thereby assisting with expenses and reducing borrowing requirements.

They are a source of savings or revenue in addition to the income generated by the sale of electricity and/or heat, and any additional revenue will always assist the profitability of a project and make it more attractive to potential investors.

Emission credits: The Canadian government has communicated plans to introduce emissions trading for several air pollutants, including greenhouse gases, nitrogen oxides, sulphur dioxide, VOCs and particulate matter. Reduction targets have been set for 2012, and emissions trading is meant to start in 2010. Biomass projects may benefit from such trading, but details of the program were not known when this Primer was completed. Please access the government's ecoACTION website (www.ecoaction.gc.ca) for more information.

Renewable energy certificates: Any type of renewable energy can create renewable energy certificates. In Canada, it is usually required that a facility is Ecologo certified before such certificates can be sold. BC Hydro has a voluntary renewable energy certificate program, which sells them to the private and institutional sectors. A certificate usually represents 1 MWh of renewable electricity, produced without the emissions associated with fossil fuels, and without the negative aspects often linked to nuclear or large hydropower. Such certificates can be sold by the biomass energy system operator to BC Hydro or other buyers. It is, however, important to make sure that there is no overlap between emissions trading and renewable energy certificates, as most stakeholders see these two markets as mutually exclusive. This means that the plant operator must choose to sell either certificates or emission credits because the same benefits are represented by both. An assessment should therefore be made at the outset of a project to determine which of these options appears more attractive. Note that renewable energy certificates may yield higher returns, but are part of a voluntary market in BC. Unless there is a high likelihood or even a contractual agreement for the sale of such certificates in BC or into U.S. markets, it may be better to engage in the mandatory emissions trading market. Verify the contractual agreement with BC Hydro or other partners for the power sold, as this may include environmental benefits from your project, which would then preclude the sale of certificates or emission reductions.

ecoENERGY for Renewable Power: This is an incentive paid to renewable electricity generators, which amounts to 1 ¢/kWh produced. The program aims at supporting 4,500 MW of power generation in Canada. You need to apply for this incentive once you are confident that you have solved the siting and technical challenges of your project; the Program requires that generation starts one year after your application has been accepted, although extensions can be granted. The incentive will only be offered as long as funds are not fully committed (generally, expectations are that funds will be used up by 2009). However, an extension of the ecoENERGY Program in the future is likely. Only projects of 1 MW electric capacity and larger may apply. A biomass project under 10 MW capacity will be allowed to receive 13 ¢/kWh for its electricity in addition to the incentive, whereas larger projects must remain at 12 ¢/kWh

or lower to be eligible. Ecologo certification is required for all biomass projects. The incentive will only be paid out for the first ten years of operation.
Link: http://www.ecoaction.gc.ca/ecoenergy-ecoenergie/power-electricite/index-eng.cfm

Accelerated write-off: Under Class 43.1, Schedule II of the federal Income Tax Act, renewable energy systems can be written off faster, allowing a company to pay less tax during the first years of operation. This improves economics during the initial years - the phase where risk capital is often needed, which can only be attracted with high returns. Biomass energy equipment costs can be fully written off within the first two years of operation under this scheme.

Standing offer program: According to the BC Energy Plan of 2007, the province will establish a fixed tariff for electricity from small facilities of up to 10 MW_{el} capacity. The Standing Offer Program will allow small projects to sell power to BC Hydro at a fixed price and with standard contract terms and conditions, and will do away with the need to wait for periodic Calls for Proposals. At the time this Primer was completed it was not known what the tariff for these facilities will be. Generally, a Standing Offer Program is meant to provide a high enough rate so that the majority of projects can go ahead. It is not clear, however, whether it will be high enough to benefit small biomass facilities. An additional advantageous feature of the program is that BC Hydro will absorb transmission / distribution network upgrade costs for individual projects subject to a cap established in consultation with stakeholders and approval from the BCUC, after which project proponents may be required to pay for additional network upgrade costs. Note that it is foreseen that no other benefits, such as renewable energy certificates or emission reduction credits, can be sold as the rights to their use will be transferred to BC Hydro under this program.
Link: http://www.bchydro.com/info/ipp/ipp51323.html

4 Grid Connection and Power Sales

4.1 Off-Grid Projects

Biomass energy facilities are not able to modulate their output very much, and are most suitable for "base load" power needs. This means they will run almost at constant output 24 hours day, seven days a week. As such they are not able to completely replace diesel generators in off-grid remote communities. They can, however, replace one or two generator sets, with the remaining generators being used for peak and backup power needs. Biomass energy facilities can therefore reduce generator maintenance and replacement costs, and create additional local employment. Biomass may also be attractive as a source of thermal energy to a community either in a dedicated or in a combined heat and power system, especially if nearby forested land can be harvested by locals. Typical remote communities in BC have electrical load requirements in the 100 to 1000 kW range and as a result they may not be well suited for typical applications of traditional biomass technologies. Remote communities interested in biomass energy options should get in touch with BC Hydro's *Remote Community Electrification Program*.

4.2 Interconnection for On-Grid Projects

Please note that interconnection process can vary greatly between tenders, Standard Offer Contracts and other options and this outline is only meant to give the reader a general idea of the process. It will be your responsibility to verify the specifics of tender documents or the Standing Offer Program and your contractual specifications to determine the exact steps to follow, as well as related costs and timelines.

All electricity projects that are connected to the grid must obtain an interconnection agreement. This agreement refers to the technical and legal requirements to ensure that the physical connection of the energy project to existing power lines is adequately done. Power lines to transport electricity to the public grid, grid interconnection costs and related control facilities can be a significant cost component of biomass energy projects. An interconnection refers to the connection of a generating source to the British Columbia Transmission Corporation (BCTC) Transmission network (greater than 35 kV) or to the BC Hydro Distribution system (35 kV or less). Some areas of British Columbia are served by electrical utilities other than BC Hydro. If a generation plant were situated in the service area served by one of these other electric utilities, an interconnection agreement would have to be reached with the local utility (e.g., Fortis) rather than with BC Hydro. The steps in BC Hydro's interconnection process include:

- initial inquiry by the generator,
- identification of interconnection options by BC Hydro,
- submission of a formal interconnection application by the generator,
- interconnection feasibility study by BC Hydro, and
- development of the interconnection requirements by BC Hydro.

The interconnection feasibility study is completed by BC Hydro, but is paid for by the applicant. Its cost can be $12,000 or more (a $15,000 deposit must be made when BCTC does the study); studies for (larger) projects with an impact on transmission will cost more. A total cost of $100,000 for studies and interconnection facilities is not unusual. In some cases, existing power lines may not have enough capacity to transport the extra power generated by the new facility. This would then trigger a transmission or distribution system upgrade, generally paid for by BC Hydro or BCTC. Within a competitive bidding process, however, projects incurring large costs in terms of transmission or distribution upgrades may be disadvantaged. BC Hydro or BCTC will conduct preliminary studies in order to provide the generator with an evaluation of the options, including an initial estimate of interconnection costs.

Once a formal interconnection request is made and the generator pays for the interconnection feasibility study, BC Hydro will let the applicant know if interconnection is feasible. The applicant then needs to pay for further in-depth studies (see Figure 4.1) to determine the cost and technical requirements for connecting the facility to the provincial power grid. Based on these studies, a document outlining the site-specific interconnection requirements will be produced. The generator and BC Hydro can then complete a Generator Interconnection Agreement (a legal document) defining the rights and responsibilities of both parties. This agreement will set out a schedule for further submissions, payments for services and construction, and various contractual procedures. BC Hydro/BCTC will inspect the final installation to ensure it is consistent with the Agreement. An initial single point of contact for interconnection inquiries is BC Hydro's Initial Inquiries and Contact Office, Office of Generator Interconnections. The page on *Generator Interconnections* on BC Hydro's website at http://www.bchydro.com/info/ipp/ipp992.html contains contact information and technical documents with more detail on the interconnection process and its variations. See also a BCTC presentation summarizing the process for transmission interconnections (http://www.bchydro.com/rx_files/info/info51670.pdf), which also contains contact numbers.

Projects under the Standing Offer Program

BC Hydro is creating a Standing Offer Program for small renewable energy projects with an electric generation capacity of under 10 MW. BCTC's *Standard Generator Interconnection Procedures* (SGIP) will apply (see http://www.bctc.com/generator_interconnection/oatt_sgip/oatt_sgip.htm for details). In addition, grid connection costs will be paid for by BC Hydro and not the developer to a certain limit. See the diagram below for a quick overview of the process.

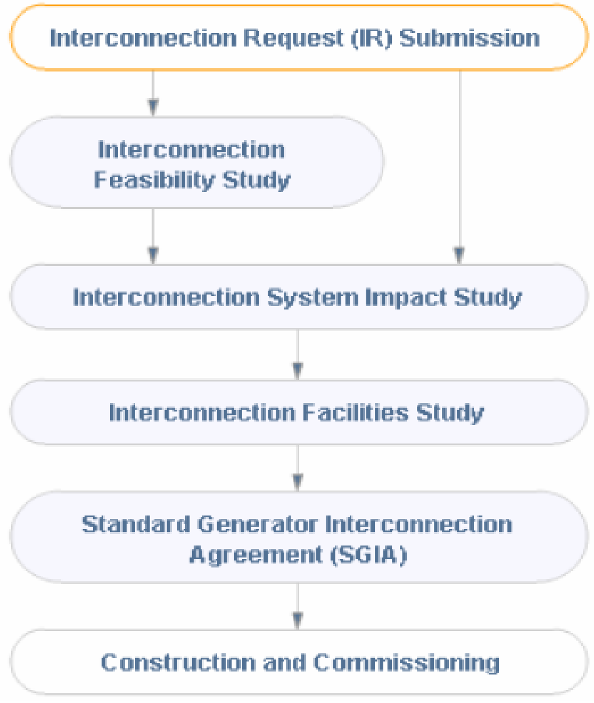


Figure 4.1 SGIP Interconnection Process

The SGIP Procedure for connecting to the BCTC transmission grid comprises several steps towards an Interconnection Agreement. It will usually take months from the submission of an Interconnection Request until the Agreement is signed. The feasibility study can take 10 weeks, and the more detailed studies 18 weeks. Expect one year or even more from your initial contact with BCTC over the Interconnection Request and further studies, until an agreement is signed.

Projects under Calls for Tenders

Specific details as to which procedures apply for interconnection will be provided for each Call for Tenders. Generally, the process used will be the Competitive Electricity Acquisition Process (CEAP). Once a project has been selected through this process, the interconnection process continues with the SGIP procedure.

4.3 Power Sales Options

In most cases, the electricity produced will simply be sold to BC Hydro – this may even apply in off-grid communities where BC Hydro runs the diesel generators. Whenever a project developer applies under the new Standing Offer Program or a Call for Proposals, the electricity will be sold to BC Hydro under long-term contracts. This is the most common option for biomass energy projects in BC.

Standing Offer Program: If your project is under 10 MW, you will be able to obtain a contract for power sales at any time under the new Standing Offer Program. However, the tariff for these contracts will be set by BC Hydro and whether or not this tariff is high enough for your project depends on your project economics. The specifics of this program were not known when this Primer was completed.

Call for Tenders: BC Hydro is preparing a specific call for biomass projects in the year 2007, and might decide to make further technology-specific calls for proposals in the future. This 2007 call will specifically target electricity from sawmill residues, logging debris and beetle-killed timber to help mitigate impacts from the provincial mountain pine beetle infestation. It may be easier for some biomass energy projects to apply under this specific call because other renewable energy systems, such as small hydro or wind power, often have a cost advantage over biomass projects. This is not always the case, however, and the business plan will reveal what power price a particular project can compete at. Please monitor the BC Hydro website for announcements and conditions for biomass energy calls. You can also bid under general calls for renewable energy projects; verify the specific conditions for each call as defined by BC Hydro.

Powerex, BC Hydro's energy marketing subsidiary is responsible for buying and selling electricity throughout North America. Powerex also buys energy from BC self-generators and independent power producers (IPPs) - especially also from green power providers (biomass energy projects will generally qualify as "green power", but should be certified under the Canadian Ecologo scheme or have equivalent certification applicable to the target market). Selling to Powerex would remove the need to wait for a BC Hydro call for power projects. Powerex may offer an indexed power price, which is based on market prices. This price insecurity may make project financing more difficult, unless it is not an issue and project proponents are ready to take such risks. Powerex can, in some instances, offer a fixed electricity price over a longer term (e.g., 10 years) but typically this is only possible whenever Powerex finds an electricity customer that agrees to purchase all the electricity generated by the facility in question for a longer period of time. Regardless of type of pricing that Powerex offers, any BC IPP (regardless of the type of generation) must be price competitive with distant markets, after wheeling costs (transmission fees), shaping, and Powerex's profit.

Direct sales to a customer outside BC: A fourth option is for the electricity to be transported (wheeled) directly to a customer outside BC. A company could enter into a firm transmission agreement at the rated electric capacity of its generating facility (subject to BCTC availability) and pay a demand charge to transport electricity to the BC border, which is about C$10 per MWh. Alternatively, an electricity producer could rent transmission capacity at flexible output rates, but the risk is that such flexible capacities are quickly used up by larger power producers. Once at the border, wheeling charges through the U.S. or Alberta would have to be added, along with other market charges such as losses, reserves and marketer costs. A BC power producer could also enter into an agreement with a third party marketer that would pay all transmission charges and sell the power outside the province, similar to what Powerex does. Contact BCTC for specific information on these options.

Note that so-called "environmental attributes" (emission reductions and other advantages; also called renewable energy certificates or green tags) of biomass energy can sometimes be sold separately from the electricity itself. Depending on the contract with BC Hydro, these attributes are either included in the sale to the utility, or can be sold to other customers separately. If the biomass energy producer has not sold these attributes to BC Hydro, it may sell them to Powerex or any other third party buyer. Powerex is in the business of buying and selling green attributes and is typically interested in growing this business. Participation in the attribute business will almost certainly require the generator to register and become a member of WREGIS – the Western Renewable Generation Information System – a tracking system that ensures attributes are from a specific generator and are not sold more than once.

5 Developing a Biomass Energy Project in BC

The Commission for Environmental Cooperation's *Renewable Energy Project Development Guide for North America* describes the entire process of developing a community energy project, including biomass energy projects, and should be consulted for more detail on most of the steps explained below. Specific information relevant to biomass energy projects in BC has been included here, mainly in terms of the permits required. A mid-sized bioenergy project may take two to three years to develop from the initial idea to start of operations. The process to develop a biomass energy project will generally include the following steps, which may not always be consecutive, but might swap or overlap with each other:

1. Developing a business idea
2. Consulting with community and other stakeholders
3. Setting up a company/community ownership structure
4. Conducting a fuel study
5. Developing a business plan
6. Selecting an appropriate technology and vendor
7. Arranging for financing
8. Arranging permits and licenses
9. Hiring and operating

It is a good idea to speak with other groups that have already successfully implemented a biomass energy project in BC, such as the City of Revelstoke (see Section 7 for contact details). They may be able to give you useful tips and contacts or references for your own project.

1. Business idea: Generally, a biomass residue, an economic activity, existing skills and interests, or specific motivation to test or apply a technology will be the first drivers to consider biomass energy. The initial questions to answer would be, what kind of a biomass resource do we have (type and quantity), and do we have the skills and human resources to successfully accomplish a project idea? Some of the stakeholders will already be identified at this stage.

2. Consultation: Depending on who drives the project, the technology choice may already be clear from the beginning. For community projects and most private sector projects, however, consultation of the locals and other stakeholders will be crucial in building the necessary support for an energy project. The choice of technology should at this point still be left open because that flexibility can offer a better chance to overcome any resistance from within the community. Consultation will continue during the entire project development process. Several public meetings to discuss the project and its impacts (positive / negative) on the community will be required, as well as direct consultations with the primary stakeholders, such as forest or agricultural businesses, the local Forest District, the municipality, government offices that will provide permits for the facility, harvesting and transport service providers, existing community and interest groups, etc.

3. Structure: This concerns the choice of organization, i.e. is it a large forestry company, an external energy project developer, a municipality, a co-op or a local business? Different structures have different advantages and disadvantages. Co-ops are more difficult to set up and manage at the beginning, but generally help the later stages of a project go more smoothly. Private business structures give more control to the project developer, but are likely to face more resistance from locals, and projects need to offer higher returns to attract private capital, as opposed to community ownership.

4. Fuel study: This is probably the most important step in developing a biomass project. The fuel study (generally done by an external consultant or a local with the necessary skills) will describe the type of biomass resource available, its geographical distribution and its availability over time (seasonal and long-term). As mentioned in Chapter 1, it is also important to identify the ownership and accessibility of the biomass resource. For example, is a sawmill willing to sell its biomass or do they already have their own plans to use it in the future? Can you obtain a license from a First Nation or from the Ministry of Forests and Range to cut trees, or to collect residual biomass from logging operations? Legal and contractual accessibility is therefore as important as the actual quantification of the resource. Usually, the biomass needs to be found within a 100 km radius; beyond that, transport costs may become too large to be used economically. The amount and type of biomass identified will determine the type and scale of technology that can be used. Note that some of the technologies discussed in Chapter 2 require large or very large amounts of biomass feedstocks, which may not be found in all locations. The larger the investment, the more important it gets to secure long-term contracts for biomass at an agreed pricing level, in order to reduce business risks.

5. Business plan: The business plan will show the “hard numbers” of the planned project. It requires pricing levels for the biomass feedstock, the capital and operational costs of the biomass energy plant, and identifies potential financing sources, business risks and risk mitigation measures. A business plan is useful for realistic planning at the community level, and is absolutely necessary to raise external capital from banks and other investors. You may write a simple plan at the beginning of your project and then refine and expand it as you progress. Sample business plans can be found in the *Renewable Energy Project Development Guide for North America*.

6. Selection of technology and supplier: As described in Chapters 1 and 2, there are many technologies, and only some of them will apply to local circumstances. Local skills, the size and type of the biomass resource, the capital available, desired energy products and other factors, such as air emissions, will limit the choice of technologies available to a project developer. Note that other factors, such as the availability of grant moneys for new technologies, may also have an impact. Generally, technologies must have a good track record before private investors will consider supporting a project. Governments or other funders may step in where the technology risk is still high. The vendor to be chosen may simply be the one closest to you, but other considerations, such as credentials, warranties and the readiness to guarantee project completion up until the full functionality of the energy plant may be factors in choosing a vendor. Some projects may use a technology company that completes turnkey energy installations with parts from a variety of vendors, including grid connection and other elements. A short “shopping list” for the most suitable technology may include:

- suitability for processing the feedstock at hand
- robustness and ability to process different feedstocks
- type of energy product (heat, electricity, fuel)
- size and value of the market for the energy products obtained
- process efficiency
- water use, air emissions, and residues
- capital and operating cost
- required personnel and skills
- company track record and references from past projects
- type of community (large/small, on/off grid)
- preferences of the community
- existing infrastructure that can be used for the project (transport, power lines, etc.)

7. Financing: Chapters 3 and 4 discuss general financing options and also the sale of electricity to the grid. Some larger companies will be able to finance a biomass energy system out of their own funds, but for most other project developers, financing will either come from private sources (banks and venture capital) or from the community (co-op structure with local ownership through shares). Newly demonstrated technologies will often be eligible for grants from government programs; other grant sources like foundations may provide some money to community groups or municipalities for feasibility studies, sometimes for capital costs as well. The BC Clean Energy Fund to be created may offer additional opportunities for biomass energy projects. A significant part of the financing process is to arrange contracts for the electricity sold: usually, a long-term contract at agreed pricing with BC Hydro will guarantee an income for the project that will in turn encourage investors to provide capital to pay for the installation (see Chapter 4 for more detail on power sale options). Other sources of income, such as the sale of emission credits or "green power" attributes, may provide a small, but sometimes significant source of income that improves the rate of return. For cogeneration projects, the sale of heat will become important. This can either be done through a contractual agreement with an industrial heat user, such as a paper mill, or in the case of district heat the project developer will want to contract with the municipality for heat sales to local buildings, or set up a new utility that provides heat services to local residents and businesses. Financing, should be in place by the time you get your construction license, but usually you will need to have a fairly good idea if you can get all permits or not (Step 8) before you can complete the financing process.

8. Permits and licenses: A number of issues need to be resolved for biomass energy projects. It is prudent to contact permitting authorities early in the process to detect any restrictions that may apply. Such talks will also help you understand the process better, as well as the costs and time related to obtaining permits. The following permits are likely to be necessary for biomass energy projects:

- Business license: The provincial government needs to issue a business license for your operation.
- Environmental Assessment Certificate: For power plant operations of 50 MW or greater (or smaller projects that have been designated as reviewable by the Minister of the Environment), an environmental assessment will be required. For projects with only an electric transmission line, the review threshold is 500 kV or greater and 40 km or more of length. Environmental assessments are administered by the BC Environmental Assessment Office (EAO). No assessment is required for heat-only applications. The contact within the EAO for power projects is:
  Mr. Brian Murphy, Project Assessment Director
  BC Environmental Assessment Office
  PO Box 9426 Stn Prov Govt
  Victoria, BC V8W 9V1
  Telephone: (250) 387-2402; Fax: (250) 356-6448
  E-mail: Brian.Murphy@gov.bc.ca
  Web site: http://www.eao.gov.bc.ca
- Federal environmental assessment: Electricity generation projects may trigger a federal environmental assessment. under the Canadian Environmental Assessment Act when the project is located on federal lands, such as a national park, or when a federal agency issues certain permits, licences or other approvals. Benefiting from the federal ecoENERGY incentive or other federal grant or loan programs will automatically trigger a federal environmental assessment. The federal BC contact is:
  Mr. Jason Quigley, Director, Pacific and Yukon Region
  Canadian Environmental Assessment Agency
  Suite 320, Sinclair Centre, 757 West Hastings Street
  Vancouver, British Columbia V6C 1A1
  Telephone: (604) 666-6989; Fax: (604) 666-6990
  E-mail: Jason.Quigley@ceaa-acee.gc.ca
  Web site: http://www.ceaa-acee.gc.ca/index_e.htm
- Environmental Management Act permit: Air emissions, ash disposal, fuel storage and wastewater/cooling water discharges, as well as safety and accident prevention are regulated by the Ministry of Environment. Provincial air emission regulations apply to biomass facilities, and a permit must be obtained from the regional BC Ministry of Environment. Municipal by-laws may exist that also restrict air emissions (wood stoves may be prohibited, whereas pellet stoves may not), or specific business activities (e.g., pellet plants have high particulate emissions). The Prince George air shed has been singled out as an area that cannot tolerate any more particulate emissions. Larger projects emitting more than 50 tonnes of particulates per year (usually projects larger than 10 MW_{el}) may not be able to obtain an air emission permit there. Smaller plants could still be allowed, but may be required to offset their particulate emissions by reducing (offsetting)

particulates through a separate project in the same air shed. Contact the following people for the Prince George/Northern BC region (or use the Government Directory to identify personnel for other regions – see Section 7.5):

Air shed planning, Omineca - Peace Region:
Mellissa Winfield-Lesk
Environmental Quality Section Head
1011 4th Ave
Prince George, BC V2L3H9
Phone: (250) 565-6094
Email: Mellissa.Winfield-Lesk@gov.bc.ca

Contact - Air emission permits (Northern BC):
Maureen Bilawchuk
Section Head - Environmental Management, Business Unit
Phone: (250) 565 6459
Email: Maureen.Bilawchuk@gov.bc.ca

- Water use license or approval: this authorization will cover the use of water in the biomass energy process, such as for cooling purposes. It is issued by either FrontCounterBC, or the regional office of the Integrated Land Management Bureau or the Ministry of Environment.
- Construction/siting permit: Your municipality or district can only issue the construction permit once the environmental assessment certificate has been obtained, if required. The Province of BC will issue this permit instead if your project is planned on Crown land, or the federal government if the project is on federal land. Your biomass energy facility must be in an industrial zoning. If you intend to build in a non-industrial zone, you need to file for a zoning exemption, which may cause delays in the project development process. The construction permit will usually include other building related permits, including:
  - A structural building permit which covers building layout and regulations;
  - A road permit to allow for the construction of access roads and other such infrastructure;
  - A traffic study will be required to assess the impact of transporting biomass to the facility, as well as waste removal;
  - A stormwater permit to make sure the local sewage system can cope with the stormwater or that runoff into a nearby watershed is allowed, or that due care is taken to prevent the pollution of local watersheds and groundwater, especially during construction;
  - A land use permit that authorizes the planned activity in the foreseen location;
  - Biomass storage license: A license may be required to store biomass either next to the power plant or in another location. There may be concerns about runoff into nearby watersheds, or fire hazards.
  - A noise permit to make sure noise emanating from the facility does not constitute an undue disturbance, subject to municipal by-laws;
- A fire safety permit (issued by local fire chief);
- Electrical and possibly natural gas permits to authorize hookups to the public utility grid (controlled by local utilities);
- Harvesting Authorization: Depending on where the biomass feedstock comes from, either a harvesting Authorization (if from Crown Land) or a timber mark (if from private land) or an agreement with a First Nation will be required. Buying biomass residues from other businesses which already have one of the above noted authorizations may negate the need for the purchaser to obtain their own (agricultural or municipal biomass would also fall under this category). Small volume, short term Harvesting Authorizations (Licenses to Cut) are issued by BC Ministry of Forests District offices and may be awarded with or without competition depending on the volume and circumstances in question. BC Timber Sales, which manages about 13% of the annual allowable cut in BC, awards Timber Sale Licenses for small to medium size volumes for typically 1–3 year terms. Longer term, non-replaceable forest licenses are advertised and awarded competitively by the Regional Offices of MOFR.

The disposal of roadside slash from logging sites is the responsibility of the forest tenure holder. To gain access to such wood you first need to confirm with the tenure holder that they have no further use for it and what their plans for mitigating fire hazard and reforestation are. If agreement with the tenure holder has been reached, contact the Forest District Office and obtain an authorization to remove the material from the site(s) in question. Issues you should anticipate include road maintenance costs, road user safety and protection of the environment related to road use, timing of your operations in relation to the tenure holder's plans to mitigate fire hazard and reforest the site.
For more information about securing access to Crown Timber, please visit an MOFR Office or http://www.for.gov.bc.ca/hth/timten/index.htm and
http://www.for.gov.bc.ca/hts/bioenergy/index.htm

- For steam engines, a licensed steam engine operator must be on-site when the system is in operation. Some biomass energy systems do not use steam and this requirement would then not apply.
- An electric generator's license is required, which you will obtain through your power purchasing contract with the local utility.
- A generator interconnection agreement with the transmission or distribution grid operator must be in place for grid-connected facilities (see Chapter 4). Likewise, agreements with BC Hydro must be in place for biomass energy facilities operating in remote grids.
- Contracts and agreements with First Nations: depending on where the biomass plant operates and where the fuel comes from, it may be necessary to negotiate with First Nations that have an interest or claims to the area where the biomass energy facility is planned. Such claims will be identified early in the process, during the consultation phase.

Details on the process set in place for obtaining authorizations under the BC Environmental Assessment Act, Water and Land Acts can be found in the *Local Government and Public Participation Mini-Guide* (see Section 7.4). The federal environmental assessment process is described in more detail on the Canadian Environmental Assessment Agency website (see http://www.ceaa.gc.ca). General information on federal permits requiring environmental assessment can be found in the *Project Description Guide: British Columbia* (see Section 7.4). Please note that the above is not guaranteed to be a complete list of permits required. You need to enquire of local, provincial and federal offices if any other permits are required for each specific project. The BC Environmental Assessment Office provides some information on applicable laws and regulations, and where to obtain specific permits (see http://www.eao.gov.bc.ca/links/). Permitting can be a very onerous process, especially when local authorities are not familiar with the technology and are therefore hesitant to issue permits without further information. Some companies called "Integrated Service Providers" will offer to take over the permitting process for you and install the system and deal with all legal and other requirements. Likewise, outsourcing the permitting process to an environmental consultant is common practice.

9. Hiring and operating: The ability to hire personnel with the right qualifications is one of the main considerations for choosing a technology and a location for a biomass project. To operate the facility, make sure you have redundant qualifications, i.e. two or more people should be trained to carry out the same duties. Usually, the technology provider will also train the local workforce in operating the equipment. Make sure you have warranties on the machinery, as well as service plans. Some servicing and maintenance can be carried out by local staff, but it is likely that a general system overhaul and cleaning is required once per year, which may involve external staff from the technology provider or a subsidiary.

Also, be on the lookout for new biomass feedstocks. Depending on the duration of your contracts for biomass, your present sources may run out and be purchased by another user, or pricing may increase. Such increases can be accommodated once the financial burden is reduced – i.e. once you no longer use high-interest risk capital, or even more so once the capital investment has been paid off. However, diversifying the biomass sources will reduce your risk and give you more leverage in negotiations.

6 Identifying Consultants and Technology Vendors

When undertaking a bioenergy project, you need to assess to which degree you need external consultants to assist with certain aspects of the project or if you have available all the required skills to plan and execute the project. If you want to develop a community energy project, you may be able to find the necessary expertise and resources within your community and stakeholders. At the least, you may be able to limit the amount of external expertise you need to hire and pay for.

6.1 Finding a Consultant

There are several degrees of third-party involvement that you may want to seek:

- A BC-based environmental consultant will be able to assist with a fuel study, feasibility study, technology selection and the permitting process. This leaves you with the responsibility of buying and combining the various technologies needed for a complete bioenergy plant, arrange for the engineering, civil works and all other tasks.
- A turnkey technology provider will be able to deliver a complete biomass energy system, including grid connections and other facilities required – as opposed to a vendor that only provides the key components of a bioenergy system, such as a boiler or gasifier. These providers are often fairly large, international companies (such as General Electric, Siemens). They do not, however, deal with permitting and civil works for the plant. You may be able to negotiate financing options directly with such providers, i.e. third-party financing may only be required for items not related to the power conversion technology itself.
- An integrated solution provider (ISP) will not only do the technology selection and installation for you, but also the related services like permitting, interconnection, etc. Such companies can be based in Canada or the U.S., and are usually not only active in one particular region, such as BC. These providers may also provide guarantees that the energy system is working properly, as well as service contracts that are crucial for the time when the project is operational. ISPs can even operate the plant for you if you wish. This is usually the most expensive option, but offers clear advantages for groups that have no capacities in-house to develop energy projects.
- Another option, if you don’t wish to get involved in the legal and technical side of things and want to leave the operation and ownership of a facility up to a third party, is to invite an energy project development company to take over the project development process from A to Z. This could be an investment fund or a project development company.

To identify a consultant, you can of course browse through the BC Yellow Pages. You will find better and more targeted information by looking at specific websites where consultants are listed. Some examples of such sites are:

- *Strategis* (http://strategis.ic.gc.ca/app/ccc/search/cccBasicSearch.do?language=eng&portal=1): This website is run by Industry Canada and offers a keyword search, as well as searches by region. Use the “Canadian Company Capabilities” section and search in the energy or environmental subsections. Consultants registering with this website are asked to provide detailed information on their areas of expertise.
- *Environmental Expert* (www.environmental-expert.com) is a website where companies from Canada, the U.S. and elsewhere can enlist to offer their services. You can search their database for “Services”, which includes consultants.
- The *Clean Energy Portal* (www.cleanenergy.gc.ca) is a website established by Natural Resources Canada that lists consultants in the field of clean energy and climate change.

- The *BC Environmental Industry Association* (www.bceia.com) has a members listing that identifies a number of environmental consultants. You may also be able to obtain more specific information by contacting the Association directly.

- You can contact BC and other universities if you want to get references for technologies or assistance with specific tasks. For example, UBC hosts the *Clean Energy Centre*, funded by the Canadian Foundation for Innovation.

- The *Canadian Bioenergy Association* (CANBIO, www.canbio.ca) may be able to refer a knowledgeable consultant. Their members list includes several consulting companies and individual consultants.

- The *BC Bioproducts Association* (www.bcbioproducts.ca) may also be able to refer local experts that can help with the issues around developing a biomass energy project.

- *FP Innovations* (www.feric.ca) is a forest research consortium that has many highly specialized experts in the biomass field who can help with transport and harvesting cost estimates and related problems in the biomass sector.

- The *Independent Power Producers Association of BC* (IPPBC, www.ippbc.com) can refer consultants and energy project development companies.

- A reference obtained from another group that has developed a similar project in BC may be a good way to identify a consultant that has done good work and is able to help you as well.

- You can post a request for proposals (RFP) in order to ask consultants to offer their services to you. For example, *MERX* (www.merx.com) is a website that publishes RFPs nationwide for governmental and corporate clients. The public sector in BC can channel its RFPs through the *BC Bid* website (www.bcbid.gov.bc.ca). If you have already identified a handful of consultants that you deem qualified to carry out the work at hand, you can also send them the RFP directly and ask them to make you an offer for services.

To ascertain that a consultant has sufficient expertise to assist you, ask for a list of projects and references for similar projects that you can call. You may want to contact two or more consultants and compare their offers and experience before selecting who you want to work with.

6.2 Finding a Technology Vendor

A number of mainly Canadian technology vendors are named in preceding chapters and their technologies are described for illustrative purposes. Note that these are merely a selection of what exists in the marketplace, and that more and more technologies are reaching the commercial stage as time progresses. The fact that some companies are named in this Primer and others are not does not indicate preference or endorsement for the ones that are included. You should always inform yourself and compare different offers from two or more vendors before making a decision to buy.

Provided that you have examined and quantified the biomass resource you have at hand and have compared the different systems available (see Chapter 2) and made a decision as to what type of system is right for you, you can now select a technology provider. If you prefer to leave this selection up to an external project developer or an integrated solutions provider, you only have to select such a service provider, and save yourself the more technical decisions as to which bioenergy system to buy. To find a provider that can offer the system you need, the issues to be raised are the following:

- Is the technology proven, or is it still pre-commercial? For pre-commercial technologies, you will need to leverage government grants or other such funding in order to reduce the investment risk for private funders. Providers of commercial technologies will be able to give you a list of reference projects. You should also ask for technology certification by a third-party technical agency that confirms the claims made by the company.

- Be aware that a technology that works in another region may still have problems in BC, e.g. because of the cold climate in some regions.
- Is the technology available in the size you need it for?
- Can it comply with local air emission regulations?
- Will the installer guarantee that the system will work according to specifications?
- What wastes and residues does the system produce?
- What qualifications are needed to operate and maintain the system?

An Internet search using the specific terms you are looking for (such as bioenergy, gasification, etc.,) will usually deliver several technology provider websites that may be relevant to you. Some targeted websites that can help you identify potential technology vendors or integrated solution providers include:

- The *Clean Energy Portal* (www.cleanenergy.gc.ca) is a website established by Natural Resources Canada that lists Canadian technology providers in the field of clean energy and climate change. It links to a number of biomass energy technology providers. You may also find listings of investment companies for biomass projects.

- The Canadian Importers Database on the *Strategis* website (http://strategis.ic.gc.ca/cgi-bin/sc_mrkti/cid/cid_e.cgi?func=start_search&search_type=by_product) may provide some company names that sell energy related equipment in Canada. Look at section P-XVI-MACHINERY to find importers of boilers, turbines and related equipment.

- Consult the *Buyer's Guide* of Cogeneration and On-Site Power Magazine. You can search technology vendors, turnkey project developers etc. by country: http://www.cospp.com/buyersguide/index.cfm. The summer edition of the printed magazine contains a listing of companies by activity and technology type.

- Use specialized search engines such as *Globalspec*, which link to technology providers and can be searched for terms such as "biomass", "gasification" etc.: http://www.globalspec.com/

- *Sustainable Development Technology Canada* (SDTC, www.sdtc.ca) invests in emerging technologies. Its website provides company names for a number of biomass technologies. Note that these technologies are pre-commercial and will usually require grants in order to implement a project.

- The *Canadian Renewable Fuels Association* (www.greenfuels.org) may be able to refer vendors active in the biofuels production field.

- The *BC Bioproducts Association* (www.bcbioproducts.ca) is a good resource for biomass related activities in BC.

- The *BC Power Technology Alliance* (www.power-technology.ca) has several members that provide electricity generation technology.

- *Renewable Energy Access* (http://www.renewableenergyaccess.com/rea/partner/search) is a North American email information service that also provides listings of consulting, financial and technology companies in the renewable energy field. You can conduct a specific search for companies in the bioenergy field.

You can also commission an environmental technology consultant to do a search and identify technologies applicable to your situation. This consultant could also assist with short-listing vendors and assessing and selecting the company you will want to work with. Here are a few things you can verify yourself to compare different vendors:

- Company track record and verifiable references from other buyers;
- Service agreements and performance guarantees;
- If the vendor uses another company as an installer, what is the track record of that installer?
- Does the vendor supply adequate training and aftercare for you to operate the system after commissioning?
- Obtain at least one more quote from another vendor that offers a similar system;
- Ascertain that all items are included in the price you were quoted (installation, transport, grid connection, applicable taxes and travel costs);
- Does the vendor/installer help you with permits and paperwork?

Again, you may want to compare different vendors or service providers before making a decision to go with one or the other. Note that price is not the only criterion you should apply. Good references are certainly one of the more important indicators that a vendor is trustworthy. Further links to organizations, websites and associations are provided in Chapter 7.

7 Additional Literature and Information

7.1 Biomass Related Associations and Organizations

BC Bioproducts Association
www.bcbioproducts.ca
An association formed to represent businesses with interests in a range of bioproducts from biodiesel, bioethanol, wood pellets, biomaterials, nutraceuticals and food products from a wide range of sources including agricultural, marine, forestry and various waste streams.

BC Hydro Biomass Page
www.bchydro.com/environment/greenpower/greenpower1733.html
Informs about biomass energy potential in BC and BC Hydro's activities. BC Hydro has created a biomass energy inventory and map, which are not available on the website.

BC Ministry of Forestry and Range Bioenergy Page
www.for.gov.bc.ca/hts/bioenergy/index.htm
Informs about the latest developments in the province concerning calls for power, pine beetle wood, etc.

BC Power Technology Alliance
www.power-technology.ca
An industry alliance formed to build the BC energy cluster by appropriately supporting the emergence, and solidifying the growth of its power technology industry.

BC Sustainable Energy Association
www.bcsea.org
A non-profit society of citizens, professionals and practitioners committed to promoting the understanding, development and adoption of sustainable energy, energy efficiency and conservation in British Columbia.

Canadian Biomass Association
www.canbio.ca
Industry association promoting the use of biomass for energy in Canada. The association may be able to put you in touch with consultants, holds workshops and offers information on biomass energy on its website.

Canadian Forest Products Association
www.fpac.ca
FPAC is the voice of Canada's wood, pulp, and paper producers nationally and internationally in government, trade, and environmental affairs. FPAC members in BC and the rest of Canada are very active in promoting and developing biomass energy.

COGEN Canada CHP Association
www.cogencanada.org
Association for the furtherance of cogeneration in Canada. This organization is not specialized in biomass but could be of help for any cogeneration project.

Community Energy Association of BC
www.communityenergy.bc.ca
A non-profit society taking action on climate change and energy sustainability by assisting communities to develop and implement energy efficiency and green energy initiatives

Independent Power Producers Association of BC
www.ippbc.com
An industry association regrouping renewable energy project developers in BC and related industries.

NewERA
www.newera-energy.ca
The New Energy Resources Alliance (NewERA) is a national, not-for-profit industry association representing its member companies in the decentralised energy industry in Canada. Decentralised energy is defined as the production, management and storage of heat and/or power close to the customer's load.

Wood Pellet Association of Canada
www.pellet.org
An association of commercial wood pellet producers.

7.2 Biomass Research and Consulting Organizations

BIOCAP
www.biocap.ca
A not-for-profit organization focusing on research and partnership building to inform Canada's investment and policy decisions re: clean energy and climate change solutions. The organization is committed to the development of biomass energy and other technologies. BIOCAP holds conferences and has examined the use of pine beetle wood in BC and other biomass opportunities.

CANMET Energy Technology Centre
www.nrcan.gc.ca/es/etb/ctec/cetc01/htmldocs/home_e.htm
Web site with information on renewable energy, research, and government funding in Canada.

CBIN
www.cbin.gc.ca
The Canadian Biomass Innovation Network (CBIN) coordinates the Federal Government's interdepartmental research and development activities in the area of bioenergy, biofuels, industrial bioproducts and bioprocesses. CBIN's website offers a public forum that can be used by the communities involved in delivering the R&D and moving it along the innovation chain.

FP Innovations
www.feric.ca
FP Innovations is a forest research consortium that has many highly specialized experts in the biomass field who can help with transport and harvesting cost estimates and related problems in the biomass sector.

Resource Efficient Agricultural Production (REAP-Canada)
www.reap-canada.com
A Research, Consulting and International Development Organization creating ecological solutions for food, fibre and energy production challenges. REAP-Canada's website provides articles and information on the cultivation of energy crops.

Universities and Colleges
http://www.aved.gov.bc.ca/institutions/welcome.htm
Several BC universities and colleges have research programs in the biomass energy field, such as the UBC Department of Forest Sciences and the Department of Chemical and Biological Engineering, or the University of Northern BC. The website given here will help identify contact details of these institutions, which may be able to assist with bioenergy project development.

7.3 Useful Biomass Related Reports and Research

An Inventory of the Bioenergy Potential of British Columbia
www.biocap.ca/images/pdfs/BC_Inventory_Final-06Nov15.pdf
Report by the BIOCAP Foundation on biomass resources in BC.

BC Bugwood: Economics, Technical Feasibility and GHG Implications of Seven Small to Medium Technologies
http://www.for.gov.bc.ca/hfd/library/documents/bib97175.pdf
Report describing technologies to use pine beetle wood, as well as economics, transport and harvesting costs.

Biomass Energy Data Book
http://cta.ornl.gov/bedb/download.shtml
Collection of key data, parameters and information on biomass energy systems collated by the U.S. Department of Energy.

ELORIN Bioenergy Feasibility Study Reports
http://66.48.22.171/site/index.php?method=public.newsitemDetail&newsitem_id=94
A series of reports describing bioenergy technologies and elements of project development. Conceived for Eastern Ontario, many aspects of these reports will also be relevant for BC.

Estimated Costs for Harvesting, Comminuting and Transporting Beetle-Killed Pine in the Quesnel/Nazco Area of Central BC
http://www.for.gov.bc.ca/hts/bioenergy/Link_Rep/FERIC_MPB%20report.pdf
Report by FERIC (now FP Innovations) on pine beetle wood economics in BC.

Feedstock Availability and Power Costs Associated with Using BC's Beetle-Infested Pine
http://www.for.gov.bc.ca/hts/bioenergy/Link_Rep/MPB_Study_Phase2_20051103.pdf
Report examining the feasibility of a 300 MW biomass power plant in BC using pine beetle wood.

From tree to fuel: woodfuel supply chain infrastructure in the USA
http://www.oti.globalwatchonline.com/online_pdfs/36317MR.pdf
100-page report by the U.K. Department of Trade and Industry on forestry practices, wood product pricing and machinery used in the U.S.

Renewable Energy Financing Case Studies: Lessons to be Learned from Successful Initiatives
http://www.cec.org/pubs_docs/documents/index.cfm?varlan=english&ID=2022
Document from the Commission for Environmental Cooperation describing renewable energy financing mechanisms and several international case studies.

The BioTown, USA Sourcebook of Biomass Energy
www.in.gov/biotownusa/pdf/Biotown_Sourcebook_040306.pdf
Report discussing biomass energy technologies in the context of a municipality in the U.S., which also describes economics and lists technology providers.

7.4 Tools and Guides

Canada-Ontario Business Service Centre
http://www.cobsc.org/en/index.cfm
Additional materials available online, including an online business planning tutorial with a section on business plans.

Canadian Renewable Energy Network
(http://www.canren.gc.ca/default_en.asp)
This web site offers excellent buyer's guides for all renewable technologies, as well as case studies.

Handbook for Developing Micro-Hydro in British Columbia
http://www.bchydro.com/rx_files/environment/environment1834.pdf
Explains the development process for micro-hydro installations in British Columbia, but covers many aspects that are common to all renewable energy technologies.

Interactive Business Planner
http://www.cbsc.org/ibp/en/index.cfm
Online tool provided by the Government of Canada.

Ontario Community Power Guidebook
http://www.ontario-sea.org/guidebookintro.html
In May 2006, OSEA launched the Community Power Guidebook. This CD must be purchased on-line and is a step-by-step guide to the process of developing your own community power project, from conception to commissioning. It contains links to numerous resources, descriptions of each phase of a project, recommendations, contact names and contact links.

Opportunities for Local Government and Public Participation in Provincial Regulatory Processes for Independent Power Producers' Projects
http://www.em.gov.bc.ca/AlternativeEnergy/documents/EAED_IPP_Mini-guide_for_Local_Government_enclosure.pdf
BC guidebook explaining the procedures and stages related to some of the main permits and authorizations relevant to biomass energy projects, i.e. those required by the Environmental Assessment Act, Water Act and Land Act.

Private Woodland Planner
http://www.enfor.com/software/pwp/
The Private Woodland Planner is a software tool that was developed to assist small woodland managers assess the timber and non-timber forest product values of their land. It allows to input tree cover, species composition and associated values to evaluate the economic opportunity related to a given cutblock.

Project Description Guide: British Columbia
http://www.eao.gov.bc.ca/pub/ceaa_nov06/Project_Description_Guide_CEAA_v2.pdf
Guide explaining the process under the Federal Environmental Assessment Act, what triggers a federal assessment, and related contacts and procedures.

RETSCREEN
http://www.retscreen.net/ang/home.php
RetScreen is free Canadian software for preliminary assessments of the financial aspects of renewable energy projects. Modules can be downloaded specific for each technology, and some resources, such as solar and wind, are programmed into the software to provide an indication of expected energy production.

The Cooperatives Secretariat
http://coop.gc.ca/index_e.php
An agency of the Government of Canada intended to help the government respond more effectively to co-ops and provide information and services to them.

The Ontario First Nation Guide to Windpower: Getting Grid Connected (2005)
http://www.ainc-inac.gc.ca/clc/tp/ofn/ack_e.html
Written by SGA Energy Ltd in association with Pembina Institute for Sustainable Development & Gale Force Energy Ltd. Many aspects on this Guide will also apply to BC.

7.5 BC Government and Other Useful Contacts

Ministry of Energy, Mines and Petroleum Resources
Bioenergy and Renewables Branch
4th Floor, 1810 Blanshard St
Victoria, BC V8W 9N1
Phone: (250) 952 0156
Email: Janice.Larson@gov.bc.ca; Garth.Thoroughgood@gov.bc.ca

Ministry of Environment
Rich Girard
Regional Manager, Omenica and Peace Regions
325 - 1011 4th Avenue, Prince George, BC V2L 3H9
Phone: (250) 565-6443
Email: Rich.Girard@gov.bc.ca

BC Government Directory – see www.dir.gov.bc.ca

City of Revelstoke
www.cityofrevelstoke.com/ (click on ENVIRONMENT – Revelstoke Community Energy Project)
The City of Revelstoke has implemented a biomass district heating project.
REVELSTOKE COMMUNITY ENERGY CORPORATION
Geoff Battersby, President, Cell # 250 837 1930
Larry Marchand, Manager, Cell # 250 837 1600
Aubrey Salon, Operator, Cell # 250 837 8597
Office address: Ste. 200, 103 2nd St. E., Revelstoke, BC
Mailing Address: Box 3199, Revelstoke, BC, V0E2S0
Phone: (250) 814 0115; Fax: (250) 837 5988; Email: rcec@rcfc.bc.ca

Glossary

Aerobic	A biological process that uses oxygen is called aerobic. Anaerobic processes, as in a digester, can only function in an oxygen-free or oxygen poor environment.
bdt	bone-dry tonne. 1000 kg of biomass that has water content of 0%. Wood will almost never have a moisture content of zero, so this is a theoretical unit that helps compare different types of biomass in terms of the higher heating value.
Capacity factors	For a power generation unit, the capacity factor represents the time the unit is running at its full capacity: if the unit is running at 50% of its capacity for one year, or at 100% for half a year, the capacity factor will be 50%.
Carbon neutral	Term used to describe an activity or product that has net zero greenhouse gas emissions, either because related processes do not emit such emissions, or because these emissions were offset by emission reductions elsewhere.
CHP	Combined heat & power (see cogeneration)
Cogeneration	The generation of both electricity and heat or steam. Cogeneration is often used in a more industrial context, where steam may be used for specific purposes other than heating. Combined heat & power (CHP) is a term more suited to the district heating and other heating applications linked to power generation.
Combined cycle	An expression from electric power generation where the waste heat from a gas turbine is used to generate steam, which is then used in a second (steam) turbine to increase overall electricity output.
Combustion	Oxidation (of biomass) with air or pure oxygen. Combustion is the most basic energy conversion process for biomass and yields ash and a hot flue gas, which can be used, for example, to produce steam.
Coppice	Harvesting young trees in 3-4 year cycles is called coppicing. Usually, willow or poplar coppice is used for energy purposes as these species are fast-growing.
Criteria Air Emissions	Smog forming air emissions, including sulfur dioxide (SO_2), nitrogen oxides (NOx), and volatile organic compounds (VOC), particulate emissions, and carbon monoxide.
Ecologo	Canadian environmental label administered by TerraChoice (www.environmentalchoice.com). Ecologo is available for electricity produced with renewable energy and related facilities, including biomass facilities. Specific criteria apply for these facilities to qualify for Ecologo certification.
Gasification	High-temperature (above 800°C) heat treatment of biomass, yielding a char and a syngas.
GHG	Greenhouse gas emissions: CO_2 and other gases, such as methane (CH_4) and nitrous oxide (N_2O)
Higher heating value	Heat energy in a feedstock without taking account of the energy required to evaporate the water contained in it, as well as the latent heat contained in water

	formed through the combustion process itself. This energy can theoretically be recovered, but is actually only partly or not at all recovered in energy conversion systems.
Hog fuel	Named after the wood grinding machine called a “hog”. Hog fuel is predominantly bark accumulated from debarking tree stems for higher-end wood products.
kV	kilovolts – a unit used to describe the capacity of electricity transmission and distribution lines.
Lower heating value	Heat energy in a feedstock after subtracting the latent heat required to evaporate the moisture contained in the flue gas. This value is more representative than the higher heating value in terms of the useful energy content in biomass.
MSW	Municipal Solid Waste
MW	Megawatt. Measure for the generation capacity of energy conversion systems. Mostly, megawatts describe electric generation capacity (MW_{el}), but can also be used to describe the thermal output (MW_{th}). A cogeneration plant would thus have both an electric and thermal capacity.
MWh	The amount of electricity produced by one Megawatt of electric capacity during one hour. This is an energy unit, whereas MW (see above) describes the capacity or power (size) of a generation unit. See also the following table to compare and convert energy related units.

Power Units	Energy Units
1 kilowatt (kW) = 1,000 watts	1 kilowatt hour (kWh) = 1,000 watts for 1 hour (1,000 watt hours)
1 megawatt (MW) = 1,000 kilowatts (or 1 million watts)	1 megawatt hour (MWh) = 1,000 kWh
1 gigawatt (GW) = 1,000 megawatts (or 1 billion watts)	1 gigawatt hour (GWh) = 1,000 MWh

The average household in BC Hydro’s service area uses about 10,000 kWh per year. 1 MWh of electrical power contains the same amount of energy (work capability) as 0.6 barrels of oil or 90 cubic metres of natural gas or 400 kg of freshly cut wood.

Nitrification	Oxidization of ammonia to nitrite and then to nitrate. Nitrate can be readily used by plants and functions as a fertilizer. Denitrification reverses the process, removing oxygen from the nitrogen compounds, eventually releasing it as gaseous nitrogen.
PJ	A unit that stand for Petajoules. Joules and kilowatt-hours are all energy units. One petajoule is 10^{15} Joules or 278 million kWh.
Pyrolysis	Medium-temperature (400-600°C) heat treatment of biomass, yielding a pyrolysis gas, char and the main product, the pyrolysis oil or liquid.
Single cycle	As opposed to combined cycle systems, a single-cycle power generation unit does not use the waste heat to generate more heat. Single-cycle units are cheaper and more flexible in regulating the output, but are also less efficient than combined cycle units.

Syngas	A mix of gases created through the gasification of a solid or liquid fuel. It is rich in hydrogen and carbon monoxide, but depending on the gasification temperature and feedstock will also contain ash, water vapour, longer-chain carbon molecules, nitrogen, and other gases. Syngas made from biomass is either combusted or reformed and purified to create useful products, such as a gas to be used in a turbine or fuel cell, or a liquid biofuel.
Torrefication	(or torrefaction) Heating of wood to between 200 and 300°C. This process does not gasify or liquefy the wood as the hotter pyrolysis process does, but improves the wood quality (lower moisture, water resistant, higher energy content, easier pulverization).

Sources

BioCost 1998	Groscurth, Helmuth-M. and Kühn, Isabel: Die energetische nutzung von Biomasse – techische, ökonomische und ökologische Erfahrungen anhand ausgewählter Beispiele. Zentrum für Europäische Wirtschaftsforschung, 1998
CEA 2006	Tampier, Martin: Handbook on Electricity generation Technologies. Canadian Electricity Association, Ottawa, May 1, 2006 (unpublished)
GLOBE 2007	The Endless Energy Project: A Blueprint for Complete Energy Self-Sufficiency in British Columbia. The GLOBE Foundation, January 2007
BIOCAP 2005	Kumar, Amit *et al*.: and British Columbia's Beetle Infested Pine: Biomass Feedstocks for Producing Power. Final Report prepared for the BIOCAP Foundation and the Province of BC, University of British Columbia, Vancouver, April 30th, 2005.
BIOCAP 2006	Ralevic, Peter and Layzell, David B.: An Inventory of the Bioenergy Potential of British Columbia. BIOCAP Canada Foundation, Queen's University, Kingston, ON, November 15, 2006
Envirochem 2004	Tampier, M. et al.: IDENTIFYING ENVIRONMENTALLY PREFERABLE USES FOR BIOMASS RESOURCES - STAGE 2 REPORT: Life-Cycle GHG Emission Reduction Benefits of Selected Feedstock-to-Product Threads. Envirochem Services Inc., Vancouver, July 19, 2004 (updated 2005)
Envirochem 2006	Tampier, M. et al.: IDENTIFYING ENVIRONMENTALLY PREFERABLE USES FOR BIOMASS RESOURCES - BC Bugwood: Economics, Technical Feasibility and GHG Implications of Seven Small to Medium-Scale Technologies. Envirochem Services Inc., Vancouver, February 15, 2006
ETSU 2002	Pointon, Kevin and Langan, Mike: Distributed Power Generation Using Biogas Fuelled Microturbines. ETSU Contract B/U1/00670/00/REP, UK, 2002
FAO 2004	Unified Bioenergy Terminology. FAO Forestry Department, Wood Energy Programme, Food and Agriculture Organization of the United Nations, December 2004
FERIC 2006	MacDonald, A. J.: Estimated Costs for Harvesting Comminuting, and Transporting Beetle-Killed Pine in the Quesnel/Nazko Area of Central British Columbia. FERIC Advantage Report Volume 7, No. 16, Forest Engineering Research Institute of Canada, Vancouver, 2006
IEA 2007	Bridgwater, Tony: Biomass Pyrolysis. IEA Bioenergy Task 34, Aston University, UK, 2007
UoM 2006	Goodrich, Philip R. et al.: Emissions from Biogas Fueled Engine Generator Compared to a Fuel Cell. Paper # 634, University of Minnesota, St. Paul, 2006