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Energy From Wood Biomass Combustion In Rural Alberta Applications

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The Agricultural Policy Framework (APF)
A FEDERAL-PROVINCIAL-TERRITORIAL INITIATIVE

Alberta





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Executive Summary

The object of this report is to demonstrate and assess the economic and environmental potential of various options for wood-based bio-energy in comparison to conventional fossil fuel energy sources in rural, commercial, institutional, and industrial facilities in Alberta.

The report shall assist wood energy stakeholders in establishing and optimizing the contribution of wood-biomass energy in renewable energy targets central to sustainable woodlot management, forestry, waste-wood management, and rural, economic development objectives.

The Key-Messages are:

Wood-based bio-energy is in its infancy in Alberta, and offers rural enterprises a feasible opportunity for economic development that improves their energy efficiency, security, and independence.

Wood-fuel resources from the forest industry, private woodlots, plus industrial/commercial wood residues for heat or heat/electricity co-generation are widely available in Alberta and can be used by communities, commerce, institutions, and industry, thereby increasing the cost-effectiveness of their operations and improving their energy efficiency.

The increased use of wood-based, bio-energy can have a significant contribution to greenhouse gas reduction targets.

Modern, fully automated wood-based energy technology is available, reliable, and affordable.

The Province of Alberta can take the lead in supporting the development of efficient and cost-effective, wood-based, bio-energy by engaging and organizing potential stakeholders, working to remove existing wood energy barriers, and demonstrating the utility of wood heating.

Conclusions

The report draws the following conclusions:

- Well-planned wood-based bio-energy utilization in rural Alberta has significant potential and can generate additional revenue, support, and partly even finance sustainable forest management, improve resource-use efficiency, reduce energy

- costs in industry and communities, improve energy efficiency, offset greenhouse gas emissions from the burning of fossil fuels, and stimulate local, rural development.
- The wood fuel supply for this type of development can be buttressed by:
    - The use of residues currently uncollected from forest-based operations, the wood-processing industry, and end users of the above products.
    - Involving private woodlot owners who treat wood-biomass as a crop.
    - The greater use of woody biomass from outside the forest.
    - The development and expansion of short-rotation, wood-biomass crops.
- The volume and composition of the sustainable wood resource available in Alberta permits the widespread development and use of wood-based bio-energy projects.
- The development of wood resources for bio-energy projects depends on many factors, including:
    - The awareness of resource owners and their willingness to harvest, process, and sell their wood to wood-heating developers.
    - The price that resource owners and processors receive for their wood.
    - The price that consumers pay for wood fuel.
    - The availability and accessibility of the resource, and its proximity to appropriate energy systems.
    - Logistical factors and the energy required to harvest, process, and transport the wood.
    - The development of transparent markets based on reliable and up-to-date information.
- The effectiveness, efficiency, and economics of harvesting, marketing, and energy conversion:
    - One of the most sensitive economic factors in wood-based bio-energy in Alberta is the distance between the wood source and the site of energy generation. The appropriate integration of chipping, pelleting, and similar technologies, can increase energy efficiency and cost-effectiveness in the transportation system.
    - For long-term success, it is essential that the wood-based energy sector be developed in a sustainable way.
    - Based on the assessed resource potential, wood-based bio-energy is well-suited to small and community-scale projects and can increase farm and forest revenue and bolster local, rural economies.
    - A greater understanding of the socio-economic benefits that could be created by developing sustainable wood-residue based, bio-energy generation, combined with energy-saving measures is desirable in Alberta.
    - To encourage the development of wood-based bio-energy in Alberta, to maximize its contribution to sustainable rural development, and the reduction of greenhouse gas emissions; a number of supporting mechanisms should be put in place by the Alberta Government, interested municipalities, the private sector, research and development institutions, and other stakeholders.

Recommendations

The report makes the following recommendations:

- The Alberta Government, with the participation of all stakeholders, should take the lead in the introduction of holistic and inclusive policies and strategies to support the development and implementation of efficient and cost-effective wood-based bio-energy projects in the Province. Specific strategies for the development of woody, biomass-based energy should recognize and encourage all practical participants; and support existing and emerging planning frameworks with the aim of securing sustainable development
- The role of wood-fuels produced in both forest and non-forest areas should be recognized, and treated as an important economic sub-sector worthy of development. Wood energy should be integrated into rural energy supply strategies and pursued as a common task for all relevant sectors, e.g. agriculture, forestry, commercial, institutional, and industrial.
- A wood-based energy sector and wood-fuel supply infrastructure needs to be developed.
- The report revealed several informational shortfalls, which due to the extensive nature of the subject, or the lack of easily available information, require additional study, analysis, and reporting.
- In order to overcome existing gaps in the general understanding of wood fueled energy systems and the related issues, Alberta Agriculture and Food should undertake an expanded series of training initiatives to upgrade the knowledge of government employees, farm operators, and rural non-farm, commercial and industrial managers and ownership of the advantages and processes of wood, heating technology and the economics of using such technology.
- To encourage biomass-energy development, prevailing rules and regulations, which hamper wood, energy development should be reviewed and amended. Policies and practices regulating the energy market in Alberta should avoid contradictory signals and unwanted outcomes, including undue market distortions.
- General standardization and clear regulation of the wood supply industry would enhance the understanding of wood heating input factors and support wood fuel substitutions. Clear definitions on waste categories and permitting conditions can help to overcome barriers for wood-biomass projects based on waste wood.

Introduction

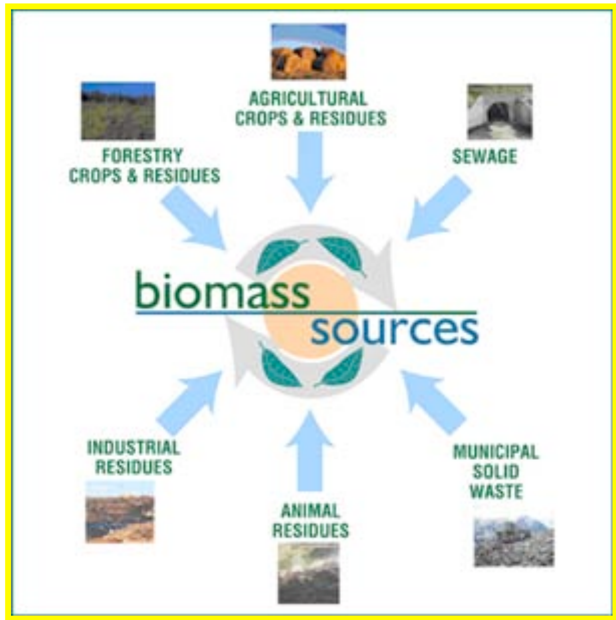
The purpose of this report is to provide information to assist the energy development efforts in the Province of Alberta in assessing "Wood-Biomass" as a viable energy alternative in rural applications in Alberta. The main objective is to investigate the existing parameters for the promotion and adoption of efficient biomass technologies to fire commercial and industrial heating systems at the individual business to network scale.

The declining supply of affordable fossil fuels and growing ecological and geopolitical concerns linked to their utilization has increasingly focused public attention on renewable energy sources, including biomass.

"Biomass" can generally be defined as all organic matter available on a renewable basis, including forest and mill residues, agricultural crops and wastes, wood and wood wastes, livestock operation residues, aquatic plants, fast-growing trees and plants, and municipal and industrial wastes.

In both Europe and North America, the energy production by biomass is clearly dominated by wood and wood bi-products.[1] The utilization of additional renewable raw materials as much as "non-combustion" technologies show a positive tendency, but are often either not yet economical or require further significant research and technological development.

Wood biomass is unique as a prevailing source of high-grade renewable heat, yet wood biomass as a heat source, apart from residential heaters and fireplaces, has barely been initiated in renewable energy development in Alberta despite the fact that heat accounts for over a third of the Province's "primary" energy consumption (see glossary).



Source: Natural Resources Canada Website

The international experience over the last forty years, particularly in Europe, has demonstrated the large potential of biomass, not just as a reliable renewable energy source, but also as a growth engine for overall sustainable development of rural areas.

> Fifty years ago, about half of all Albertans lived in rural communities. Today, the percentage has dropped to below 20%. Alberta's cities are growing rapidly while many rural communities are facing declining populations and uncertain futures. Much of the province's economic growth has occurred in the cities and along the Highway 2 corridor between Edmonton and Calgary. Rural communities have

struggled to preserve their own local businesses, attract highly skilled professionals, and create opportunities for young people to stay in smaller communities without having to leave to build their futures.[2]

Potential stakeholders attracted to a renewable energy initiative will find a variety of practical, economical, and ecological arguments supporting their individual projects. It needs to be understood, nevertheless, that in any given scenario the project size defines its economical and environmental impact. Several positive aspects of wood energy projects need to be considered:

Considerations for Communities and Municipalities

One of the main objectives of communities and municipalities is local or regional economical development. Environmental considerations have also become an issue of growing significance.

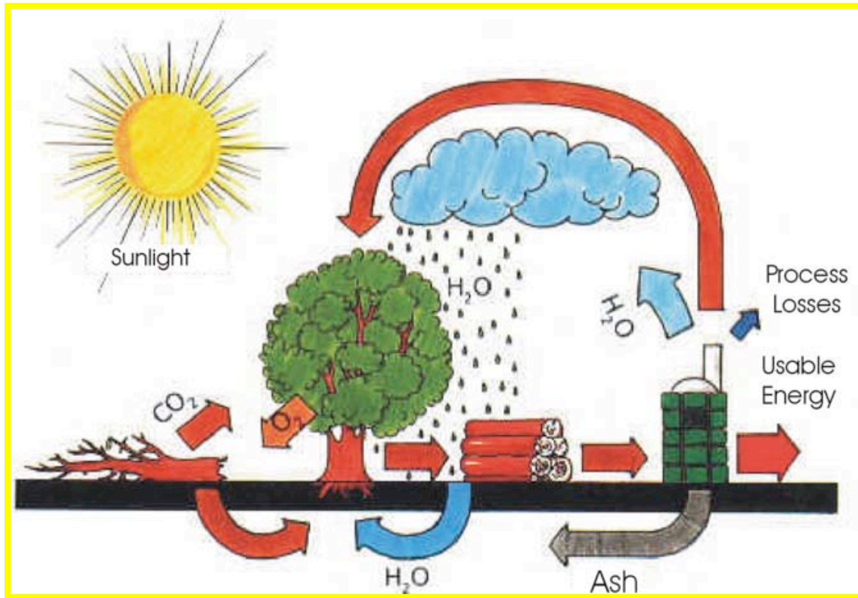
The utilization of biomass gives rural communities an opportunity to create new jobs in the region. Local companies and personnel can provide the goods and services required for both the construction and operation of biomass heating systems. Local craftsmen usually provide the construction of any biomass heating system, including boiler rooms, fuel storage facilities, and heat-distribution systems. Depending on the size of the individual system, both operation and maintenance are long-term services, again to be secured by local providers. Therefore, a high percentage of the initial investment, plus the fuel supply and other operational costs will likely stay in the local community and contribute to local or regional economic development.

Furthermore, there is the opportunity to integrate waste-wood products from various industrial and commercial operations into the energy production cycle. Beside the general opportunity to save on waste disposal costs the community can decrease its landfill capacity requirements. For instance the wood biomass waste from pruning and maintaining public green spaces can be used as a cheap additional fuel supply. These economic opportunities will be enhanced through accommodating the growing public demand for a reliable and affordable energy supply. By utilizing local waste-wood biomass sources the community can actively take charge of its individual energy solutions and start to reduce its dependency on declining fossil fuel resources and correspondingly increasing oil and gas prices.

Contrary to the clearly noticeable changes in the fossil fuel market, there is a lower risk of significant price increases for wood biomass, due to the significant under developed and under utilized wood biomass resource in Alberta. Standard rules of supply and demand economics apply here. As long as supply exceeds demand prices will remain low, and near the break-even point for wood biomass producers, and at the tipping fee, plus transportation cost level for waste-wood.

Concerted effort towards a renewable, decentralized energy supply can also enhance the feeling of community, by being part of a progressive and supportive society. In addition to these considerations, the positive environmental impact of wood, biomass energy systems is a strong argument in support of such projects. Generally there are two ways to reduce emissions that have been identified to have a global environmental influence. The first step is a general reduction of energy consumption through implementing energy conservation and efficiency strategies, driven by strong energy management practices. The second measure is the use of renewable energy sources to replace fossil fuel combustion wherever possible and feasible.

If biomass is burned efficiently, including wood, it is generally defined to be a "CO_2 neutral" energy source.[1] The natural growth cycle of all plants, including trees, fixes environmentally available CO_2 within their cellular structure. When woody plants are burned, the recently stored carbon is released back into the “active” environment. This simply recycles the environmentally “active” carbon, as opposed to burning fossil fuels that release carbon that has been fixed for hundreds of centuries.



Source: Harald H. Welling

Additional CO_2 emissions are created as part of the fuel supply chain when the wood is processed and hauled to the biomass system. A decisive argument supporting community biomass energy development is the significant reduction in greenhouse gas emissions. The following table indicates the differences in CO_2 emissions between fossil and renewable energy sources.

Fuel	Heat Content (Btu/lb)	Heat Content (MJ/kg)	Carbon Content (kg-C/kg)	Fossil Carbon Intensity (lb-C/MBtu)	Fossil Carbon Intensity (kg-C/MJ)
Coal	13,700	31.798	0.78	56.9	24.5
Oil	18,000	41.778	0.85	47.2	20.3
Natural Gas	23,800	55.240	0.76	31.9	13.8
Wood (dry)	8,000	18.568	0.45	Zero*	Zero*

*Note: “Fossil” carbon intensity is the measure relevant to greenhouse gas and by this measure wood from renewable growth of trees is zero in carbon intensity. If the carbon in the fuel is put straight into the same formula used for fossil fuels, ignoring the greenhouse gas addition there, the natural carbon intensity for the wood is 54.2 lb-C/MBtu or 23.4 kg-C/MJ.

Source: GEMIS (Global Emission Model for Integrated Systems) 2006.[3]

The Health Benefits of Renewable Energy

The emissions from the fossil fuels used for electricity and heating that have the greatest impact on human health are nitrogen oxides (NO_x), sulphur dioxide (SO_2), and particulate matter (PM). Recent studies indicate that approximately 1 out of every 13 non-traumatic deaths occurring in Canadian cities can be attributed to air pollution from the burning of fossil fuels.[4] This results in enormous costs to Canadians and the Canadian health-care system.

A 1997 report compiled for the National Air Issues Coordinating Committee estimates that reducing SO_2 emissions by 50% in eastern Canada (approximately 1 million tonnes) would avoid 950 premature deaths, 1,530 emergency room visits, and 209,350 asthma symptom-days. Economists estimate the value of these avoided health costs to be between $1 and $7 billion per year.[5] Although the population in Western Canada is considerably less, and the intensity of the stated emissions are also considerably lower, the point is relative in specific industrialized areas of Alberta.

Similarly, a 1995 study carried out for the U.S. Environmental Protection Agency estimates that if the U.S. achieved its Clean Air Act target of reducing 10 million tonnes of SO_2 by 2010, the annual savings in health-care costs would be between $12 and $78 billion.[6]

If implemented, the measures identified in the Canadian paper will reduce emissions of both NO_x and SO_2 by approximately 20,000 tonnes. The ratio of CO_2 emissions to SO_2 and NO_x is on average roughly 1000 to 2 based on the emission coefficients from Alberta based coal-fired and natural gas thermal electricity plants.[7]

Although the resulting health-care savings are difficult to quantify, the studies cited above suggest that they could total between $20 and $140 million per year.

The avoided SO_2 emissions as a result of the proposed measures would likely be more dispersed than in the studies quoted. However, the health care savings as a result of reductions in other potentially harmful pollutants (NOx and PM) have not been included in the analysis, nor have the health benefits as a result of the emission reductions caused by an increased use of biofuels.

The Employment Benefits of Renewable Energy

Largely due to the staffing short falls of urban businesses, the energy production sector in oil sands development, and along the Edmonton to Calgary corridor, rural Alberta has generally been stripped of its one time surplus of employable individuals. This has caused declining populations in many smaller rural centers, making it difficult for these communities so support educational, recreational, social, and economic facilities. This in turn makes it progressively more difficult for individuals wanting to find employment within their local community. Finding work away from "home" is relatively easy in Alberta's heated economy, but this requires relocation or commuting to regional job sites.

Renewable energy development can create employment at the local level. In a 1997 study for Environment Canada, the Pembina Institute found that investment in energy efficiency and renewable energy produce substantially higher levels of employment than equivalent levels of investment in conventional energy supply.[8] The report found that for every million dollars invested, an average of 36.3 jobs are created in the energy efficiency sector or 12.2 in the renewable energy sector. For every million dollars invested in conventional energy, an average of only 7.3 jobs are generally created locally.

According to the Pembina report, the main reasons for the higher employment levels are the relative labour intensity of the work and the jobs created from the re-spending of energy savings. Another advantage lies in the type of jobs created. Renewable energy and energy efficiency investments result in jobs that have broad regional distribution, are ongoing in nature, and involve modest employee relocation, which as mentioned previously is very important in many rural communities. The report also found that moderate levels of government investment in energy efficiency and renewable energy can leverage significant private investment. On average, every million dollars of government spending was found to result in six million dollars of private sector spending.

Considerations for energy users

The primary consideration for the energy user must be the lower initial energy price, not just in comparison to the current prices for fossil fuels, but also long-term price stability. If connected to a biomass fired heating network the user can rely on a stable and less expensive energy supply. Biomass boilers usually run with sufficient back up systems that can be fired with fossil fuels. Back up boilers cover excessive peak heating demand, in particularly cold weather phases, and secure the energy supply during maintenance shut-downs.

While fossil fuel costs are constantly increasing and highly vulnerable to a vast variety of international market influences the use of local wood biomass tends to produce reliable, price stability. In Europe the wood fuel supply is further secured by long-term contracts with local or regional producers.

It needs to be stressed that the maintenance processes associated with the operations of buildings connected to a biomass, heating network become clearly more convenient and cost effective for the participant. Regular maintenance and repair activity is conducted by the central system operator at the heat generation end of the operation with no routine maintenance operations required by the energy user. With no heating equipment installed in the users premises, other than piping and valves, there is little maintenance activity needed.

In many cases a combination of high-energy consumption and wood or waste-wood availability in private enterprises and industries support individual biomass energy conversions. A number of different commercial operations, not just in forestry related industries, are dealing with increasing waste-wood issues as a cost factor on a daily basis. The problems range from waste-wood as production leftovers, for instance in furniture production, to woody packing and transport material, plus shipping pallets in numerous economic sectors. Converting the heat requirements of such enterprises to wood biomass gives the business the opportunity of a double advantage. While significantly reducing regular energy costs, often not supported by government price-capping subsidies, the costs of wood waste disposal are turned into a revenue stream.

Considerations for Wood Fuel Suppliers

Large parts of Alberta's forest industry processes wood in a variety of wood product manufacturing operations. Industrially not usable forest components usually stay in the forest, while further waste wood on the production site is only partly introduced into the energy supply cycle as electricity production only, without utilizing the clearly higher thermal energy output.

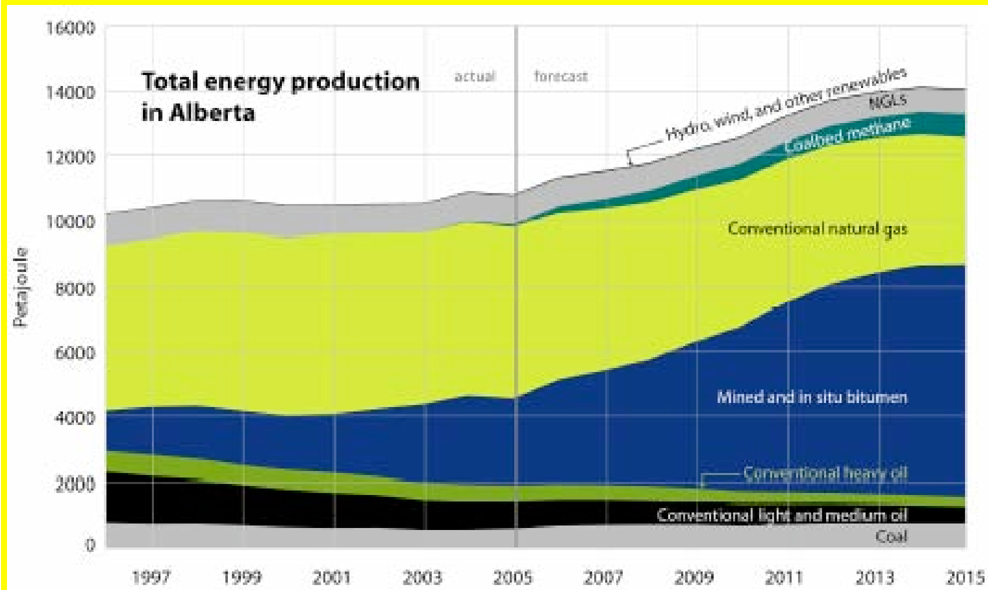
All unused waste wood components can be converted into wood chips and hog-fuel as part of a larger wood fuel supply infrastructure. This would create new jobs and economic revenue in primary and secondary forest industry. Primary and secondary forest industries have the opportunity to become wood fuel suppliers.

Private woodlot owners get the opportunity to turn their wood stand into a marketable crop. Being part of an energy supply infrastructure would make it feasible for wood-lot owners to "farm" their woodlots in a sustainable way.

Alberta Energy Use

Energy Production in Alberta

The graphic below indicates the total energy produced, but not necessarily used, in Alberta since 1996, and projected to 2014.[9] Of considerable importance to this report, is the narrow black line indicating "renewables" in total, with no mention of wood fuel production. This is indicative of the huge potential for renewable, energy substitution for fossil fuel, and the potential market for wood fuel, if developed appropriately now and in the future. The prices of two common fuel sources, coal and wood, have remained relatively stable for a considerable length of time. If the cost of other fuel continues to rise much faster than, or perhaps even driving the inflation rate, the wood fuel market will remain open to development.



Source: Alberta Energy and Utilities Board[9]

Energy Use By Sector

In order to understand the potential benefit of substituting biomass, renewable energy for fossil fuels, and in particular, wood in its many available forms, we must first gain an understanding of the energy demands in Alberta. Natural Resources Canada, Office of Energy Efficiency, breaks the energy used in Alberta down into six sectors: [10]

- Industrial
- Commercial/Institutional
- Electricity Generation
- Agricultural
- Transportation
- Residential

Data from the above-mentioned source, illustrate the energy used by two of the sectors selected for this study.

Industrial Sector

The industrial, secondary user, also known as the "end-user" of the various energy sources in Alberta will be reviewed. This does not include the energy production-stream users. For example, electric power plants in Alberta are the heaviest users of coal but are not included in the following two tables. Electricity "generation" is considered primary energy use. Nevertheless, the industrial end-users of electricity make up 111.2 PJ (petajoules) or 14.2 percent of the total of 782.1 PJ of energy used by the industrial sector in Alberta in 2004.

A petajoule (PJ) equals 1 x 10^{15} joules, or perhaps to use terms that we are more familiar with, 1,000,000 GJ. The average new home in the Calgary area uses 90 GJ annually for heating. In other words, one PJ would heat over 11,111 newer residences.

Table 1, below, shows that natural gas (NG) is the largest energy source of the aggregated industrial users at 371.0 PJ or 47.4 percent of the 782.1 PJ total. Selected industrial processes utilize still gas or petroleum coke as an energy source which totals 22.9 percent of the energy use total in Alberta. However, the purpose of this work is to understand energy demand and seek out potential opportunities for the economic and technological substitution of wood fuel. However, it must be remembered that wood cannot be substituted economically or technologically for all NG used in the Industrial sector. A large volume is used for purposes other than heating.

Greenhouse gas (GHG) emissions can in certain cases become a high impact decision-making factor when considering the substitution of wood fuel for fossil fuel due to the fact that CO_2 produced by wood energy is generally considered CO_2 neutral. The yet to be resolved Federal Government GHG standards may also have a significant impact on decision making in this area.

Natural gas, although considered to be clean burning, nonetheless, produces 53.6 percent of the GHG emitted by this sector. This is followed by still gas or petroleum coke with 33.7 percent of total GHG emissions.

Table 1: Alberta* Industrial Sector – Aggregated Industries

Secondary Energy Use

	2004
Total Energy Use (PJ)	**782.1**
Energy Use by Energy Source (PJ)	
Electricity	111.2
Natural Gas	371.0
Diesel Fuel Oil, Light Fuel Oil and Kerosene	36.2
Heavy Fuel Oil	0.1
Still Gas and Petroleum Coke	179.4
LPG and Gas Plant NGL	17.0
Coal	5.8
Coke and Coke Oven Gas	0.0
Wood Waste and Pulping Liquor	52.5
Other**	8.9

Share (%)	
Electricity	14.2
Natural Gas	47.4
Diesel Fuel Oil, Light Fuel Oil and Kerosene	4.6
Heavy Fuel Oil	0.0
Still Gas and Petroleum Coke	22.9
LPG and Gas Plant NGL	2.2
Coal	0.7
Coke and Coke Oven Gas	0.0
Wood Waste and Pulping Liquor	6.7
Other**	1.1
Activity	
GDP (million $97)	47,208
Energy Intensity (MJ/$97 – GDP)	**16.6**

** “Other” includes steam and waste fuels from the cement industry.

GHG Emissions by Energy Source*

	2004
Total GHG Emissions Excluding Electricity (Mt of CO_2e)	**34.4**
GHG Emissions by Energy Source (Mt of CO_2e)	
Electricity	–
Natural Gas	18.5
Diesel Fuel Oil, Light Fuel Oil and Kerosene	2.9
Heavy Fuel Oil	0.0
Still Gas and Petroleum Coke	11.6
LPG and Gas Plant NGL	1.0
Coal	0.4
Coke and Coke Oven Gas	0.0
Wood Waste and Pulping Liquor	0.0
Other**	0.0
Share (%)	
Electricity	–
Natural Gas	53.6
Diesel Fuel Oil, Light Fuel Oil and Kerosene	8.4
Heavy Fuel Oil	0.0
Still Gas and Petroleum Coke	33.7
LPG and Gas Plant NGL	3.0
Coal	1.2
Coke and Coke Oven Gas	0.0
Wood Waste and Pulping Liquor	0.0

Other**	0.0
GHG Intensity (tonne/TJ)	**44.0**

* Data on GHG emissions are presented excluding GHG emissions related to electricity production.

** "Other" includes steam and waste fuels from the cement industry.

Source: Adapted from Natural Resources Canada data.[10]

Unfortunately, although the tables for the Industrial Sector are comprehensive, generally, the published information does not break out the end-use of the energy, for example: space heating, water heating, and other uses. Therefore from this data, base, it is difficult to accurately determine the substitution potential for wood energy sources. Nevertheless, it is substantial, although indications are that it would be somewhat less than the 70.4 % shown for space and water heating by the Commercial/Institutional Sector due to the process heat and feedstock uses for NG by industry. This informational gap underscores the need to diligently gather, up-to-date, accurate information before committing to any alternate energy project.

Commercial/Institutional Sector

Unlike the Industrial Sector data cited above, the Commercial/Institutional Sector data-bases of Natural Resources Canada do provide end-use data for our consideration. Upon reviewing the commercial and institutional sector, illustrated in Table 2 below, we discover that NG is again the energy source of choice with 110.2 PJ used out of a total of 170.4 PJ. That amounts to 64.7 percent of the total energy used and 90.2 percent of the GHG emitted by this sector.

Table 2: Alberta* Commercial/Institutional Sector

Secondary Energy Use

	2004
Total Energy Use (PJ)	**170.4**
Energy Use by Energy Source (PJ)	
Electricity	50.5
Natural Gas	110.2
Light Fuel Oil and Kerosene	0.1
Heavy Fuel Oil	1.9
Steam	0.1
Other**	7.6
Shares (%)	
Electricity	29.6
Natural Gas	64.7
Light Fuel Oil and Kerosene	0.1
Heavy Fuel Oil	1.1

Steam	0.0
Other**	4.4
Activity	
Total Floor Space (million m^2)	83.5
Energy Intensity* (GJ/m^2)**	**2.03**
GHG Emissions by Energy Source	
Total GHG Emissions Excluding Electricity (Mt of CO_2e)	6.1
GHG Emissions by Energy Source (Mt of CO_2e)	
Electricity	–
Natural Gas	5.5
Light Fuel Oil and Kerosene	0.0
Heavy Fuel Oil	0.1
Steam	0.0
Other**	0.5
GHG Intensity (tonne/TJ)	35.8
Heating Degree-Day Index	0.91
Cooling Degree-Day Index	1.07

* Data on GHG emissions are presented excluding GHG emissions related to electricity generation.

** "Other" includes coal and propane.

*** Excludes street lighting.

Source: Adapted from Natural Resources Canada data.[10]

It is not enough to understand what the sources of fuel are that run the Province of Alberta. In order to grasp the opportunities for wood fuel to be substituted for other fuels, the end use of the various sources must be also reviewed.

Table 3: Alberta* Secondary Energy Use and GHG Emissions by End-Use

	2004
Total Energy Use (PJ)	**170.4**
Energy Use by End-Use (PJ)	
Space Heating	103.9
Water Heating	16.0
Auxiliary Equipment	17.7
Auxiliary Motors	13.0
Lighting	15.3
Space Cooling	3.7

Street Lighting	0.8
Share (%)	
Space Heating	61.0
Water Heating	9.4
Auxiliary Equipment	10.4
Auxiliary Motors	7.6
Lighting	9.0
Space Cooling	2.2
Street Lighting	0.5
Activity	
Total Floor Space (million m^2)	83.5
Energy Intensity2 (GJ/m^2)	2.03
Total GHG Emissions Excluding Electricity (Mt of CO2e)**	6.1
GHG Emissions by End-Use (Mt of CO2e)	
Space Heating	5.2
Water Heating	0.8
Auxiliary Equipment	0.1
Auxiliary Motors	0.0
Lighting	0.0
Space Cooling	0.0
Street Lighting	0.0
GHG Intensity (tonne/TJ)	**35.8**
Heating Degree-Day Index	**0.91**
Cooling Degree-Day Index	**1.07**

* Data on GHG emissions are presented excluding GHG emissions related to electricity production.

** Excludes street lighting.

Source: Adapted from Natural Resources Canada data.[10]

Table 3 indicates that in Alberta, 103.9 PJ of energy is used for space heating, plus 16.0 PJ for water heating, totaling 119.9 PJ out of a total of 170.4 PJ or 70.4 % of the energy used in this sector. NG is the current fuel of choice for those purposes in Alberta. In fact, a long history of convenient, efficient, and inexpensive NG virtually guaranteed such a choice. Currently, when we add the minimal use of renewables and other heating fuels in Alberta (heating oil and propane), plus electricity used for heating to the equation, the opportunity for wood biomass substitution is demonstrated to be massive.

Wood Biomass Substitution

The above numbers, 371.0 PJ of natural gas for the Industrial Sector with an assumption of at least half (185.5 PJ) being used for space and water heating, and without the energy used from other fuels for this purpose being known, the substitution potential for wood heating appears great. The potential for process heat being supplied by wood in the Industrial Sector can only add to this number. Additionally, in the Commercial/Institutional Sector, the total of 119.0 PJ used for space and water heating also indicates a huge untapped potential for wood biomass heating in Alberta. This is on the basis of straight substitution. Technological, and economic feasibility must also be explored.

Other Sectors

Although the Electricity, Residential, and Agricultural Sectors present a considerable opportunity for wood heating, they are not defined as part of this analysis. It suggests that a subsequent review of these sectors would be prudent.

On the other hand, the remaining Transportation Sector presents no current opportunity for wood burning applications. Although wood gasification technologies may evolve to produce usable transportation fuel, that is not in the near future.

Additionally, no rural versus urban energy use data was determined by the authors. Therefore, Alberta Agriculture and Food, the wood industry, and wood energy developers must apply the rural focus.

Alberta Wood Resource

Alberta Forestland Resource

Table 4 provides a rough estimate of Alberta forestland. The source is a somewhat dated document from the Alberta Agriculture and Food Website (September, 2003, which quotes estimates from the National Forestry Database Program, 2002), indicates that Alberta's Forestland approximates 38,406,000 hectares.[11]

Table 4: Ownership of Forestland in Alberta

Owner	Area (Ha)
Provincially owned	32,974,000
Federally owned	3,441,000
Privately owned	1,718,886
Other	272,000
Total Forestland	**38,405,886**

This indicates a starting point for determining the wood heating potential in Alberta. However, it is simply the starting point, as the volume of wood available from sectors within the resource, areas within the province, and the sustainability of its use are significant unknowns. Nevertheless, if careful assumptions are made and reasonably accurate answers are gained from knowledgeable sources the gap between fact and loose speculation can be closed somewhat.

Table 5 indicates the annual harvesting history of provincially and privately owned forestland in cubic meters. We see that the annual harvest has moved from 11,645,085 cubic meters in 1990 to as high as 24,529,465 cubic meters in 2002 and dropped back to 23,445,425 cubic meters in 2004. This table in itself is not of much value in an attempt to understand energy potential until we convert cubic meters to tonnes and then tonnes to GJ

Table 5: Volume of Harvested Wood by Ownership Category, and Species group 1990-2004 (net mechantable cubic meters)

Year	Softwood			Hardwood			Total		
	Provincial	Private	Total	Provincial	Private	Total	Provincial	Private	Total
1990	9,326,603	N/A	9,326,603	2,318,482	N/A	2,318,482	11,645,085	N/A	11,645,085
1991	9,720,830	436,000	10,156,830	2,172,944	556,000	2,728,944	11,893,774	992,000	12,885,774
1992	10,789,108	661,200	11,450,308	2,627,685	366,300	2,993,985	13,416,793	1,027,500	14,444,293
1993	9,605,382	1,069,900	10,675,282	3,489,070	664,200	4,153,270	13,094,452	1,734,100	14,828,552
1994	10,536,125	2,577,982	13,114,107	4,586,699	1,602,640	6,189,339	15,122,824	4,180,622	19,303,446
1995	12,449,921	1,494,274	13,944,195	4,528,848	1,674,972	6,203,820	16,978,769	3,169,246	20,148,015
1996	12,213,852	551,550	12,765,402	5,549,844	1,715,528	7,265,372	17,763,696	2,267,078	20,030,774
1997	13,169,608	1,183,848	14,353,456	5,864,876	1,970,143	7,835,019	19,034,484	3,153,991	22,188,475
1998	9,668,533	397,850	10,066,383	5,511,141	1,583,939	7,095,080	15,179,674	1,981,789	17,161,463
1999	14,907,827	371,865	15,279,692	6,760,995	1,688,152	8,449,147	21,668,822	2,060,017	23,728,839
2000	13,959,809	277,730	14,237,539	7,548,636	1,632,090	9,180,726	21,508,445	1,909,820	23,418,265
2001	14,169,146	403,669	14,572,815	7,299,344	1,602,236	8,901,580	21,468,490	2,005,905	23,474,395
2002	14,861,519	247,307	15,108,826	7,551,101	1,869,538	9,420,639	22,412,620	2,116,845	24,529,465
2003	14,699,075	286,553	14,985,628	7,157,829	2,020,622	9,178,451	21,856,904	2,307,175	24,164,079
2004	13,913,093	311,326	14,224,419	6,978,353	2,242,653	9,221,006	20,891,446	2,553,979	23,445,425

Source: Alberta Agriculture and Food, Woodlot Program[12]

Table 6 converts the harvested cubic meters to GJ with an assumed chipped heating value of 15 GJ/tonne for the 2004 harvest.

Table 6: Alberta Harvested Wood in GJ, 2004

Ownership	SW (M^3)	Tonnes (Range)		GJ (Range) @ 15 GJ/t	
		From	To	From	To
Provincial	13,913,093	11,408,736	12,104,391	171,131,044	181,565,864
Private	311,326	255,287	270,854	3,829,310	4,062,804
Total	14,224,419	11,664,024	12,375,245	174,960,354	185,628,668

Ownership	HW (M^3)	Tonnes (Range)		GJ (Range) @ 15 GJ/t	
		From	To	From	To
Provincial	6,978,353	6,280,518	7,676,188	94,207,766	115,142,825
Private	2,242,653	2,018,388	2,466,918	30,275,816	37,003,775
Total	9,221,006	8,298,905	10,143,107	124,483,581	152,146,599

Ownership	Total (M^3)	Total Tonnes (Range)		GJ (Range) @ 15 GJ/t	
		From	To	From	To
Provincial	20,891,446	17,689,254	19,780,579	265,338,809	296,708,688
Private	2,553,979	2,273,675	2,737,772	34,105,125	41,066,579
Total	23,445,425	19,962,929	22,518,351	299,443,935	337,775,267

Source: Alberta Agriculture and Food, Woodlot Program[12]

The GJ value of Alberta's wood harvest totaled between 299,443,935 and 337,775,267 GJ or 299.4 – 337.8 PJ. It must be remembered that this was the merchantable total, which indicates that it was all, more or less, sold for purposes other than energy production. Nevertheless, this situation embodies two potential sources of wood for heating:

- Logging waste wood – currently left in the forest
- The competitive sale of logged wood for heating purposes

The logged wood represents the quality wood taken from the forest for lumber and/or the pulp and paper industry. The cost of this wood source when added to the cost of processing, transportation, storage, marketing, plus a profit margin may make it an uneconomical fuel source in some locations at this time. However, logging wastewood offers a different picture. Table 7 indicates that the heating resource potential from this source, assuming a 19.5 GJ/t rate (generally accepted as the heating rate for oven-dry wood), totals approximately 113,569,950 GJ or 113.6 PJ.

Table 7: Annual Logging Wastewood

Source	Oven Dry Tonnes	GJ@19.5GJ/t
Logging Residues*	3,500,000	68,250,000
Low Quality Trees**	1,100,000	21,450,000
Stumps***	0.0	0.0
Deads or Dieing****	500,000	9,750,000
Mill Processing Residues*****	724,100	14,119,950
Total	**5,824,100**	**113,569,950**

* Tops and branches
** Varies from 1,100,000 - 1,770,000 (10-15% of total harvested volume). Accessibility problems a concern.
*** Not harvested in Alberta; but virtually always harvested in Europe.
**** 1,000,000t, Insects/disease/wildfires - currently 50% unharvested.
***** Bark and Sawdust currently unused.

Source: Natural Resources Canada, Edmonton[13]

Farm Woodlots/Woodlands

The following Table represents the wooded areas of Alberta municipalities with subdivided farmland, by Hectares of primarily Aspen, various conifers, and mixed stands composed of Aspen, coniferous, and other species. Not all Alberta municipalities have been analyzed, and only wooded areas amounting to 8 Hectares or greater are included. Therefore, the actual wood resource from this source is greater to an unknown degree.

Table 8: Alberta Woodlot Inventory

Municipality	Ha Mixed	Ha Aspen	Ha S. Wood	Total
Central AB				
Athabasca County No. 12	21,706.52	64,109.51	6,347,079.00	6,432,895.03
Barrhead County No. 11	3,676.49	31,489.37	0.00	35,165.86
Beaver County No. 9	46.51	7,329.07	0.00	7,375.58
Bighorn County No. 8	13,256.07	9,738.52	56,059.23	79,053.82
Bonnyville County No. 87	12,632.94	129,143.46	19,621.16	161,397.56
Brazeau County No. 77	18,283.13	47,804.79	26,380.54	92,468.46
Camrose County No. 22	313.64	9,673.20	0.00	9,986.84
Clearwater County No. 99	32,637.80	37,188.09	32,932.33	102,758.22
Foothills County No. 31	2,297.50	10,327.12	5,116.82	17,741.44
Kananaskis ID 5	156.02	306.10	7,330.53	7,792.65
Kneehill County No. 48	152.48	711.05	0.00	863.53
Lac St. Anne County No. 28	5,588.89	57,957.71	0.00	63,546.60
Lacombe County No. 14	3,410.87	20,953.40	206.32	24,570.59
Lakeland County	3,375.64	44,459.65	5,899.52	53,734.81
Lamont County No. 30	2,293.87	9,395.77	0.00	11,689.64
Leduc County No. 25	4,238.08	27,286.62	0.00	31,524.70
M.D. of Woodlands No. 15	7,020.20	25,314.18	0.00	32,334.38
M.D. of Yellowhead No. 94	33,017.23	58,197.15	0.00	91,214.38

Minburn County No. 27	20.17	13,501.97	0.00	13,522.14
Mountain View County No. 17	17,623.41	28,612.24	7,728.79	53,964.44
Parkland County No. 31	5,682.17	40,877.52	10,301.63	56,861.32
Ponoka County No. 3	8,765.42	29,520.23	5,089.81	43,375.46
Red Deer County No. 23	8,566.76	21,638.52	1,190.97	31,396.25
Rocky View MD 44	5,151.20	10,003.19	8,753.87	23,908.26
Smoky Lake County No. 13	6,947.07	70,258.35	28,031.80	105,237.22
St. Paul County No. 19	5,001.28	63,698.69	8,445.55	77,145.52
Starland County No. 47	0.00	34.62	0.00	34.62
Stettler County No. 6	1,152.73	13,252.35	0.00	14,405.08
Strathcona County No. 20	1,612.09	10,603.48	0.00	12,215.57
Sturgeon County No. 90	2,464.06	5,353.57	0.00	7,817.63
Thorhild County No. 7	4,284.79	22,609.49	0.00	26,894.28
Two Hills County No. 21	2,162.39	18,248.80	0.00	20,411.19
Vermilion River County No. 24	273.03	12,732.94	0.00	13,005.97
Westlock County No. 92	4,956.32	15,697.80	0.00	20,654.12
Wetaskiwin County no. 10	11,765.51	39,845.97	115,112.30	166,723.78
Total	**251,340.81**	**1,011,784.82**	**455,760.62**	**1,718,886.25**

Source: Alberta Agriculture and Food, Woodlot Program[12]

The above municipal totals, plus the overall resource total are relatively accurate numbers in terms of land area. However, this provides us with little indication of the volume of wood per hectare. When specialists from Alberta Agriculture and Food were addressed this question they advised that "natural woodstands" in the inventory area yielded approximately 40 - 80 tonnes/acre or 98.8 – 197.6 tonnes/ha. The total wood resource would therefore be approximately 169,825,957 – 339,651,913 green tonnes and using a heating value of 15 GJ/t (assumed heating value of processed, and properly stored wood chips), the energy totals between 2,547,389,355 – 5,094,778,695 GJ or 2,547.4 – 5,094.8 PJ. The total heating value, of course, bears no relationship to the sustainable heating value. Knowing the heating value of the total standing wood resource in any category of supply is simply a starting point. Since privately owned woodstands can be used with little restriction although increasingly subject to municipal development regulation, the sustainable harvest or sustainable heating value remains an unknown factor. Nevertheless, Alberta's wood resource is huge. Currently, the opportunity to substitute wood for other heating fuels is massive, and the availability of potential wood supply outstrips the ability of the wood heating industry to penetrate the market.

Species Variation

Although there is a weight and heating value variation between species of green wood (birch vs. poplar for example) there is also a variation between categories (hardwood vs. softwood or poplar vs. spruce). Nevertheless, the heating value of oven-dry (also bone-dry) tonnes is in effect the same. The volume per tonne of wood does continue to vary and therefore species enters the equation again when calculating the fuel storage capacity required for wood fired heating units.

Construction, Renovation, and Demolition Waste

Alberta Environment advises that waste from construction, demolition, and renovation (CRD) amounts to approximately one million tones per year with about half of it ending up in landfills. Diverting the wood component of this source can be an inexpensive source of fuel, but also has a positive effect on the environment.

Source: Alberta CRD Waste Reduction Advisory Committee, Alberta Environment.[14]

Of the 27% of the total waste stream, or 1,000,000 tonnes annually, CRD waste is composed of 28% waste-wood, or 280,000 tonnes. If we assume it to be of the standard chipped wood heating value of 15 GJ/t it would total 4,200,000 GJ or 4.2 PJ. In terms of substitution of wood for other fuels in Alberta, this would have a small impact.

Source: Alberta CRD Waste Reduction Advisory Committee, Alberta Environment.[14]

Unless medium to long-term contractual arrangements are made with a landfill, or major construction or demolition company, this is not a reliable source of fuel. Nevertheless, it does constitute an emergency fuel source or if part of a management function, staff can be directed to capture the wood at the construction, renovation, and demolition sources.

Heating Values of Fossil and Biomass Fuel Sources

Table 5, below illustrates the wide variation, not only between fossil and renewable fuels, but also within each fuel category. Generally, there is less usable energy within the renewable energy category, but when available supply, price stability, and the environmental impact factors are considered, it can become a desirable alternative.

With respect to wood biomass, CRD material generally ranges from kiln dry (0% moisture) to dry (up to 20% moisture), but various tree species plus the moisture content of the natural wood source produces notable differences in heating value. Wood is generally considered "burnably dry" at 35% moisture, but the heating value decreases as the moisture content increases.

Table 9: Comparison of Various Fuels Lower heating Values (LHV)

Fuel	**Lower Heating Value**	
	BTU/lb	**GJ/t**
Natural Gas	22,865	53.18
Propane	19,940	46.37
Gasoline	18,831	43.80
Diesel #2	18,401	42.80
Biodiesel	16,251	37.80
Fuel Oil #1	15,910	37.00
Ethanol	11,479	26.70
Coal (Bituminous)	10,318	24.00
Coal (Sub-Bituminous)	9,000	20.93
Flax straw (dry)	8,587	19.97
Wood Pellets	8,512	19.80
Wheat straw (dry)	7,680	17.86
Corn stover (dry)*	7,540	17.50
Shelled corn (15%	7,000	16.20
Flax straw (20% moisture)	6,635	15.43
Wood (15% moisture)	6,450	15.00
Wheat Straw (20% moisture)	5,908	13.74
Biogas	7,159	17.25

*PAMI Research Update #719, 1995.

**OMAFRA Agdex #111.768, 1997.

Source: GHG Bulletin Number 9, AAFRD.[15]

Whenever new, renovation, or upgrading energy projects are under consideration, the full spectrum of energy technology and fuel options should be explored – life-cycle, cost analysis with all known values included and estimated values noted and ranges of outcomes determined. The cost of fuel is the most important operational cost factor whether the project is using renewable or fossil fuel energy.

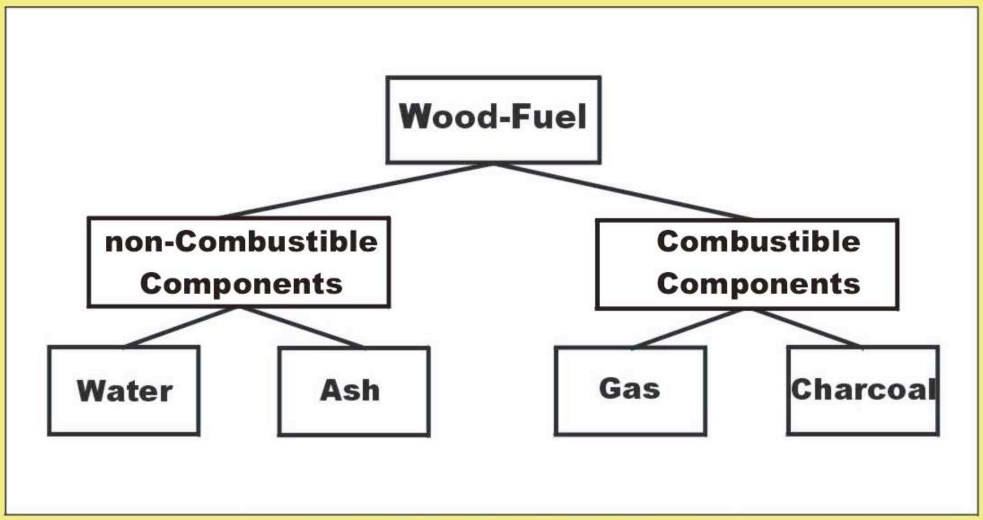
Wood Resource Utilization

Wood-Burning Technology

The Modern Wood-Burning Process

In order to get a better understanding of the above outlined impact of the technologies described below, it is necessary to elucidate the principles of modern wood-burning processes.[16]

Solid fuels contain both combustible and non-combustible components. The non-combustible components are basically ash and water. One major difference between wood and coal for instance is the higher volatile and lower ash content in wood. The moisture content of wood (water) is variable. While freshly harvested wood has moisture content of between 40-50%, air-drying for a period of two to three years reduces the moisture content to between 15-20%.



Schematic Consistence of Wood-Fuel

Source: Harald H. Welling

Efficient and complete combustion is a prerequisite of utilizing wood as an environmentally desirable fuel. In addition to a high rate of energy utilization, the combustion process should therefore ensure the complete destruction of the wood and avoid the formation of environmentally undesirable compounds.

In order for combustion to continue efficiently, there are certain basic conditions that should be met:

- An adequate mixture of fuel and oxygen (air) in a controlled ratio must be ensured.
- The fire already started in the boiler/furnace should transfer some of its heat to the in-feed assembly in order to ensure a continuous combustion process.

It is important to understand that gases burn with flames, that solid particles glow, and that during the combustion of wood, approximately 80% of the energy is released from combustible gas and the remaining portion from the charcoal. During mixing of the fuel and air, it is important to achieve good contact between the oxygen and the combustible constituents of the wood. The better that contact is, the faster and more complete is the combustion. If the fuel is in the form of gas, such as natural gas, the mixing is optimal, since we have two gaseous substances that can be mixed to exactly the desired ratio. The combustion may then occur rapidly, and thus the control is fast too, since we can introduce more or less fuel or oxygen. In order to achieve the same situation with wood, it may be necessary to pulverize the wood to very small particle size (like that of flour). These fine particles will follow the movements of the air. A good mixture can thus be achieved with a combustion resembling a gas or oil flame. However, the production of wood powder, if not available as sawdust already, is very expensive. In practice, fuel is therefore marketed in sizes and consistency varying from sawdust and waste wood, to wood pellets, wood chips, and logs as illustrated below.




Firing technology for wood and other solid fuels is thus more difficult and complicated than the firing technology used in natural gas or oil-fired heating systems. In order for optimal combustion to occur, the wood fuel must pass through three stages:

- Drying
- Gasification and combustion
- Charcoal burnout

When wood is heated, water begins evaporating from the surface of the wood. Hence two things occur: Gasification occurs at the wood surface – the heating of a fuel without the introduction of oxygen is termed pyrolysis – and the temperature deeper inside the wood will increase resulting in further evaporation of moisture from the interior of the wood. As the water evaporates and is exhausted, the area that is pyrolysed spreads into the wood. The gas thus produced is ignited above the fuel and transfers heat to the ongoing evaporation and pyrolysis. The combustion process is continuous. The gasified wood becomes glowing charcoal, transformed by oxygen, until only ash is left.

A general rule for wood combustion is the larger the fuel particles, the longer the combustion process. Imagine a handful of sawdust quickly burning as it is thrown into a hot fire. There is a good contact between fuel and air, since the small particles quickly dry, give off gases, and burn, resulting in a high combustion intensity. If instead you throw a log into a hot fire, it will take a long time before it is burned out. It can be compared the cooking of a sizable roast put into the oven. Although it has roasted for an hour, it may still be raw in the middle. The size of the fuel, therefore, is of great importance to the speed of combustion.

The moisture content in fuel reduces the available energy content, since part of the energy produced will be used for evaporation of the water. Dry wood has a high calorific value, and the heat from the combustion process should be drawn away from the combustion chamber in order to prevent overheating and consequent damage to the equipment. Wet wood has a low calorific value per kg of total weight, and the combustion chamber should be insulated so as to avoid reduction in boiler efficiency and enable a continuous combustion process. This is typically accomplished by using refractory linings round the walls of the chamber so as to conserve the heat that is generated. The boiler chamber will therefore normally be designed for burning wood within a certain moisture range. Moisture content in wood above 55-60% of the total weight will make it very difficult to maintain the combustion process.

Ash

The fuel contains various impurities in the form of incombustible component parts - ash. Ash itself is undesirable, since it may require the filtering of flue gas for particles, plus the subsequent ash and slag disposal from the firebox as the result. The ash contained in wood comes primarily from mineral components absorbed in the tree growth process. Wood ash also contains heavy metals that can cause an undesirable environmental effect, but the content of heavy metals is normally lower in wood than in other solid fuels. A special characteristic of ash is its heat conservation property.

For wood stoves, the ash layer at the bottom of the stove forms a heating surface, transferring heat to the final burnout of the char. For heating systems using a grate, the ash content is important in order to protect the grate against heat from the flames. Wood also contains salts that are of importance to the combustion process. It is primarily potassium (K) and partly sodium (Na), based salts resulting in sticky ash, which may cause deposits in the boiler unit. The K and Na content in wood are normally so low that it will not cause problems with traditional heating technologies.

Volatiles

Wood and other types of biomass contain approximately 80% volatiles (in percentage of dry matter). This means that wood will give up 80% of its weight in the form of gases, while the remaining portion will be turned into charcoal. This is one reason why a sack of charcoal seems light compared to the visual volume. The charcoal has more or less kept the original volume of the green wood, but has lost 80% of its weight. The high content of volatiles means that the combustion air should generally be introduced above the fuel bed (secondary air), where the gases are burned, and not under the fuel bed (primary air).

A given fuel requires a given amount of air (oxygen) in order to be converted stoichiometrically, i.e. the amount of excess air (lambda) should be equal to 1. The fuel is converted stoichiometrically when the exact amount of oxygen required for the conversion of all of the fuel under ideal conditions is present. In practice, combustion will always take place at an excess air figure higher than 1, since it is not possible to achieve complete combustion at a stoichiometric amount of air.

Environment

The fuel structure has an influence on the combustion efficiency. At complete combustion, carbon dioxide (CO_2) and water (H_2O) are formed. An incorrect mixture of fuel, type of heating system, and introduction of air may result in an unsatisfactory utilization of the fuel and a consequent undesirable environmental outcome. An efficient combustion process requires the appropriate integration of the following:

- High temperature
- Excess oxygen
- Combustion time
- Mixture

This ensures a low emission of carbon monoxide (CO), hydrocarbons (some of which connected to bad odors), and a low amount of unburned carbon in the slag. Unfortunately, these conditions (high temperature, a high amount of excess air, long combustion time) are also directly related to the formation of Nitrous Oxides (NO_X). The technology applied should therefore be a so-called "low-NO_X" technology, i.e., a technology applying methods resulting in a reduced NO_X emission.

In addition to CO_2 and H_2O, the flue gas will contain air (O_2, N_2, and Ar) and a low to high amount of undesirable reaction bi-products, such as CO, hydrocarbons, PAH, NO_X, etc. These components need to be elucidated more comprehensively.

Carbon Monoxide (CO)

A high CO content is a certain indication of incomplete combustion in a wood combustion system and should be maintained as low as possible, because:

- CO is a combustible gas. A high CO content results from poor efficiency.
- Odour nuisance, and a high CO value go together.
- PAH, dioxin, and a high CO value go together.
- Exposure to high concentrations of CO is hazardous.

According to the European Emission Guide, the CO content in the flue gas may not exceed 0.05% for biomass-fired heating plants. The same requirements apply to the environmental approval of many woodchip-fired heating plants.[17] During normal operations, the wood-chip, fired heating plants can comply with this, but in connection with starting up, very wet fuel, and other unusual operating situations, problems may arise.

> Efforts to determine Canadian and Alberta environmental standards regarding flue gas emissions for wood burning heating systems revealed a great deal more complexity than the European approach which simply measures the constituents at the emission point. The Alberta Environment approval process integrates the distinctions demonstrated by the industry involved (commercial, institutional, industrial, agricultural, and residential), the fuel source used (woodlot harvest, forestry waste, and construction and demolition waste), volume of wood used (over or under 10 tonnes/month), and the location of the heating plant (urban vs. rural).
>
> Particulate matter emissions are a central focus of Alberta Environment with 2 gm/kg in urban areas being permitted and 4 gm/km in rural locations. Therefore, it is strongly recommended that Alberta Environment be contacted, early on in the feasibility analysis of any commercial, institutional, or industrial heating project.

Carbon Dioxide (CO_2)

The emission of CO_2 to the atmosphere is problematic, since CO_2 is considered a major cause of the greenhouse effect. During the combustion of woodchips and other wood fuels, no more CO_2 is released than was bound-up during the growth of the tree. Furthermore, during combustion the same amount of CO_2 is produced as would be released during the decomposition of a dead tree or rotting processed lumber if not used for energy purposes. Wood fuel is thus considered CO_2 neutral.

At this point it is very important to understand, that in the efforts to reduce greenhouse gas emissions, decomposition of wood (on forest floors, in landfills, or anywhere else for that matter) is an undesirable alternative. During decomposition, wood, like other organic materials containing carbon, releases the carbon in the form of Methane Gas.

Methane (CH_4)

Methane (CH_4) is a principal component of natural gas. It is also formed and released to the atmosphere by biological processes occurring in anaerobic environments. Once in the atmosphere, methane absorbs terrestrial infrared radiation that would otherwise escape to space. This property can contribute to the warming of the atmosphere, which is why methane is a greenhouse gas.

Methane is about 21 times more powerful at warming the atmosphere than carbon dioxide (CO_2) by weight. Methane's chemical lifetime in the atmosphere is approximately 12 years, which is a relatively short atmospheric lifetime. The short lifespan, coupled with its potency as a greenhouse gas, makes it a candidate for mitigating global warming over the near-term - if emission is reduced (i.e., the next 25 years).[18]

Sulphur Dioxide (SO_2)

Sulphur emissions from the combustion of woodchips results from sulphur compounds that have been absorbed by the tree during its growth. Therefore, the combustion of woodchips does not change the total amount of sulphur present in the environment, but the emission of sulphur with combustion smoke contributes to the pollution of the atmosphere. However, pure wood from forestry operations contains only a very limited amount of sulphur.

During combustion approximately 75 % of the sulphur in the wood will be captured in the bottom ash and fly ash, so that only the remaining 25 % will end as SO_2 in the flue gas. Many analyses of the sulphur content in wood fuel show values that are below the laboratory equipment limits of detection. The average of a range of analyses shows sulphur content of approximately 0.05% (percentage by weight proportion to the dry matter content in the fuel).[16] Firing with wood at heating plants causes much less SO_2 emission than the fuel oil or coal the wood often replace. If the alternative is natural gas, and if it is sulphur-free at production, there will be no SO_2 advantage by using wood as a fuel.

Nitrogen Oxides (NO_X)

"Nitrogen oxides, or NO_X, is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO_2) along with particles in the air can often be seen as a reddish-brown layer over many urban areas.

Nitrogen oxides form when fuel is burned at high temperatures, as in a combustion process. The primary manmade sources of NO_X are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels. NO_X can also be formed naturally.[18]

During the combustion of wood chips, approximately the same amounts of NO_X are produced as during the combustion of other fuels. The formation of nitrogen oxides occurs on the basis of the nitrogen contained in the air and the fuel. Both, nitrogen contained in the fuel, and the design of the system combustion chamber play an important role in the production of NO_X. Important parameters for low NO_X formation include:

- Low nitrogen content of the fuel.
- Staged combustion at low excess air during the first stage.
- Low flame temperature.
- Recirculation of flue gases.

"Nitrous oxide (N_2O) is a clear, colorless gas, with a slightly sweet odor. Due to its long atmospheric lifetime (approximately 120 years) and heat trapping effects —about 310 times more powerful than carbon dioxide on a per molecule basis — N_2O is an important greenhouse gas.

Nitrous oxide has both natural and human-related sources, and is removed from the atmosphere mainly by photolysis (i.e., breakdown by sunlight) in the stratosphere. In the United States, the main human-related sources of N_2O are agricultural soil management, mobile and stationary combustion of fossil fuel, adipic acid production, and nitric acid production. N_2O is also produced naturally from a wide variety of biological sources in soil and water. On a global basis, it is estimated that natural sources account for over 60% of the total N_2O emissions.[18]

Other Pollutants

In addition to particulate matter (PM), SO_2, NOx and CO, flue gases may contain other pollutants, such as polyaeromatic hydrocarbons (PAH), dioxins, hydrogen chloride (HCl), etc. PAH is a joint designation for a range of chemical compounds consisting of carbon and hydrogen. It is created by incomplete combustion. Some of them are noxious (some even cancer-causing) and should therefore be avoided. Since 1985 several investigations have been carried out all showing that there is a close connection between the formations of PAH and CO. High CO content and high PAH content go together.[16]

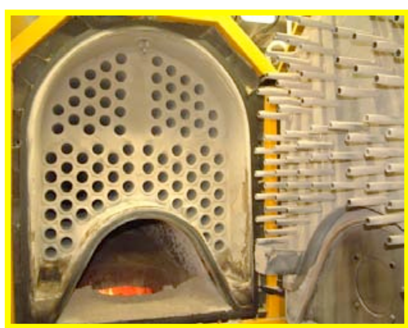
Technology

Thanks to technological progress, driven by fuel cost and environmental concerns, wood has become an attractive source of sustainable energy over the past forty years - especially in Western Europe.

A wide range of technologies has already been developed to utilize the biomass resource, and enhanced technologies continue to evolve. These vary from direct combustion in burner systems to the production of more advanced bio-fuels, through a variety of processing techniques such as fermentation, pyrolysis, and gasification.

Direct Combustion

Combustion systems for burning biomass vary from small stoves to multi-megawatt combined heat and power (CHP) systems. Combustion is best suited to bio-fuels with low moisture content, as it uses a portion of the energy to evaporate the water. The technology is usually limited to providing heating but it can also be used for electricity generation. The graphic to the right illustrates a modern biomass boiler showing tubes and air cleaning system.



Source: Koeb & Schaefer, Austria[19]

Fermentation

This process can be used on certain sugar producing energy crops to produce ethanol, a simple alcohol. It uses a simple and well-established method; yeast is added to the biomass and the mixture is then allowed to ferment under specific conditions. The resulting brew is then distilled to produce 'bio-ethanol'. This can be used on it's own in specialized combustion engines or it can be mixed with gasoline to produce 'gasohol'.

Source: Vogelbusch Bio-Ethanol Plant, Canada[20]

Pyrolysis

Pyrolysis is a basic thermo-chemical process of converting solid biomass into a more useful liquid fuel, commonly called a bio-oil. This bio-oil can be used in existing oil-fired burners (with very little adjustment) to generate heat and electricity.

The process involves heating solid biomass to a temperature of around 800^{o}C, in the absence of oxygen. This forces the volatile substances out of the biomass, leaving a small quantity of solid biomass (char). The volatiles are then collected in liquid form as the bio-oil. This process produces a better quality fuel as the oil can be transported easily and cheaply, and the solid char has a higher energy quality than the original fuel. It is also smokeless, which means it is suitable for home use.

Source: Ensyn's Wood-Biomass Pyrolysis System[21]

Gasification

Gasification involves subjecting solid biomass to hot steam and air to produce a gaseous bio-fuel. This gas (also called synthesis gas or syngas) can be burned for heating, electricity production, or may be further converted to act as a substitute for almost any fossil fuel.

The advantage of this process is that the synthesis gas is a better fuel than the original solid biomass, and can be stored and transported more readily.

> **Note:** Some of the above cited technologies have been developed further than others. A detailed analysis of the utilization of technologies other than combustion systems in rural applications is not included in the scope of this report. Due to the complexity of these technical alternatives, additional studies are warranted.

Wood Burning Installations

Modern heating systems for wood-waste, sawdust, pellets, chips, or logs have become increasingly popular. In addition to much greater operating comfort, modern wood and pellet boilers are low in pollutants and characterized by especially efficient combustion. Pellet and Wood-Chip Boilers usually achieve a standard efficiency of over 90 percent. Distinctions should be made between manually fired boilers for fuel-wood and automatically fired boilers for wood chips and wood pellets.

Heaters and Furnaces

The range of log and pellet systems includes everything from stoves used to heat individual rooms to central heating systems installed in the basement or dedicated boiler room. Depending on the application, they can cover the entire heat requirements of a building on their own or in combination with other renewable heating systems such as a solar, thermal system.

Manually fired heaters and boilers should be installed with a storage tank (hot water buffer tank) so as to accumulate the heat energy from one in-feed of fuel (a full magazine). This ensures both the greatest comfort for the user and the least financial and environmental strain.

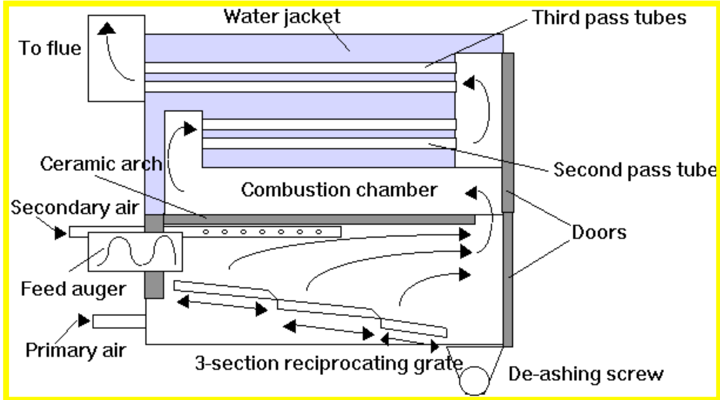
Small-scale systems for residential use or individual farm operations are not included in this report and should be the subject of an additional study.

Source: Koeb & Schaefer, Austri[19]

Boilers

Automatic boilers are equipped with a silo or other storage rooms containing wood pellets or wood chips. An auger or other feeding system matches fuel input with the output demand of the overall heating system. Great advances have been made over the past ten years in respect to higher efficiency and reduced emissions from the chimney. Improvements have been achieved particularly in respect of the design of the combustion chamber, combustion air supply, and the automatic control of the entire combustion process.

With the automatic chip-fired system, the chips are loaded onto a conveyor and into an auger from the silo, and then pass onto the grate where the combustion takes place. The movements of the grate, push the ash towards the ash chute and then ash is moved further out with the ash conveyor. The flue gases are cooled by passing through the boiler tubes which are surrounded by water.



Source: Heating With Wood Fuel[22]

Despite an often, simple construction, most of the automatically fired boilers can achieve an efficiency of 80-90%, and a CO emission of under 100 ppm. For some boilers, the figures are 95% and 20 ppm, respectively. An important condition for achieving these high results is that the boiler efficiency during day-to-day operation is close to full load. At individual plants with oxygen control, the load can, however, be reduced to approximately 30% of the nominal output without significantly influencing either the efficiency or emissions to any appreciable extent. By oxygen control, a lambda probe measures the oxygen content in the flue gas, and the automatic boiler control varies the combustion air inlet.

The nominal thermal output of various modern boiler systems ranges from 100 kW (341,000 BTU/h) to 5 MW (17 million BTU/h).

For automatic boilers, it is of great importance that the boiler nominal output (at full load) does not exceed the maximum output demand in winter periods. Therefore a major consideration in the design of a biomass heating system is the sizing of the boiler. Two approaches are commonly taken. In peak load design, the boiler system is large enough to meet the maximum heat load that is anticipated to occur. In base load design, the system is only large enough to meet the base load, that is, the load that most often occurs during typical heating season operation.

Source: Köb & Schäfer[19]

Peak load design maximizes the use of wood and minimizes the use of fossil fuels. This can be advantageous when the cost of fossil fuel is very high. However, the boiler system required to meet the peak load will be larger and therefore more expensive than in the base load design. With variable loads, it will often operate at a load well below its nominal capacity and consequently efficiency will suffer and emissions may be more severe.

Base load design typically permits a much smaller boiler system, significantly lowering capital costs. Nevertheless, because it satisfies the base load, most of the annual energy requirements are met by the biomass system. This arrangement can be very cost-effective. Furthermore, since the boiler operates at or near its design load most of the time, efficiency is high and emissions are reduced. However, a conventional peak heating system is also required, and fossil fuel consumption is higher.

While the best approach will depend on the nature of the installation, large systems with high continuous energy demand tend to use the peak load approach and small installations used exclusively for space heating or variable loads tend to use the base load approach.

In the transition periods (3-5 months) spring and fall, the output demand of the heated space will typically be approximately 20-40% of the boiler nominal output, which means a deteriorated operating result. During the summer period, the output demand of the building will often be in the range of 1-3 kW of heat, since only the hot water supply will be maintained. This equals 5 -10% of the boiler nominal output. This operating method reduces the efficiency (typically 20-30% lower than that of the nominal output) and an increased negative effect on the environment. The alternative to the deteriorated summer operation is to combine the installation with a hot-well or buffer storage tank, natural gas furnace, electrical power heated hot water supply, or solar heating system.

The boiler nominal output (at full load) can be calculated on the basis of the known annual consumption of Natural Gas or the floor space, age, and insulation rating of the building.

It is essential for every wood-heating project to carefully evaluate project viability, with respect to seasonal base load demand, peak heating-demand, and analyze all capital, operating, and life-cycle cost factors.

District Heating

The term district heating plant refers to plants dedicated to the generation of heat, but without power generation. The heat is distributed to a district heating system to which all consumers (residential, commercial, industrial, or institutional) within technological and economic reach of the system have the opportunity of being connected. In many European countries the use of forest chips at district heating plants has increased significantly since the first systems came into operation at the beginning of the 1980s. Seen in an international perspective, the use of wood chips at district heating plants has increased tremendously during a relative short period of time. Biomass District Heating Systems consist of a heating plant, a heat distribution system, and a fuel supply operation.

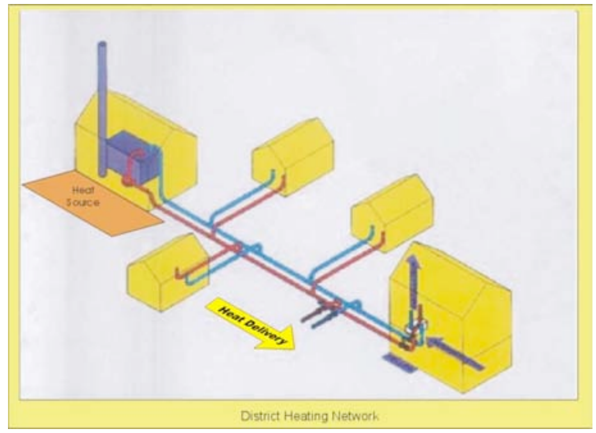
Typically, the heating plant contains four sources of heat. Firstly, whenever possible, the plant makes use of a waste heat recovery system providing free or low cost energy recovered from an industrial process or electricity generation system.

Secondly, the base load heating demand in excess of that provided by waste heat recovery is provided by a biomass combustion system.

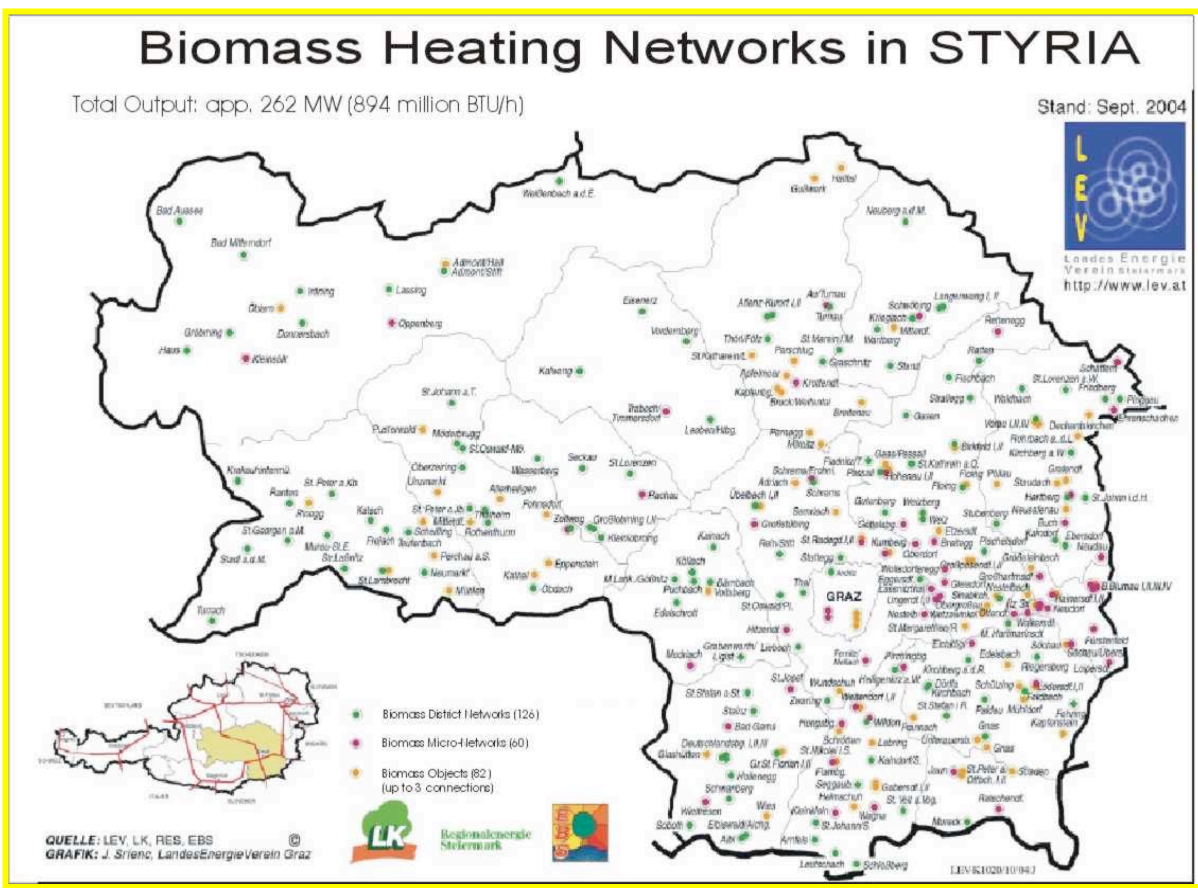
Thirdly, when the heating load outstrips the combined output of waste heat recovery and the biomass combustion systems, a peak load heating system is brought on line. It is designed to meet only a small portion of the annual energy demand.

Fourthly, in case of a biomass system shutdown or an interruption in the biomass fuel supply, a backup heating system provides heat. In some cases, the peak load heating system eliminates the need for a backup system; the waste heat recovery system is also optional.

The heat distribution system transports heat from the heating plant to the locations where it will be used. These locations may be within the same building as the plant or, in the case of a district heating system, a cluster of buildings located in the vicinity of the plant. A network of insulated piping conveys hot water away from the plant and returns the cooled water back to the plant for reheating.



Along with Sweden and Denmark, Austria now has one of the fastest growing biomass heating infrastructures. A good example is Styria, a small province in the southeast of Austria, covering 16,388 km^2 (6,327 Sq.Miles) with a population of 1.2 Million.



Source: Srienc, J., Projektarchiv, LandesEnergieVerein Graz[23]

Kalwa biogenics

Wood chip-fired district heating plants are established either in order to replace oil or coal-fired district heating plants, connected to old district heating systems, or as new plants and systems (the so-called “urbanization” projects). Wood chip-fired boilers at European district heating plants are designed for the generation of heat in the range of 1 MW and 10 MW; the average being 3.5 MW.

Although these plants require a considerable total investment, they are more and more often implemented in small communities. Wood chip-fired boilers used here are smaller than the average of 3.5 MW mentioned above. The biomass technology has recently received increased interest by commercial and industrial users.

System Size and Plant Technology

When deciding the size of a new chip-fired system at a district heating plant, it is necessary to know the annual heating demand of the district heating system. It is also necessary to know the changes in the heating demand of the district heating system per day and per year, for the above mentioned reasons.

Depending on the energy demand, District Heating Networks can be sized as small as a few hundred kW, all the way to almost unlimited MW sizes.

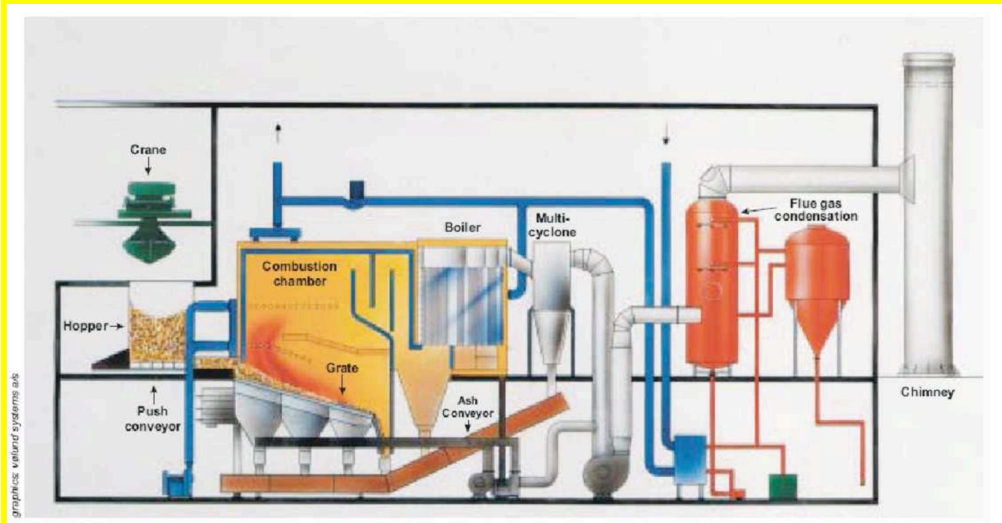
Source: Koeb Pyrtec Networks, Germany; Koeb & Schaefer, Austria[19]

The typical wood chip plant is constructed around a solid fuel boiler with step grate or moving grate. The boiler has refractory linings around the walls of the chamber in order to ensure the combustion temperature despite the relatively wet fuel. The plant designs are highly automated so that the feeding system of wood chips from storage onto the grate is carried out by means of a computer controlled technology that simultaneously keeps track of the fuel storage level.

All the systems have the same main components:

- Wood chip storage
- Crane or other chip handling
- Feeding system
- Combustion chamber and boiler
- Flue gas purifying (filtering)

- Flue gas condensation
- Chimney
- Ash disposal



Source: Wood for Energy Production[24]

The following describes the main principles of the technique that is typically used with wood burning energy systems and wood chip-fired district heating plants.

Wood Chip Storage

The size of the fuel storage facility depends on various factors, especially the supply contract(s) made with the fuel supplier(s). However, a storage facility that matches the requirements of a minimum of 5 days and nights supply at maximum heat-production should always be the operational standard. This insures adequate supply during weekends and for security during extreme weather conditions. Most European plants settle for an indoor storage facility and leave the handling of larger, outdoor storage facilities to the suppliers of wood chips. However, a few plants do include outdoor storage. Under current Alberta wood fuel supply logistics, greater attention must be paid to storage.

Handling of the fuel

The majority of operating problems generally experienced by the plant system is the movement of wood chips from storage into the feeding system. The entire feeding system from storage to boiler should be viewed as a chain in which the reliability of operation of the individual links is of critical importance. The entire district heating plant stops if there is a “missing link” in the fuel, feeding chain. At plants with outdoor storage, it is normal to use a wheeled loader with a large bucket for the movement of wood chips to the indoor wood chip storage. Between the indoor wood chip storage and boiler feeding system, a number of options can be used for the movement of wood chips.

Overhead Crane

The crane is flexible, has a high capacity, and is also the handling equipment that best tolerates a poor wood chip quality. However, it is important for the crane shovel to be toothed. If not it is difficult to fill and easily rolls over on top of the pile. For relatively large plants, the crane is also the most cost effective, while it is a very expensive solution for small systems.

Hydraulic Push Conveyor

The hydraulic push conveyor is used for unloading rectangular silos or storage bunkers with level floors. It is normally not as technically reliable as the crane solution. The hydraulic push conveyor is relatively inexpensive and is therefore particularly suitable for small systems (0.1-1 MW boiler nominal output).

Tower Silos

Tower silos with an auger can be used for wood chips, if properly designed and matched to the fuel type. The silo is time-consuming to fill due to the greater tower height, which can be solved by "blowing" the fuel into the silo. For storage and handling of wood pellets, the equipment used in the livestock feed-handling industry is normally suitable.

Augers

Augers are inexpensive, but vulnerable to foreign matter and slivers. In general, augers with bolted-on tops are recommended instead of augers enclosed in tubes. The recommendation is easily understood after just one experience of manually emptying a tube system blocked by slivers or foreign matter. Similarly, it may be considered poor design if augers are embedded in concrete floors or otherwise located so that repair work and replacement of parts is difficult. Like other mechanical conveyors, augers should be considered equipment prone to wearing and must be easily accessible for maintenance work. Correctly dimensioned, augers are an acceptable solution at small plants (0.1-1 MW boiler nominal output). Unless hardened steel is used, normal wear and tear will result in a relatively short life of an auger. Augers are seldom used as fuel handling equipment at large district heating plants.

Belt Conveyors

Belt conveyors are rather insensitive to foreign matter. Generally, they are better than augers, but unless equipped with barriers, the belt conveyor cannot manage as steep an inclination as the auger. High price and dust emissions (which may necessitate covering) are the major drawbacks of the belt conveyor.

Pneumatic Conveyors

In general, pneumatic systems are not suitable for the movement of wood chips. If wood chips are available in a particularly uniform size, however, movement by pneumatic conveyors may be a possibility, but the energy consumption of pneumatic conveyors is significant.

Feeding Systems

There are several types of feeding systems for wood chip-fired boilers. The choice of feeding system depends on the size of the plant and whether the use of solid fuels other than wood chips is desired. Here are a few examples:

Hydraulic Feeding System

Many plants use this quite reliable feeding system. Wood chips fall from a hopper into a horizontal, square box, from which hydraulic feeding devices force wood chips on to the grate. The design of the system is critical to its reliability. If correctly designed as most often seen today, it is among the best feeding systems for wood chips.

Stoking

Small systems (0.1-1 MW boiler nominal output) often have screw stokers feeding the boiler. At some plants, the screw stoker is positioned across the longitudinal direction of the grate. This gives a good distribution of the fuel over the width of the grate.

Grate with Feed Hopper

Some wood chip plants have a simple hopper that feeds the wood chips on to the grate. The system is known from coal-fired boilers with moving grate and requires that the height of the wood chips in the hopper will be high enough so as to function as an airtight plug between the feeding system and the boiler. The problem of bridging in the hopper can be remedied by an appropriate design of the hopper, and as a last resort by mechanical stirring/scraping systems.

Spreader Stoker

Wood chips are thrown into the combustion chamber by a rotating drum in a spreader stoker. Only a few plants use the system.

Pneumatic Stoker

Wood chips are blown into the combustion chamber and fall on to the grate. Spreaders and pneumatic stokers are often used in connection with combustion of wood chips with a high, moisture content.

Combustion Chamber and Boiler

Wood chips are introduced for combustion on the grate in the combustion chamber that is often situated immediately below the boiler. The most common type of grate in wood chip-fired systems in district heating plants are the step grate/inclined grate, and the chain grate/moving grate. For both grate types, the primary air that is needed for the combustion is supplied from underneath the grate and passed up through the grate.

The step grate has the advantage that wood chips are turned upside down when tumbling down the “steps”, which increases the air mixing and burnout.

The moving grate is known from coal-fired systems. The wood chips lie without moving in a uniform layer, whose thickness is controlled by a sliding gate. During combustion the grate and the chips move towards the ash chute. Combustion-air is introduced by two fans in the form of primary, and secondary air (see Wood Burning).

The combustion chamber has refractory linings round the walls. This insulation ensures a high combustion temperature and suspended arches radiating heat to the wood chips. The amount and the design of the lining are factors of great importance to the combustion quality during the combustion of wet fuels. When firing with dry fuels, e.g. wood pellets, the lining is of no benefit to the combustion quality. Rather the opposite, since the combustion temperature will be too high, thereby risking soot in the flue gas and grate slagging. Therefore, the type of fuel and its water content should be determined well before installation.

The “Wood Burning Process” description above, sets out in detail the requirements for good combustion quality. These requirements can be “boiled down to” “the 3 T’s” (Temperature, Turbulence, and Time). The temperature should be sufficiently high to enable efficient drying, gasification, and combustion. Air and combustible gases should be mixed adequately (turbulence), and finally there should be space and time for the gases to burn out before they are cooled too much by the boiler water.

Boiler

The flue gases pass from the combustion chamber to the part of the boiler, where the heat is given off to the circulating boiler water. Most often, the boiler is situated above the grate. The flue gas flows inside the tubes that are water cooled on the outside surface. In small systems, the combustion unit and the boiler may be completely separated, since wood chips are burnt in a separate pre-combustor, from where the flue gases are passed into the boiler. In the boiler unit or as a section after this unit, an economizer may be installed that cools the flue gas down to a temperature of approx. 100 °C. The increased cooling improves the efficiency.

The boiler room should be large enough for repair work and for ordinary maintenance work, including boiler purifying, to be carried out in a proper way. The building round the boiler should be designed so as to give room for cleaning of the boiler tubes and replacements of tubes.

With respect to the boiler life, it is important that the temperature of the return water to the boiler be sufficiently high. It is recommended to keep a return water temperature of at least 75-80 °C in order to reduce the corrosion of the boiler tubes in particular. The life of tubes varies a lot in various wood chip-fired plants. In addition to the operating temperature, the boiler life depends on the operational patterns, fuel, combustion quality, and choice of material.

Flue Gas Purifying - Fly Ash

The fly ash is the part of the ash that remains in the flue gases on its way through the boiler. Flue gas filtering is first and foremost a question of reducing the amount of fly ash emitted through the chimney. The fly ash is transported from the flue-gas purifying unit to the remaining part of the ash system by screws. The separation of fly ash from the flue gas may be accomplished either by means of a multicyclone, bag filter, or other flue gas purifying equipment.

Most wood burning plants are equipped with a multicyclone. The fly ash from the combustion of wood consists primarily of relatively large particles that can be readily trapped by the device. A well-dimensioned system can filter to a level of approximately 200 mg/m^3. Multicyclones are inexpensive to buy and maintain, and are used for pre-cleaning before the flue gas condensation unit.

Bag filters can filter to a level of 10-50 mg/m^3. Normally, bag filters are only capable of withstanding flue gas temperatures of up to approx. 180 °C. In order to avoid embers and sparks in the bag filters, the flue gas must pass cyclones or a filter chamber situated before the bag filters. Bag filters are automatically deactivated if the maximum temperature or the maximum value for the oxygen content in the flue gas is exceeded.

Like the bag filter, the electrostatic precipitator (ESP) cleans efficiently, but it is more expensive to install in relatively small wood chip-fired systems. However, operating costs are lower, however, than those of the bag filters. Bag filters, ESPs etc. are not extensively used today at wood chip-fired district heating plants.

Ash Disposal

Wood chips contain 0.5-2.0% of the dry weight in the form of incombustible minerals which are turned into ash in the combustion process. The ash is handled automatically at all district, heating plants. The manual work in connection with the ash system is limited to ordinary inspections and intervention in case of operations stoppage. With properly designed and integrated technology slag-build up is not a widespread result at wood, chip-fired heating plants.

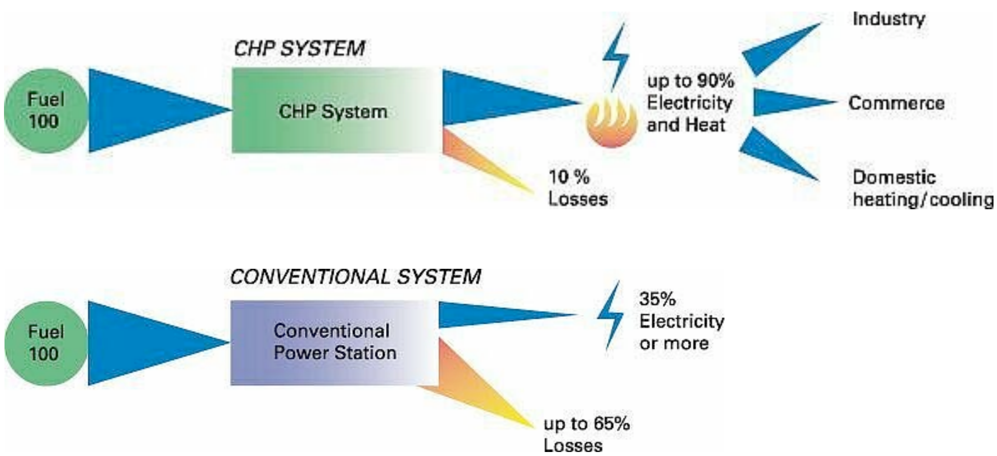
The ash drops from the grate onto an ash conveyor or other ash collection system. The ash system may be arranged as a wet or dry ash system. A wet ash system is a dual function system, since it is efficient as a trap, hindering false air entering the boiler at the same time as extinguishing glowing ash. A drawback of the system is the heavy weight of ash in the ash container and the corrosion resulting from the wet ash. The emptying of the containers varies with the consumption of wood chips, that is, from approximately every second week to once every three months.

Ash contains the unburned constituents of fuel, including a range of nutrients, such as potassium, magnesium and phosphorus, and it can therefore be used as fertilizer in the forests if the content of other substances that are not problematic to the environment.

Cogeneration and Power Plants

Cogeneration (Combined Heat and Power or CHP) is the simultaneous production of both heat and electricity. The central and most fundamental principle of cogeneration is that, in order to maximize the many benefits that arise from it, systems should be focused according to the heat demand of the project.

This can be sized to an individual building, a commercial or industrial facility, or a community, district, town, or city served by the distributive heating and/or cooling project. Through the optimal utilization of the heat, the efficiency of a cogeneration plant can reach 90% or more. Cogeneration therefore offers energy savings ranging between 15-40% when compared to the separate supply of heat and electricity from conventional heating boilers and electric power plants.



Source: COGEN EUROPE[25]

In conventional electricity generation, further losses of around 5-10% are associated with the transmission and distribution of electricity from relatively remote power stations via the electricity grid. These losses are greatest when electricity is delivered to the smallest consumers.

Due to the fact, that transporting electricity over long distances is technologically easier and economically cheaper than transporting heat, cogeneration installations are usually sited as near as possible to the heating end-user. Ideally, they are built to accommodate the local heat demand. Otherwise, an additional boiler may be necessary to overcome the transportation and delivery loss, and the environmental advantages will be partly hindered. This concept is central to effective and efficient cogeneration.

When less electricity is generated than needed, it will be necessary to purchase extra from the grid. Generally, when the scheme is sized according to the heat demand, more electricity than needed is generated. The surplus electricity can be supplied to other consumers via the distribution system.

It is important to understand that both the economical and particularly the environmental impact of "true" cogeneration from wood, requires the full utilization of the thermal and electrical energy production. Many wood-burning facilities operating in the Canadian forest industry are only technically "Cogeneration Systems".[26] If they generate electricity from waste-wood combustion, without fully using the heat as such, they produce the same efficiency losses as shown for all conventional power systems.

So it is important to point out again how true cogeneration can optimize the energy supply to many types of consumers with the following benefits to both users and society at large:

- Increased efficiency of energy conversion and use. Cogeneration is the most effective and efficient form of heat and electricity generation.
- Lower emissions to the environment, in particular of CO_2, the main greenhouse gas. Cogeneration can deliver a high impact on Kyoto targets
- Large, energy cost savings, providing additional competitiveness for commercial, institutional, and industrial users, and offering affordable, stable energy prices for domestic users.
- An opportunity to move towards more decentralized forms of electricity generation, where the plant is designed to meet the needs of local consumers, providing high efficiency, avoiding transmission losses, and increasing flexibility of system use. This will particularly be the case if wood is the energy source.

A well-designed and operated cogeneration scheme will always provide better energy efficiency than a conventional plant, leading to both energy and cost savings. A single fuel is used to generate both heat and electricity; so cost savings are dependent on the price-differential between the primary energy fuel and the outside generation and delivery of electricity that the scheme displaces.

However, although the profitability of cogeneration generally results from its cheap electricity, its success depends on using recovered heat productively. As a rough guide, cogeneration is likely to be suitable where there is a fairly constant demand for heat for at least 4,500 hours in the year.[27]

Cogeneration Technologies

As pointed out above, this report is focusing on wood, heating technologies and therefore not on the CHP technologies that allow successful and reliable cogeneration with the currently available systems for rural applications in Alberta. Many of the different wood heating technologies previously explained as compared to the existing technologies for CHP, are characterized by different scales of the thermal capacity, different efficiencies, and different stages and levels of complexity in development. Only some of the options are generally implemented on the market and usable for applications in Alberta.

In the last 10-15 years, significant technological progress has been made to enable engine and turbine technology to be widely implemented and promote more decentralized forms of cogeneration. Increased cost-effectiveness and decreasing emissions have resulted. There are increasing variations of cogeneration technology applications in commercial, institutional, industrial, and residential use.

The most commonly used system for such applications was traditionally the steam power generating cycle, using steam turbines which allowed exhaust steam to be used for process heating. Intensive developments over the past two decades have made a wide variety of equipment available, enabling cogeneration packages to be matched accurately to specific site requirements.

There are three broad categories of cogeneration application:

- Small-scale cogeneration schemes, usually designed to meet space and water heating requirements in buildings, based on spark ignition reciprocating engines.
- Large-scale cogeneration schemes, usually associated with steam raising in industrial and large buildings applications, and based on compression ignition reciprocating engines, steam turbines or gas turbines.
- Cogeneration schemes fuelled by renewable energy sources, which may be at any scale.

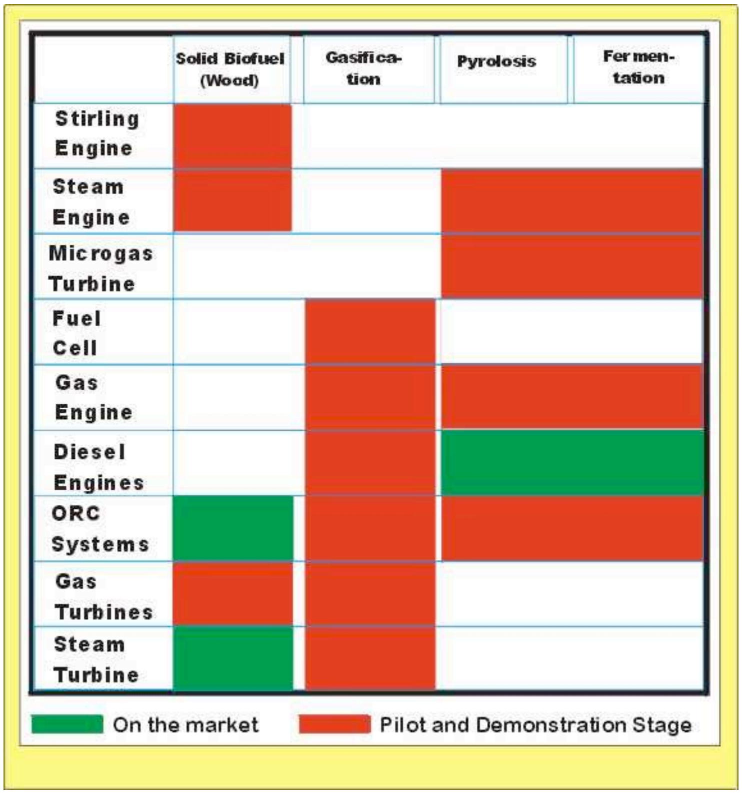
Cogeneration units are generally classified by the type of prime mover, that is, the drive system, generator, and fuel used. Currently available drive systems for cogeneration units include:

- Steam turbines;
- Reciprocating engines;
- Gas turbines;
- ORC process (Organic Rankine Cycle)

New developments are bringing new technologies into the market to become economically available and technologically reliable within the next ten years.

- Fuel cells;
- Stirling engines;
- Micro-turbines.

The following figure shows the technical concepts available for CHP based on biomass, including wood (solid fuel) combustion.



Source: CHP based on biomass - technologies and potential[28]

The currently practicable technologies for the aspirated implementation of systems in rural Alberta are ORC Systems and Steam Turbines. Between the alternatives the size of operation defines the technological preference.

The ORC Process

ORC Turbo-Generators are a very promising solution for biomass cogeneration with nominal outputs between 400 and 1,500 kWe (kilowatts electricity) per unit. Developed in Europe since the early 1980's, more than 50 plants have been in operation in different countries by the end of 2006. The advantages of this technology in terms of high availability, low maintenance costs, high automation or unmanned operation, and high efficiency for biomass CHP systems - in this power range, have been confirmed in practice.[29]

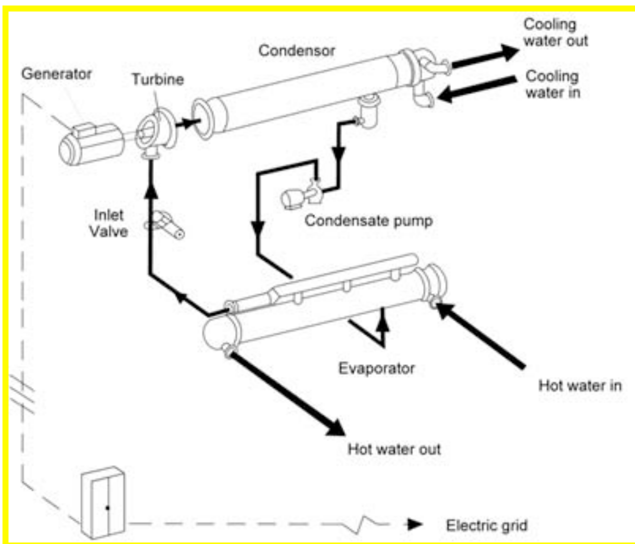
Economic evaluations based on experience with these installations show, that these plants are suitable for economically competitive electricity production, especially where premiums for renewable electricity production are implemented. Typical applications are cogeneration, district, heating networks and cogeneration in wood manufacturing, industries, where (in Europe) this technology is experiencing a fast growing number of installations.

The concept of this cogeneration system is based on the principle that the electrical production follows the thermal requirement, of the district heating users. For example, which means that the wood-fuel is burned according to the thermal demand only.

The system is based on the following main steps:

- The wood-fuel is burned in one of the above described, individually sized boiler systems.
- Hot thermal oil (silicone-oil) is used as a heat transfer medium, giving a number of advantages, including low pressure in boiler, large thermal inertia and insensitivity to load changes, simple and safe control and operation. Moreover, the adopted temperature (about 300 C) ensures a very long life for the oil. More importantly, the utilization of a thermal oil system also allows operation without the licensed operator required for steam systems in Alberta.
- An Organic Rankine Cycle, turbo-generator is used to convert the available heat to electricity. With ORC, the use of a properly formulated working fluid and the optimization of the system design, both high efficiency, and high reliability are obtained. The condensation heat of the turbo-generator is used to produce hot water at typically 80-90 C, a temperature level suitable for district heating and other "low" temperature uses including wood drying, grain drying and cooling through absorption chillers etc.

So, the ORC is basically a binary system, taking heat from the wood-burning (or other) source and transferring it to the working fluid in a closed system to be vaporized and pressurized, typically turn a turbine, then condense back to liquid form before flowing through the heat exchanger again to repeat the cycle. The diagram below breaks out the typical components of an ORC system:



Source: Turboden[30]

As mentioned above these systems range from 400-1,500 kWe and therefore cover the smaller scale cogeneration. To get a better understanding, the following data sheet shows the technical details of the standard system units:

	T500-HR	T600-HR	T800-HR	T1100-HR	T1500-HR
Heat source	thermal oil in a closed loop	thermal oil in a closed loop	thermal oil in a closed loop	thermal oil in a closed loop	thermal oil in a closed loop
Thermal oil nominal temperature (In/Out)	265 / 165 °C	265 / 165 °C	265 / 165 °C	265 / 165 °C	265 / 165 °C
Thermal oil flow (about)	11,5 kg/s	13,8 kg/s	17,9 kg/s	24,6 kg/s	34,5 kg/s
Thermal power input from thermal oil	2850 kW	3425 kW	4425 kW	6100 kW	8550 kW
Hot water flow	36,6 kg/s	44,0 kg/s	56,4 kg/s	77,8 kg/s	109,7 kg/s
Hot water temperature (In/Out)	28 / 43 °C	28 / 43 °C	28 / 43 °C	28 / 43 °C	28 / 43 °C
Thermal power to the coling water circuit (about)	2275 kW	2735 kW	3510 kW	4840 kW	6825 kW
Net active electric power output	500 kW	600 kW	800 kW	1100 kW	1500 kW
Module dimensions	See Doc. 03Q00064_e	See Doc. 03Q00064_e	See Doc. 03Q00084	See Doc. 03Q00052_e	See Doc. 04Q00032_e
Electric generator	asynch., 3 phase, L.V., 650 kW	asynch., 3 phase, L.V., 750 kW	asynch., 3 phase, L.V., 930 kW	asynch., 3 phase, L.V., 1250 kW	asynch., 3 phase, L.V., 1650 kW

Source: Turboden[30]

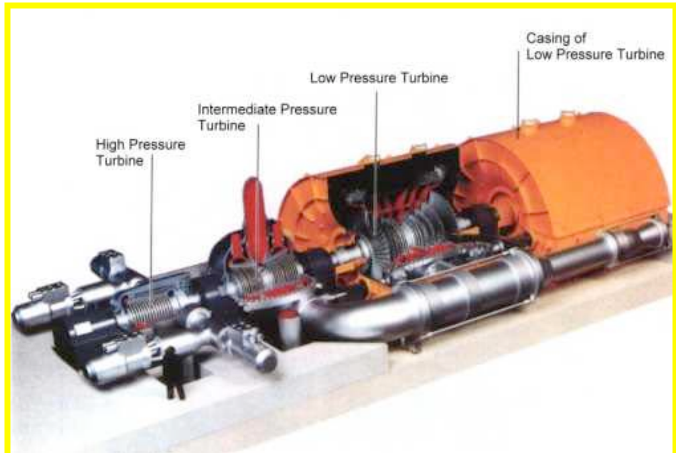
1,500 kWe 200 kWe

ORC System, Source: Turboden[30]

Steam Turbines

Steam turbines have been used as prime movers for industrial large-scale cogeneration systems for many years. High-pressure steam raised in a conventional or wood fired boiler is expanded within the turbine to produce mechanical energy, which may then be used to drive an electric generator. The power produced depends on how much the steam pressure can be reduced through the turbine before being required to meet site heat energy needs. This system generates less electrical energy per unit of fuel than a gas turbine or reciprocating engine-driven cogeneration system, although it's overall efficiency may be higher, achieving up to 84% (based on fuel gross calorific value).

For viable power generation, steam input must be at a high pressure and temperature. Residual heat output is relatively low grade. Typical inlet steam conditions are 42 bar/400 C or 63 bar/480 C. The temperature required by the process dictates actual outlet steam conditions. The higher the turbine inlet pressure, the greater the power output, but higher steam pressures entail progressively greater boiler capital and running costs. Optimum pressure therefore depends on the size of the plant and the required process steam pressures. Steam cycles have the great advantage that the associated boiler plant can be designed to operate on virtually any fuel, including wood, gas, heavy fuel oil (HFO), coal, residues, and municipal or other wastes, and are often capable of operating on a range of fuels.



Section through a steam turbine above. Condensation steam turbine with 10 MWe below.
Source: Energytech[31]

At a traditional steam-based CHP plant with condensation operation, 40-45% of the energy input is converted to electrical power, while the remaining part is not utilized. It disappears with the cooling water into lakes and rivers and with the hot flue gas from the boiler up through the chimney into the atmosphere.

These plants are capital intensive because a high-pressure boiler is required to produce the motive steam, with high investment and operating costs.

Nevertheless, under true cogeneration conditions with the full utilization of the thermal output, wood-burning heat and power plants generating their electrical output on larger scales from stem turbines can have the desired economical and environmental impact.

A good example of a state of the art, wood-firing cogeneration plant is the system in Pfaffenhofen, Germany.

This plant, shown to the right, is comprised of fuel delivery and storage, conveyor systems, biomass furnace and a steam generator, flue gas cleaning, flue gas condensation, steam turbine, an air condensation plant, equipment for heat generation and district heat extraction including the associated water/steam cycle, fire protection equipment, and the electrical and computer systems for the operation and monitoring of the overall plant.[32]

Table 10: Pfaffenhofen Technical Data

Thermal furnace performance of biomass steam generator	26.7 MW
Electrical performance of steam turbine	6.10 MW
Net thermal performance	32.5 MW
Thermal furnace performance of standby steam generators	31.0 MW
Fuels	Wood Chips, Bark, Sawmill Waste

Source: Kraftanlagen Muenchen[32]

The commercial CHP biomass plant Pfaffenhofen is owned by four private businessmen from Pfaffenhofen, and was commissioned in 2001. The main fuel is wood-chips. The biomass plant uses about 80,000 t/year of untreated wood and the heat back-up system of approximately 800 tonnes of fuel gas/oil per year. The wood chips have average moisture content of approximately 60 %. The biomass demand (30 % natural wood and bark, 70 % wood waste from sawmills) requires efficient logistics for harvesting, processing, and transportation of wood. Forest owners can supply wood ranging from intact stems to wood chips. Container trucks transport the fuel to the cogeneration plant, which guarantees a flexible and efficient supply with minimal traffic.

Despite the high moisture content of the wood fuel, the overall efficiency of the biomass boiler including flue gas condensation is 95.4 %. The nominal load of the biomass boiler controls the CHP plant in Pfaffenhofen. The heat back up system is controlled by the heat demand.

Two steam boilers with a total capacity of 31 MW support the biomass unit during high loads and ensure safe heat delivery. Flue gas is used as the main heat source. However, in case of gas being switched off, it is also possible to use fuel oil. The thermal output of the plant is used in full, for heating, process steam, and cooling.

Energy usage:

- Steam conducting pipe (1 km) to a producer of baby-food (HIPP).
- Steam parameters: temperature inlet 200°C, return 65°C, pressure 12.5 MPa (34 600 MWh/a).

- District heating with more than 150 customers with a connected power between 15 and 3500 kW (44 900 MWh/a).
- High-temperature network: 11 km @ 130°C/70°C.
- Mid-temperature network: 4 km @ 85°C/ 45°C.
- Low-temperature network: 45°C/30°C.
- Cooling-capacity for a hospital: 300 kW.
- Cooling-capacity for two business-buildings: 600 kW.
- Cooling-capacity for a brewery during night and for air-conditioning of several business buildings by district cooling during daytime: 650 kW.

The biomass plant storage facility has a capacity maximum of 8000 m³. This corresponds to roughly 1-2 week full load operation. Approximately 90 % of the ash can be used in the agriculture and forestry sector as fertilizer because of its high contents of nitrogen and trace elements.

The highly efficient biomass thermal power plant uses only untreated wood chips to supply households and industry with energy at market prices. The Federal and Provincial Government in Germany provided financial and professional support to this project. A positive additional effect: Up to 200 jobs were created during the 18-month construction of the biomass thermal power station. Another 25 permanent jobs were created after the commissioning of the unit.

Technology Conclusion

Biomass combustion systems can provide heat and cogeneration for commercial and industrial buildings, process heat, and community energy systems. Where wood-fuel is available as a residue having few or no alternative applications, it can serve as a very low cost fuel. Compared with fossil fuel-fired systems, biomass-heating plants are physically larger, have higher initial costs, and require more operator involvement. However, when heating loads are high over a considerable fraction of the year, the reduced fuel costs, and reduced emissions of greenhouse gases and acid rain-causing compounds make biomass-heating systems very attractive.

Due to the complexity of any renewable energy project, commercial, institutional, industrial, residential, or municipal, it is vital to implement a detailed assessment of all the prevailing circumstances and general project conditions, as this report will further outline below.

Wood Fuel Supply Chain

Elements of the Supply Chain

Based on European and North American wood fuel supply chains, pellets, chips, and/or briquettes are usually the wood fuel type supplied to commercial, institutional, and industrial end users. For the sake of simplicity, the following section refers specifically to wood chips although it can be generalized to include the other two types of fuel. The wood-chip fuel supply chain includes some or all of the following:

- Felling
- Toping, delimbing, and crosscutting (bucking)
- Move timber and cuttings to roadside – specialized bunching and wrapping technology needed to complete collection of tops and limbs.
- Transport from forest to processing area
- Drying and chipping, or chipping and drying, or both processes combined
- Storage
- Packaging and/or carrier loading
- Transport to customer
- Off-loading to customer storage bin or fuel hopper

Key Questions

The supplier will likely be faced with several key alternatives:

- Purchase standing timber, fell, and extract to roadside or purchase logs and/or cuttings at roadside?
- Process in the forest and deliver direct to customer or process in specifically designed processing facility?
- When does chipping take place? Before or after drying?
- What is the most viable method of drying?

Supply Chain Models

The range of different wood-chip supply chain models include:

- Entire supply chain - woodlots and buildings, owned and managed by one owner who processes, and delivers dried wood-chips directly to customers.
- Supply chain managed by woodlot owner and fuel user:
    - Customer purchases timber and carries out all processing.
    - Woodlot owner delivers partly processed fuel to customer.
- Woodlot owner supplies wood to fuel processing business, which delivers dry woodchips to customers.
- Several businesses operate individually to provide links in the chain.
- Several businesses operate co-operatively to provide supply chain.
- Community groups cooperate with individual businesses or public bodies.

How would the wood-chip supply chain likely develop as demand increases?

It is expected that the wood-chip demand will increase in the near to mid-term future and that large-scale production and supply of wood-chips will then become economically viable. Some idea of how the supply chain may develop can be gained by considering how small-scale and large-scale suppliers might operate.

Small-scale Operation

- A small-scale supplier will need to minimize costs and could apply a system similar to the following:
  - Air-dry logs in forest to 20% moisture content – two to three years.
  - Hire mobile chipper – sized from tractor drawn, either self-powered or PTO driven, up to a self propelled, mid-range machine.
  - Chip directly into delivery bags or bulk transport trucks.
  - Deliver directly from forest to customer.
- The main drawbacks of this system would be:
  - Slow and possibly unreliable air-drying of logs in forest.
  - Dried logs require more power, therefore more time, fuel, and cost.

Large-scale Operation

- A large-scale supplier will need to maximize speed of processing and could apply a system similar to the following:
  - Establish wood-processing facility in forest or as close as possible to wood supply.
  - Transport freshly felled logs to on-scene or centralized processing facility.
  - Chip logs into drier (using industrial sized, upper range chipper).
  - Dry chips using forced, hot-air ventilation.
  - Store dry wood-chips if and when necessary.
  - Load dry wood-chips into bags or bulk transport trucks.
  - Deliver to customer.
- Main drawbacks of this system would be:
  - High capital cost of buildings, chipper, and dryer.
  - Double transport and multiple handling.

Supply Chain Summary

- Increased use of wood for heating commercial, institutional, and industrial buildings would benefit the customer, the environment, and the local economy.
- Automated wood pellet, chip, and briquette heating systems are more appropriate than log-burning systems for most commercial, institutional, and industrial customers.
- Current distributed, demand for wood-chip heating fuel in Alberta is not sufficient to support a commercially viable, wood-chip supply industry separate from the pulp and paper sector.
- Some potential customers may be reluctant to install wood-chip heating systems because of the current lack of a reliable wood-chip supply.

- The wood-chip supply chain consists of a complex variety of processes, which may be carried out in many different ways.
- The costs of each stage of the supply chain are **highly variable and difficult to predict**.
- While demand is low, supply is likely to be provided by businesses, which can supply wood-chips as a sideline to other activities. For example, waste wood recycling, sawmilling, or arboriculture, or by organizations, that can obtain public funding to support supply chain development.
- Production of wood-chip fuel may be combined with production of wood-chips for other uses but it may be difficult to obtain a wood-chipper, which can produce a wide variety of wood-chips to different specifications.
- As demand increases, a range of different supply chain models will be possible.
- Community groups may be able to assist in wood-chip supply chain development by accessing funding for capital investment in buildings, machinery and equipment, and for research and training.

Wood Fuel Cost

Alberta Agriculture and Food has developed an excellent 18 page, publication titled, "Private Woodlot Enterprises", as part of the "Ag Ventures" series, which covers the following topics:[33]

- Industry Highlights
- Regulatory Basics
- Marketing Basics
- Production Basics
- Economic/Finance Basics
- Key Management Issues
- Publications

The "Production Basics" and "Economic/Finance Basics" sections are of the most significance to this report. The following adjusted table from that source indicates the average historic Alberta prices for privately owned timber measured in cubic meters.

Table 11: Average Alberta Log Prices in $\$/m^3$ (1997-2002)

Timber	Landowner	Logging	Hauling	Mill Price
Coniferous	30	20	15	65
Deciduous	3	12	14	29

Source: Private Woodlot Enterprises[33]

The above table provides the firewood purchaser with the starting point in determining the price for wood fuel. It must be stressed that this is the starting point only. The prices for standing Aspen have varied from $2.00 per cubic meter to as high as $60.00 for large, high quality logs. Logging costs will vary according to the logging system used to harvest the timber. Currently in central Alberta, trucking costs amount to $3.00/tonne/trucking hour, which is calculated on a round trip basis. Therefore, it is readily understood that each wood-heating project needs to complete an accurate assessment of the cost of obtaining fuel wood for their specific project. In addition, the above numbers do not include processing the logs into firewood logs, chips, pellets, or briquettes. This must be added to the equation before an accurate, reliable estimate can be obtained. Where the processing is done, in the forest or at the plant, has a significant impact on the total cost. Each project is very individualistic in this regard. Some commercial or industry projects have an "in-house" source of wood, and others are located near sustainable sources of CRD or other waste-wood, which decidedly changes the cost of wood fuel for those particular projects.

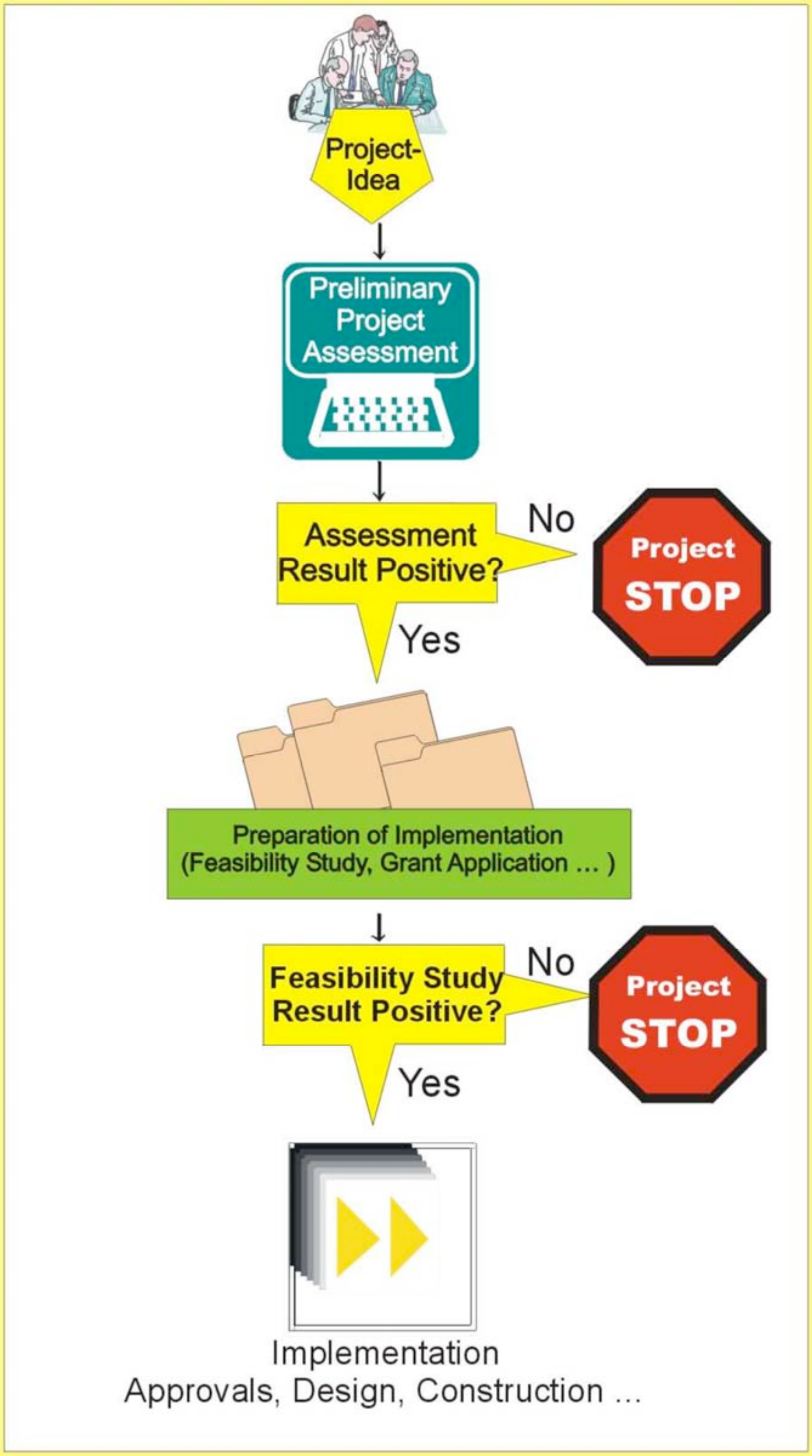
Project Feasibility

Once the idea of a biomass, energy project is born, the project initiator is advised to undertake an assessment of the project feasibility, which should indicate: first, a general, and then a detailed project assessment.

The preliminary project assessment surveys the general, technical, and economical evaluation of the anticipated project, including all prevailing circumstances, legal, organizational, financial, and logistic aspects.

A positive result of such an assessment facilitates a full-scale feasibility study, evaluating the project specifications in detail in order to substantiate a solid business plan for the project implementation.

This report describes the operational and organizational structure of preparing, planning, and implementing a biomass energy project based on an assumptive standard project by taking the experiences of completed operating biomass projects into account.



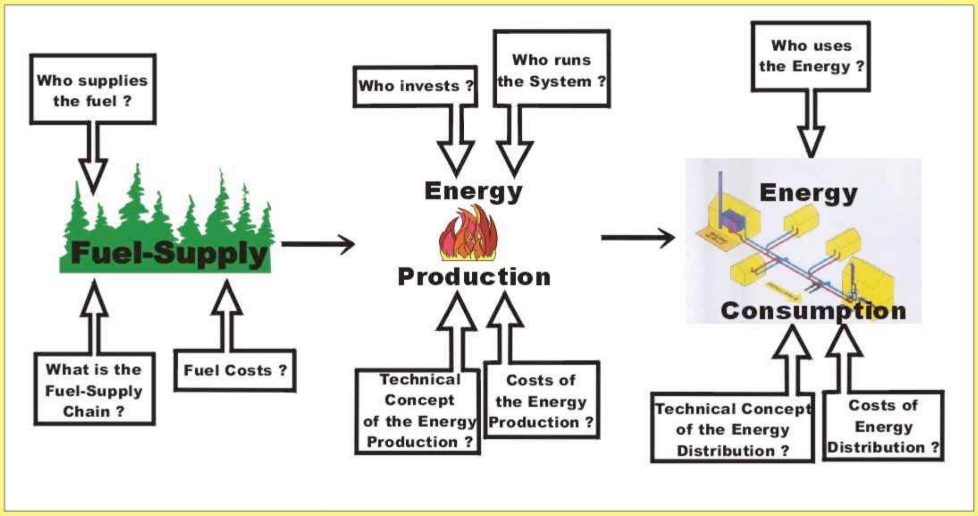
Integration of Preliminary Project Assessment into Project Procedure (Welling)

The complexity of the individual project defines the complexity of the planning requirements. The following sections assume the planning of a biomass energy project on a community scale.

It needs to be understood that with "smaller" or less complex projects, a number of the evaluation aspects can be answered more easily or might even be of a minor nature. If a wood lot owner or a business producing waste wood as a part of their operations decides to cover some of their heating requirements from that source, there may be little significant need to explore the logistics and organizational aspects of the wood-fuel supply.

Still, a preliminary project assessment, though on a clearly smaller scale, would be advised.

With the development of bio-energy projects, it is important to become aware of the over all complex system and all its components; staring from fuel procurement and fuel supply chain, the actual energy production components all the way to the energy consumption, and the possible energy users.



Planing Development of a Bioenergy Project (Welling)

It seems obvious that bio-energy projects involve a number of particular features different than traditional fossil fuel projects included in the project graph:

- The supply and availability of wood biomass fuel might be affected by seasonal fluctuations. Therefore, the fuel supply logistics need to be optimized in order to guarantee the viable operation of the project.
- A functioning market for wood fuel, as much as other bio-fuel, has not yet been established in Alberta and each project needs to secure the individual long-term fuel supply logistics.
- Bio-energy projects, though successfully used in Europe for decades, are introducing technology that is fairly new to Alberta. Therefore the need for General information is clearly higher than with any conventional energy system.
- Bio-energy projects may involve a number of potential partners in every aspect of planning an operation. Partners need to be identified and actively involved in the development of the project, especially at the early stages.

The preliminary project assessment and the following feasibility study analysis, defines the viability and financial foundation of the project and establishes the basis for possible grant applications. Experienced biomass project developers should perform both. The project initiator assists in providing available data and information.

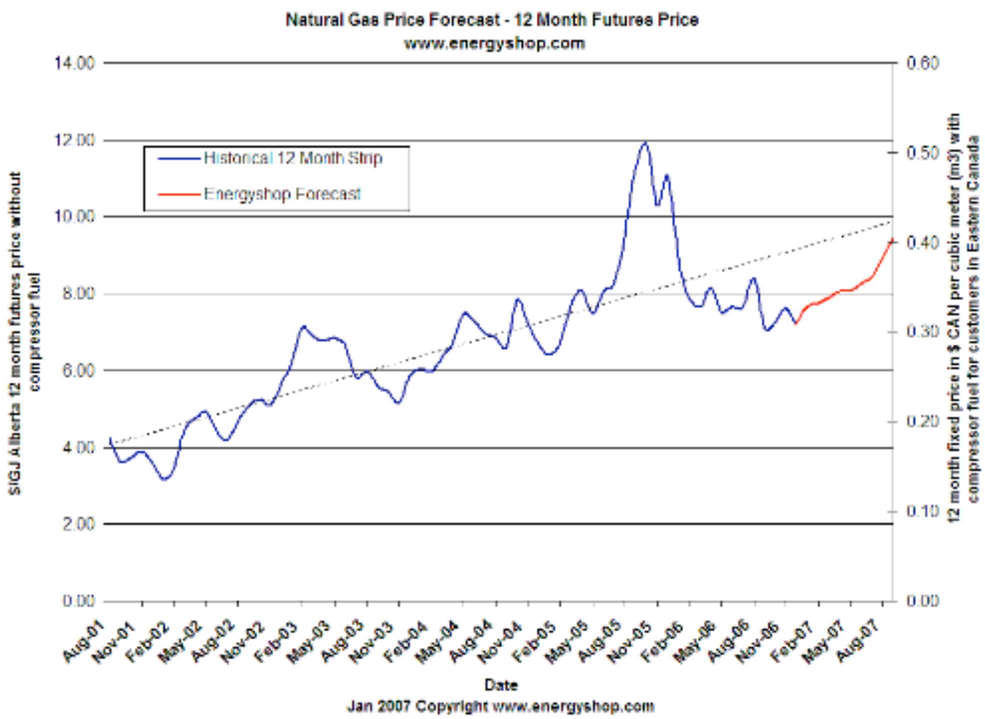
Project Initiation

The initial starting point for any biomass energy project is the fundamental idea. For both the private and the communal sector we find a number of possible incentives to bring a biomass energy conversion project into consideration.

Private Initiative

Private enterprises often face a number of economic circumstances that might suggest the conversion of existing heating systems to biomass. The most obvious incentive is the continuous upward trend in NG prices, particularly for all commercial operations that are not eligible for the provincial natural gas rebate program. Due to the fact that provincial gas rebates only partly cover incremental price increases, the rebate system generally creates a distorted image of the actual price developments and the economic risks lying within. Detailed information on the provincial rebate program can be found on the Alberta Energy Website.[34]

The price development over the last number of years has been alarming and should be considered a strong incentive to explore energy alternatives.

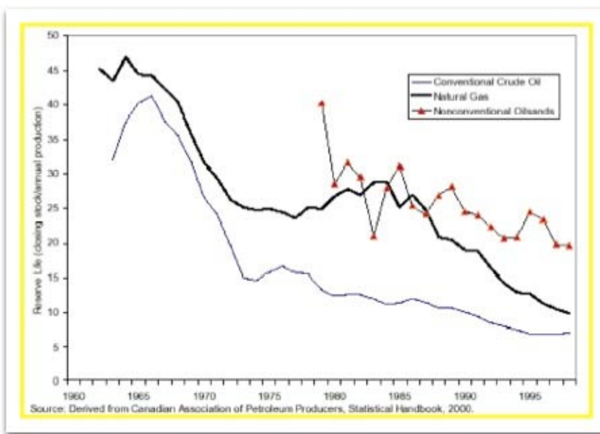


Source: Used with permission of Energyshop.com[35]

Gas prices have generally followed the oil prices over the past years. The exception is in the very short-term price. Both the winter of 2005/2006 and the start of the winter 2006/2007 were so warm there has been more natural gas in storage than ever before. However, while that brought down short-term prices, the long-term fundamentals have maintained the long-term prices stubbornly high. One thing to keep in mind additionally is that natural gas traded in North America is priced in US Dollars, and therefore, the increasing value of the Canadian Dollar has recently reduced the price paid by Alberta Consumers. If the dollar value goes down, the NG prices will go up without any change in the availability of the commodity effecting the price.

Forecasts suggest that natural gas prices will track the "just below the trend line" shown in the graph above for the near future. Long-term economic activity, demand and supply balance, and the price of oil will result in a steady price increase for natural gas for the following reasons:

- Natural gas demand in North America is increasing at about 3% per year whereas supply is increasing at about 1%.
- Increasing economic activity, growth, new businesses, and new homes increase gas demand.
- Production of many older gas wells is declining rapidly.



- 1998 – 16.16 bcf/d
- 2001 – 17.02 bcf/d
- 2004 – 16.30 bcf/d
- 2007 – 16.16 bcf/d

In essence, after drilling Over a hundret thousand Wells in the decade 1998 -2007 Canadian NG production will be basically the same in 2007 as it was in 1998

Source: Alberta Energy and Utilities Board[9]

- More natural gas is being used for electricity generation. Any new electricity capacity brought online currently is likely generated by natural gas, rather than oil, coal, hydro, or nuclear, let alone biomass.
- As the price of fuel oil increases, some industries switch to natural gas. Many industries developed a dual fuel capability when gas prices skyrocketed in 2001.
- Prices are not expected to come down until new major gas pipelines are built connecting new gas fields in Alaska, Northwest Territories, and the Yukon. That development is at least 6 years away. Recent reports, however, suggest that virtually all of this gas will be used to extract oil from the oil-sands in Northern Alberta.
- Liquefied natural gas (LNG) will likely become a factor in North America, but expensive terminals and custom tankers will have to be approved and constructed.

It is safe to say, that the price forecast for natural gas is up. That alone can be reason enough to consider investing in alternative energy and heating technology.

In many cases a strong additional incentive can basically be found "in the back yard" in form of availability of wood-fuel supply.

As shown above, existing wood-stands, privately or publicly owned, can provide a significant amount of energy, particularly with sustainable management.

Another dependable source of wood-fuel is the waste-wood stream. Many commercial enterprises are dealing with the necessity of waste-wood disposal as part of their operational costs. Waste-wood includes "cut-offs" in the construction or timber processing industry, or in the disposal of transport materials like crates or pallets.

These materials have been recognized and dealt with as a business cost-factor in the past, however, with increasing energy prices it is becoming more obvious that each tonne of "waste-wood" can be a valuable energy resource with the potential of saving as much as three times its disposal costs through bio-energy conversion.

Community Initiative

Numerous circumstances can encourage communities to consider Bio-Energy-Projects. For example:

- An existing heating system in a community property, such as, a school, office building, hospital, recreation facility is being renovated, and the old heating system needs to be upgraded or replaced. All long-term remediation projects open the possibility of economical and ecological alternatives, including the conversion to biomass, energy systems.
- New developments – new and often, large public buildings and housing developments can implement biomass energy systems, if the feasibility is reviewed at an early stage in the development process. The community is central to ongoing development plans, and in many cases owns suitable land for energy project development. This provides the community with the opportunity to include renewable energy alternatives. Housing developments and public buildings can be part of a functioning district heating network.
- As part of routine energy management, communities audit the detailed energy consumption of public buildings. The results are part of, and often the basis of the decision making process about long-term energy supply contracts and general energy saving concepts. In this context the potential of bio-energy conversions can and should become part of the equation.
- Wood from publicly owned wood-stands as much as cuttings from rural landscape maintenance or roadside clearing is a possible fuel resource controlled by the community. Furthermore the communities have to and can control the handling and management of local waste-wood. These wood-fuel sources can either be utilized by the community in their own bio-energy project or introduced into a general wood-fuel supply stream.

With the development of biomass, energy projects communities can, with every project, predefine their practical and financial involvement, depending on their individual capacities. Some communities have the financial and technological resources to implement such projects independently. That means planning, design, implementation, and operation of the energy system or network being executed and controlled by the community.

If the community is facing limited capacity, but still wanting to take an active part in the project development, the community can evaluate the possibilities of partnerships or public corporations.

Preliminary Project Assessment

The preliminary project assessment is, as shown, the first step in implementation of a biomass energy project, prefixing the feasibility study, and the following project phases.

The objectives of the preliminary project assessments are to:

- Evaluate the technological and economic feasibility based on the general conditions, and the legal framework enabling decision-making.
- Establish the basis for estimation of technical and economic risks.
- Identify possible exclusion criteria.
- Identify possible project partners (fuel supply, investment, construction, energy users, etc.).
- Establish the basis for a detailed feasibility study, business plan, and possible grant applications.

Different from the feasibility study, the preliminary project assessment is usually smaller in scale, less detailed and less costly. With each individual project presenting specific circumstances, it is hardly possible to define a typical exemplary preliminary project assessment template. With this in mind, the following description is meant as a guideline for the structure of such an assessment process.

As mentioned above, one of the objectives of the preliminary assessment is to identify possible exclusion criteria that might prevent the project implementation. Identifying such circumstances as early as possible enables the proponent to:

- Make necessary adjustments to any part of the project planning and implementation process to overcome obstructive circumstances before remedial measures become expensive or even impossible.
- Stop the project, if necessary, at a phase of relatively low expenditure

Naturally, the possible exclusion criteria can be as unique as the project itself. The most common are:

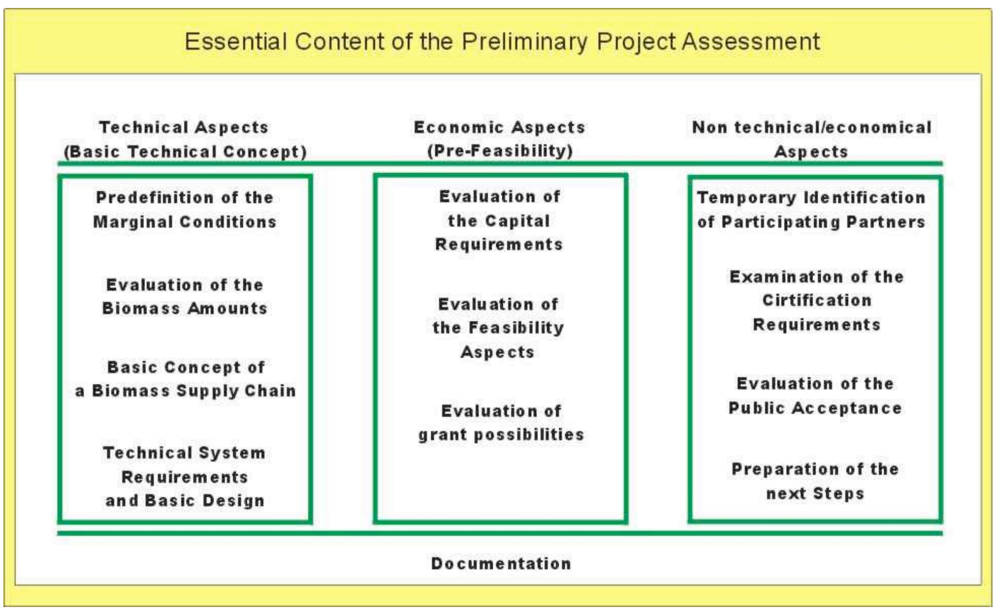
- The potential energy users reject the concept.
- There is not enough energy demand or there are not enough users willing to be connected to the system network.
- The project shows holes in the budget that can neither be filled by public grant money nor by additional partnerships.
- None of the initiating partners are taking charge of the project and/or suitable investors cannot be found.
- There is not enough biomass available.
- The certification of the anticipated system is difficult or incurs unacceptable legal or technical constraints.
- There isn't any or enough available space to install the system and the operating equipment components.
- There is a low-level of acceptance in the local population, which might cause complications in the approval process or project development.

Content of the Preliminary Project Assessment

Based on the above-mentioned objectives, the project-draft has to answer the following primary questions:

- What are the marginal conditions for the project - particularly economic conditions?
- Who are the potential energy users and what would their estimated energy requirements (primarily heat) be?
- What is the anticipated basic technical design concept of both energy generation and energy distribution?
- How much, and what kind of wood-biomass is available? What are the required processing steps needed to utilize the fuel with the anticipated technology (including supply-chain logistics)? What are the available transportation and storage alternatives?
- What regulatory and environmental approvals are required?
- What is the estimated investment and annual operational cost (in comparison to alternative solutions) and are there possible holes in the budget?
- Are any grant funds or subsidies available?
- What government operations, businesses, or institutions could be potential project partners?
- Who will be in Charge of the project development?

These questions pre-define the essential content of the Preliminary Project Assessment, which can be subdivided into economic, technical, and non-technical aspects.

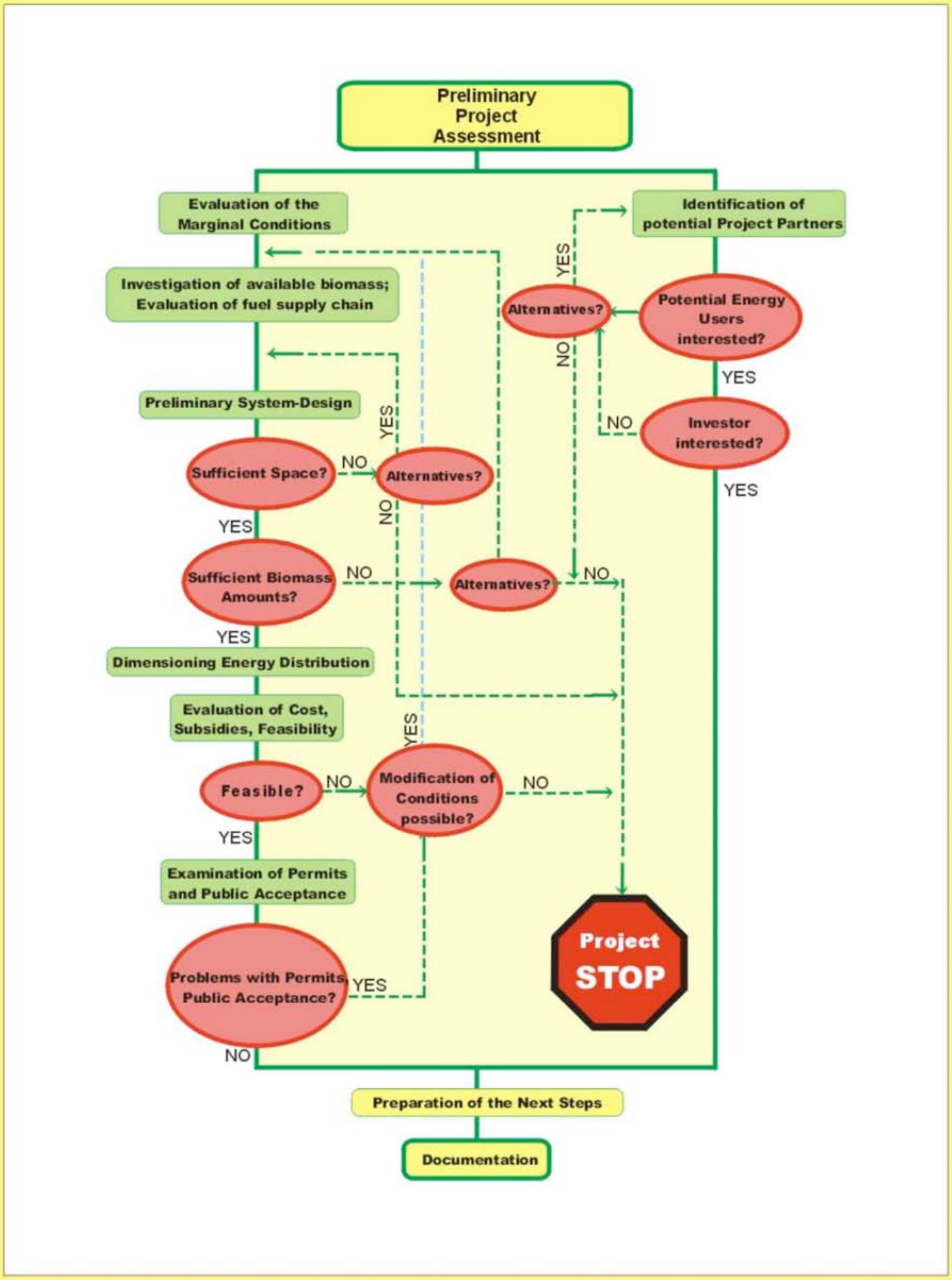


Source: Harald H. Welling

As mentioned, the “Preliminary Project Assessment” does not need to evaluate these aspects in significant and final detail. That level of detail can and should be achieved as part of the subsequent developmental phases. It is desirable that for each general project requirement, there are at least one, if not more possible solutions.

Nevertheless, as the process advances it is vital for both the technical and the economic aspects of the project, to have an in-depth assessment of the anticipated energy requirements. If a reliable, energy-use profile is not available; it is advisable to perform the first (Yardstick Audit) of a series of energy audits determining the annual energy demands in support of the basic decision on type, structure, and size of various technologies needed to meet these demands.

The project proponent can save time and expense by securing these data sources prior to retaining professional consulting and support. A number of auditing tools are also available in the digital market place.



Course of the Preliminary Project Assessment (Welling)

Project Assessment Template

One of the best templates for energy project assessment is provided by Natural Resources Canada, titled: “Federal Buildings Initiative, Audit Standards Guidelines”, cited in the Bibliography.[35] The guidelines provide a comprehensive description of the various levels of audit, including:

- Yardstick Audit
- Screening Audit
- Walkthrough Audit
- Engineering Audit

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Nevertheless, the gas worksheet contained in this publication does not adequately accommodate the Alberta deregulated gas distribution and retailing system. We recommend using the alternate worksheet provided by the authors in Appendix 1.

Barriers

Previous sections of this report demonstrate considerable potential for satisfying energy needs in Alberta with wood biomass. Nevertheless, most of this potential is currently under utilized. This exists in spite of the fact that generation of heat for buildings and communities, plus agricultural, commercial, and industrial processes is well suited to wood-biomass direct combustion. The technologies are available, affordable, and reliable. However, the wood-biomass for heat concept has hardly been considered in the existing energy schemes across the province. The role that wood, bio-energy can play in the future will largely depend on overcoming several barriers to greater market penetration.

Wood Fuel Supply Infrastructure

Securing adequate supplies of biomass fuel at acceptable cost and quality is a prerequisite for the successful implementation of any bio-energy project and thus the lack of certainty of fuel supply is another significant barrier to bio-energy projects. If wood biomass is to play a larger role in the Alberta energy mix, a steady supply of woody material must be readily obtainable.

The renewable energy community in Alberta, including wood, biomass is in its infancy. In all but the logging, lumber, and pulp industry, the infrastructure needed to acquire, produce, harvest, process, transport, dry, store, market and use wood for heating and electricity generation is simply not available for that purpose. The existing, long-established, forest and energy industry fully utilize its current capacity. In the future, the wood, biomass industry will simply have to develop into its own dedicated infrastructure. It can piggy-back on established components for a time if a symbiotic relationship is encouraged. Ultimately however, as it grows and demand increases, it will have to become competitive in Alberta's heated market place.

The development of a functioning bio-energy market in Alberta would involve a number of different stakeholders working together to build a sustainable wood-fuel supply infrastructure. Currently such structures are not in place. The partners involved should include:

- The biomass owners and producers (forest industry, woodlot owners, woodlot associations, municipalities, Alberta Government)
- The producers of bio-energy technologies (boiler, feeding, and fuel storage manufacturers, advanced technology companies)
- The existing energy producers and distributors (utility companies, distribution line owners, transportation companies)
- Financing institutions, Federal and Provincial Government, and possible energy end-users

However, this is not a small task—essentially, a new industry must be formed to harvest, transport and prepare biomass in a useable form. If biomass heating plant operators must supply steady heat year-round, especially for industrial or commercial purposes, there must be enough wood biomass available throughout the year to fulfill their obligations.

It is important to involve agriculture, forestry, and waste (recycling) sectors in any efforts to implement a wood-fuel supply infrastructure. Private woodlot-owners can also play a significant role in this development.

As part of the fuel supply considerations, the fuel quality factor needs to be understood as a particular problem with biomass fuels, since they are often bulky and have or can acquire high moisture content in storage and transport, leading to variable and unpredictable quality. Fuel standardization (terms and conditions) and techniques for fuel upgrading (drying, chipping, pelleting, briquetting,) are advancing and will play an important part in the solution of this problem.

It has to be understood, that the generally desired widespread use of woody biomass in energy generation may, despite the shown currently large availability of wood in Alberta, face a future potential of conflicting demand, as suppliers of biomass do not sell just to the energy market. For example, although wood chips are the feedstock for the pulp and paper industry, they can go into horticultural mulch or animal bedding. Other wood waste can be recycled into new products. Thus bio-energy operators will find themselves competing with other industries for biomass. Fuel supply risks from competing markets for the biomass can be overcome by appropriate contracts and forward sales agreements, which can also cover variations in quality and long-term supply requirements to further reduce investment and operational risks.

Market Perception

Over the last number of years renewable energy providers have been faced with utilizing a more or less traditional model of providing public extension activities as part of their marketing strategy. Although spectacular results can be achieved in changing public perception and understanding of the significant issues, it needs dedicated staff and a solid budget. Small, for profit, corporations cannot be expected to finance this type of educational component of marketing. This has been a role traditionally assigned to government.

User bias

Historically, Alberta has had strong economic and generally beneficial ties to the traditional fossil fuels industry, and until recently enjoyed relatively low prices. As a result, information about the modern technical aspects of creating bio-energy from woody biomass has not been of significant interest in Alberta and therefore not been disseminated in the province as it has in other parts of the world. While a rapidly growing awareness of environmental issues, and as much as the soaring prices for fossil fuels have focused attention on energy alternatives, we face a significant information and education shortfall in the province.

Many people, including energy professionals consider wood combustion a “fuel of the past”, because of its traditionally low, energy efficiency and high atmospheric emissions. The operation of low-performing combustion technologies, that sell cheaply in many cases, add to this poor image. Wood-biomass combustion in open-fires, or poorly designed bio-energy plants has been the cause of health problems through their high levels of particulate matter, and aromatic hydrocarbon emissions. However, these problems can be overcome by proper installation of modern, clean burning, highly efficient technologies, that meet modern air emission standards.

Corporations operating in the wood, biomass fields are confronted with considerable negative bias when proposing such projects. Pollution, operational labor intensity, dependability, fire safety, and other issues rooted in outdated knowledge of “old fashioned’ technology and energy economics create many hurdles to overcome. A report completed for Natural Resources Canada by the Association of Canadian Community Colleges in 2003 supports the above statement and is further quoted below.[37]

> A consensus emerged during the interviews of renewable energy industry representatives to the effect that consumers are not familiar with the various renewable energy technologies and some industries have an image problem….

Some renewable energy industries must cope with problems of consumer perception, and misconception, when consumer expectations are too high in relation to market realities. The industries must also focus on not sending out too idealistic a message suggesting that the typical home can operate economically solely on renewable energy.

The industries must meet the financial concerns of consumers, who are discouraged by the high initial investment cost characteristic of most renewable energy systems. Consumers are concerned with the design and aesthetics of the technology. In some cases, the consumers are also concerned of the impact of some renewable energy technologies on the environment such as biomass combustion systems….

Social factors are major barriers in the development of the renewable energy market. Consumers from the institutional, commercial and industrial sectors have a lack of knowledge towards energy efficiency practices and technologies. During interviews with many experts, reference was made to the need to raise the awareness and training of those responsible for managing buildings so they can acquire skills in the field of energy efficiency and computer tools designed to optimize energy performance.[16]

Who Knows?

Professionals in the energy sector are usually not familiar with biomass sources, biomass energy conversion technologies, and biomass markets. As a result, project initiators often rely on local professionals with limited knowledge. Such professionals often "reinvent the wheel" when designing projects, thereby driving up costs or creating a less than optimal project. And few woodlot owners and loggers have experience with growing, processing, storing, and transporting wood suitable for combustion. With biomass competing against fossil fuels for different applications, inconveniences based on inexperience are enough to discourage early adoption. Additionally, public perception of biomass and waste processing is not typically high. It is not as glamorous as the other renewable energy sectors, like wind or solar.

Additionally, public and institutional stakeholders show a tendency to focus on the latest developments in bio-fuel research, for example, biomass to liquid technology, where bio-fuels are made from lignocellulosic biomass feedstock, including wood, using advanced technical processes (bio-hydrogen, bio-ethanol, bio-diesel, etc.).

Without underestimating the future potential of these technologies particularly for larger scale renewable energy projects, it has to be emphasized, that most of them are still at a research development stage, many even still subject to highly controversial debate amongst researchers. For example: A new joint study from Cornell University and University of California-Berkeley states that fuels produced from biomass are uneconomical as they use much more energy in their creation than the resulting ethanol or bio-diesel generates.[38]

Essentially, these technological developments receive all the press and this tends to leave little room for the very practical, effective, and efficient implementation of wood biomass utilization in rural Alberta. Their innovative publicity can potentially divert some stakeholders focus from supporting biomass projects that are economically and environmentally feasible today. Nevertheless, ethanol and bio-diesel advancements need to be recognized for their contribution to our future energy needs.

Most importantly, the business models and strategies that can make wood biomass energy projects successful are often lacking from the toolboxes of industry, entrepreneurs, and government policy-makers. Opinion leaders, and decision makers all need up-to-date, reliable information on wood biomass energy to make this huge resource a cost-effective reality.

Lack of Renewable Energy Training

Regulatory and enforcement staff are generally not particularly versed in wood biomass project development, and as a result, businesses developing such projects are subjected to extra scrutiny, involving repetitious, lock-step processes designed for fossil fuel based developments.

Engineers with a background in bio-energy projects in general, and sizeable wood biomass projects in particular are in short supply. Many of the superior technologies in this area are based in Europe and engineering is often supplied as part of the installation, and commissioning costs.

Trades workers trained in renewable energy projects are not readily available in most of Alberta. The huge demand within the traditional trades fields provides little incentive for this shortfall to be rectified by current market forces.

Few educational institutions in Alberta or Canada for that matter have yet to recognize the need for new renewable energy disciplines, let alone moved to fill the educational gap at anything but an awareness level. The above noted survey completed by the Association of Canadian Community Colleges in 2003 also supports the above statement. At that time, only eleven organizations offered such training – most of it at the public awareness level.

> The survey data suggest that the training currently available through colleges and other institutions and organizations that responded to the survey represents a fairly small volume of activity. It should be noted that the training available is generally not specialized technical training and targets an informed public as well as people showing an interest in renewable energy but with no relevant background. Based on this data, we can conclude that the training specifically available to workers in the renewable energy industries is quite limited.[37]

Table 11: Characteristics of Courses Available

Characteristics of Course	Number of Responses
Credit Course	6
Workshop	2
Conference	2
In Class	8
On line	3
Correspondence	1
Solar	5
Wind	8
Biomass	3
Earth Energy	3

Source: ACCC[37]

Although the above data are three to four years old, significant change cannot be seen in upcoming renewable energy education and training.

Economic Barriers

The most important fiscal barrier is the initial high investment costs and the expected risk for investors that might make bio-energy projects appear not to be competitive with other forms of energy. Bio-energy systems usually have higher investment costs compared with fossil fuel technologies, which increases their payback period and makes them less attractive to potential users. Increased depreciation rates and public funding could reduce the investment cost barrier and encourage increased investment in bio-energy plants. For small investors, a good solution is the joint investment in a larger project (like the Pfaffenhofen Power plant in Germany). The Natural Resources Canada "Office of Energy Efficiency Program" is a step in the right direction.[39]

The Regulatory and fiscal barriers to biomass include the absence of effective markets such as green pricing to stimulate the biomass industry. "Green energy marketing" is just beginning to provide choices in restructured energy markets for both heating and electricity consumers to purchase energy from renewable or environmentally preferred sources, such as biomass. Green pricing allows customers to support a greater level of investment in renewable energy technologies.

International efforts in climate change policy are considering carbon credit markets as a key motivator to reduce greenhouse gas emissions and support the development of renewable energy sources, including wood biomass. An operational market for trade in carbon credits is now emerging in Alberta and Canada. The effectiveness of such markets is subject to intense political debate and outside the scope of this report.

Policy and Regulation

The Government of Alberta's deregulation strategy, which embedded strong intentions within its rationale for the electricity and heating supply and delivery markets, has achieved only partial successes in the desire to stabilize, and perhaps through competition, reduce energy costs in comparison to the North American Market.

Nevertheless, supply and delivery of all types of energy has remained concentrated in very large multi-national corporations that are not readily inclined to change their perspectives on a host of customer service, competition, return on investment, environmental impact adjustment, and other market forces. The larger the ship the longer it takes to turn around.

Current energy regulations operating through the Alberta Energy and Utilities Board, for example, are designed for fossil fuel driven energy projects.

Consultants and corporations seeking approval for even small-scale energy projects have been confronted with processes containing up to 27 separate and distinct steps.[40] Although the processes cited in the report are related to the integration of heat and electricity into the project, they appear to have been designed for mega-projects, in the fossil fuel industry, and do not accommodate small to medium, or perhaps even large renewable energy projects. Without sizeable budgets funding cadres of engineering, accounting, and legal personal to move them to completion, such projects become unnecessarily difficult and costly, even when other barriers are surmounted. This favours the existing, large energy corporations operating in the fossil fuel industry, hence the status quo will persist.

Small to medium sized businesses have been lobbying the government for adjustments to legislation and regulation to accommodate smaller-scale energy projects on a more level playing field.

As previously mentioned, determining the applicability of environmental regulations is not an easily definable process. There are a series of operational factors to be integrated into the design and location of a heating plant beyond the direct approval of the heating technology prior to its purchase and installation. Therefore, considerable caution must be exercised and contact with Alberta Environment maintained throughout the development and commissioning process. This takes time and a solid budget to accommodate the expense.

Subsidies

The Government of Alberta NG and other fossil fuel based heating rebates is an example of a government program designed to soften the blow of short-term to medium-term significant energy price increases. Although this tends to protect Alberta consumers from crushing energy costs, the incentive to seek out cost-effective, alternate heating sources and resources is dampened by the same initiative.

Originally the program was slated for a three-year term, but has currently moving through its first renewal. If the rebate continues without compensating incentives to alternative energy developments, it will deter short and long-term movement toward renewable energy substitution, including wood, biomass. Conundrums of this nature appear to be the order of the day for the foreseeable future.

Harvesting Forest Waste

In Europe, the standard approach to forestry harvesting is to remove all trimmings as well as the timber. This includes the stumps, which is never done in Alberta. Europeans believe that the methane gas given off by forestry waste rotting on the forest floor is vastly more harmful to the environment than the benefit received from the nutrient release and microclimate created (methane is 21 times more damaging to the atmosphere than carbon dioxide). In Europe, this practice is mandatory. Some reconsideration of our forestry practices would seem to be a reasonable strategy.

Recommendations

Alberta taking the lead

This report has shown that the potential of wood-biomass as an alternative, high-grade, heating, energy source in Rural Alberta is significant. The economic and environmental impact of heat generation from renewable wood resources deserves to be fully integrated into the Alberta energy equation.

The Alberta Government, with the participation of all wood-industry stakeholders, should take the lead in the introduction of holistic, and inclusive policies and strategies to support the development and implementation of efficient and cost-effective wood-based, bio-energy projects in the Province.

> Alberta has restructured its electricity industry, introducing competition in the generation sector in 1996 and retail choice in 2001. Since deregulating, the private sector has dramatically increased the wind generation capacity to about 170 MW and there are a number of proposals for a wide range of new wind, hydro and biomass projects. However, the Alberta government is committed to the principles of deregulation and the need for a level playing field among all electricity generation sources. It does not, however, believe that it is prudent to directly subsidize the renewable or alternative energy sectors. The government's efforts to support these sectors will instead be focused on removing policy, regulatory or technical barriers; facilitating customer choice and consumer understanding of the emissions intensity of their purchases; and working with stakeholders to identify realistic yet challenging expectations on the appropriate minimum capacity of renewable and alternative energy the province should be moving towards.[41]

Specific strategies for the development of woody biomass-based energy should recognize the contribution of all participants, including the existing forest-based and related industries, private woodlot owners, and all industries that produce wood biomass residues and the roles they all can play in fulfilling these strategies. Issues relating to bio-energy should be integrated into existing and emerging planning frameworks with the aim of securing sustainable development.

Promotion of Wood-Fuel

The role of wood-fuels produced in both forest and non-forest areas should be defined, and treated as an important economic sub-sector requiring development. Wood energy should be integrated into rural energy supply strategies and pursued as a common task for all relevant sectors – residential, agricultural, commercial, institutional, and industrial. Wood-fuel should be looked on as an important product in its own right, rather than just as a by-product of agricultural and/or forest land. Integrated wood-fuel production on agricultural land should be promoted.

There is a need to encourage woodlot owners to form "industrial clusters" and improve wood energy supply chains (production through harvesting to processing and delivery) with dependable and sustainable capacities. A focus should be given to providing increased information and educational programming to forestland owners so that they can make informed decisions about forest management. Special attention should also be paid to the great number of small-scale woodlot and shelterbelt owners.

Research and Reporting

The process of developing this report revealed several informational shortfalls, which due to their extensive nature, or the lack of easily available fundamental information, require additional study, analysis, and reporting. These areas include:

- Emission standards – the legislation and regulations that apply to wood heating applications need to be analyzed according to project scale, plus the location, fuel source, and the economic sector involved. The authors discovered that there are no easy answers to the question of acceptable emission levels available from or within a single coherent source.
- Heating equipment manufacturers and suppliers – there has been a surge of wood heating technology hitting the prairie market. Farm media publications show the number of suppliers advertising in these publications has increased many fold in the past few years. No doubt there are quality products in that mix, however, it is not just the suppliers that are new, so are very many of the manufacturers. There is no rating system of the businesses and technologies now competing for sales in a hot and growing market. The market place will have to decide on who is worthy of market share. However, some appraisal of technologies needs to be done, at least to the fundamental level of essential requirements in modern wood heating equipment in order to protect the unaware, and untrained from costly mistakes. The original source of the list of manufacturers and suppliers contained in Appendix 2 was the Natural Resources Canada, RETScreen Software.[42] This list not only needs to be expanded to include all legitimate participants in this field, and although it is assumed that all boilers meet Canadian safety standards, the quality and efficiency of the equipment needs to be rated by a Provincial or Federal authority. Perhaps this is a role that the Prairie Agricultural Machinery Institute could undertake.
- A more accurate forestland inventory determining land area, species, and population density would be desirable. Even more important would be solid research and determination of some sustainability factor. The term sustainability itself produces argument among forestry specialists. Forestry management profiles vary considerably. For example, huge volumes of dead trees fall to the forest floor and are left to rot annually. In some jurisdictions in Europe, to permit this to happen is illegal.
- With Alberta's booming economy, commercial and industrial sectors have experienced huge growth in the past three years. Numbers from 2004 and earlier do not fully reflect energy consumption in Alberta. Wherever practical, more up-to-date numbers need to be secured. Statistics Canada reports an exceptional increase in all-sector, building permits across Canada, but especially the commercial component, and especially in Alberta and B.C.

> The dynamic commercial component (the largest of the three non-residential components) has been on an upward trend since October 2005. Furthermore, the average monthly value of commercial permits issued since the beginning of 2007 was 21.2% higher than in 2006.[43]

Two significant sectors were, by intention, not included in this report – the Agriculture and Residential Sectors. Although the residential sector is included to a minor degree under district heating projects, it was not specifically addressed. It is recommended that the Agricultural and Residential Sectors become the topic of a dedicated study. Additionally, it is the opinion of the authors that the Agricultural Sector presents the greatest opportunity for successful implementation of wood, heating projects. This is especially true in areas of the province supporting native tree stands and some planted woodlots. In this case, the fuel is already owned by the farmer, or part of his mortgage structure, and generally supported by other agricultural enterprises. This positively affects two significant input factors; a reliable source of wood, and transportation costs.

Extension

The level of understanding of basic wood heating parameters no longer exists as common knowledge in our population – rural or urban. The basics of wood heating were not passed on from grandpa as natural gas took over from coal and wood after WWII. When we speak of the development and operation of modern wood-fueled boilers, the information gap becomes huge. It is strongly recommended that Alberta Agriculture and Food undertake an expanded series of training initiatives to upgrade the knowledge of government employees, rural, farm individuals, and rural, non-farm commercial and industrial managers and ownership of the advantages and processes of wood heating technology and the positive economics and environmental value of using such technology:

- Wood biomass must become a profitable business for energy companies, sub-contractors, and forest owners in order to see any sustained success. This is unlikely to develop rapidly or on any sizeable scale without the direct involvement of government. The climate needed to produce economic success is missing many of the positive factors cited in the barriers and recommendations sections.
- The environmental value of using wood heating – GHG neutral status – is not at all understood by consumers and amazingly, also by a large proportion of government employees and officials involved in shaping alternative heating choices.
- Education and training should play a central role in mobilizing the wood-energy resources. Government, academic institutions, and professional bodies should address education, training, and the need for the sensitization of all wood producing stakeholders and energy consumers with regard to wood-energy skills and entrepreneurship. Wood-energy issues should be introduced into forestry training curricula.

Legislation, Policy, and Regulation

General Policies

In order to encourage biomass-energy development, prevailing rules and regulations, which hamper wood energy, development should be reviewed and amended. Policies and practices regulating the energy market in Alberta should avoid contradictory signals and undesireable outcomes, including undue market distortions.

- The government should verify that strategies and legislation outside the renewable energy policy area do not have negative effects on bio-energy development efforts.
- The rebate program for Natural Gas causes an artificial price gap between fossil fuel and bio-energy use with a negative effect on the feasibility of bio-energy projects. The Province of Alberta should offer financial incentives to stimulate the use of woody biomass and encourage technical innovation as a way of narrowing the price gap.

- Strategies for the efficient utilization of wood resources should be developed with reference to the existing agricultural woodlot programs, including the enhanced promotion of the positive environmental and socio-economic impacts.
- Regional development plans and programs should be used particularly to facilitate small and medium-sized bio-energy projects.
- The Province of Alberta can set examples by promoting bio-energy through sponsoring demonstration projects with non-governmental organizations and retrofitting existing government buildings with bio-energy heating systems.

Standardization

Standardization of terms would enhance the understanding of input factors of the wood fuel source. Virtually all energy consumers in Alberta purchase natural gas, in GJ, for heating their home or business premises. Also, NG comes with a standardized heating value as designated under government regulation. Tighter regulation of the wood supply industry terminology is an obvious need in support of wood fuel substitution:

- In order for the average consumer to make informed choices, they must determine the heating value yielded by their proposed wood fuel (HHV, and LHV, also GHV or NHV), and the moisture content varying from wet to green to oven-dry and convert numbers usually involving BTUs and/or kWs into GJ. This must also be integrated into the efficiency rating of the proposed new wood-heating equipment. Only then can it be compared to the GJ use of the existing NG, heating technology.
- Additionally, the users or purchasers of round wood (firewood logs) may also need to integrate cords of various types into their calculations. For chip, pellet, and briquette users, tons, tonnes cubic feet, cubic yards, and cubic meters have to be rationalized into the process. The promoted qualities of birch, fir, pine, and spruce, over poplar and willow only add to the confusion.
- The choice of logs, chips, pellets, briquettes, added to the possibility of sawdust, and waste wood do not make the understanding of the choices any easier. Many heating appliances are sold to consumers who have no grasp of the cost/GJ of the more expensive pelleted, bagged fuel they need to purchase. This eventually leads to considerable user dissatisfaction.

Permitting Processes

As demonstrated previously, industrial wood-waste is a significant resource for wood fueled energy projects in Alberta, which triggers a discussion of the terms “waste or biomass”. While wood-waste is attractive through the disposal, tipping-fee savings or neutral fuel price aspects, it may introduce disadvantages through Alberta Environment permitting and approval processes and the negative public impression of waste incineration. Redefinition of wood-waste categories and permitting conditions would help to overcome this barrier to wood-waste, biomass projects.

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Appendices

Appendix 1: Heating Audit

The form below enables the auditor to separate out all cost factors experienced in an Alberta NG heating system, and therefore capture month by month totals for comparison since the NG supply system was de-regulated. Price changes do not generally occur at month end and NG landed costs include administration fees, distribution fees, franchise fees, and GST, in addition to the price of gas. A wood heating system removes some but not all of these incidental expenses contained in NG heating systems. This understanding is critical when analyzing the cost factors of replacing NG with wood.

Energy Audit - Heating Cost

Audit Date

Fuel Type
Site Number **Meter Number**
Building use **Location**
Energy Use Period

Month	Day F-T	Fuel Cost								Delivery Cost				
		GJ	Rate	Fuel Cost	Adm	GST	Fuel S-total	Rebate	Fuel Total	Fixed Cost	Var. Cost	GST	Del. S-total	Total Cost
Jan														
Feb														
Mar														
Apr														
May														
Jun														
Jul														
Aug														
Sep														
Oct														
Nov														
Dec														
Total														

Audit completed by

Appendix 2: North American Heating Product Suppliers[41]

Advanced Alternative Energy Corp.
1207 North 1800 Rd.
Lawrence, KS 66049 USA
phone: +1 785 842 1943
fax: +1 785 842 0909
mailto:lbj@cjnetworks.com
http://www.aaecorp.com/

Alce Co.
10 rue de la Dime
4053 Embourg, Belgium
phone: +32 4 365 04 40
fax: +32 4 365 04 40
mailto:alce@skynet.be
http://www.users.skynet.be/sky36365/

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12 Sefton Lane, Meltham
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sales@alpineboilers.co.uk

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Appendix 3: Glossary and Abbreviations[10]

Glossary

A

Activity (Activité): Term used to characterize major drivers of energy use in a sector (e.g. floor space area in the commercial/institutional sector).

AECO-C Hub (Centre de stockage AECO-C): A hub is a market centre where several pipelines interconnect and where many buyers and sellers trade gas, thereby creating a liquid pricing point. The AECO-C hub is the main pricing point for Alberta natural gas and represents the major pricing point for Canadian gas. Prices are determined via the spot market, which includes all transactions for sales of 30 days or less, but most typically refers to a 30-day sale.

Agriculture (Agriculture): The agriculture sector includes all types of farms, including livestock, field crops, grain and oilseed farms, as well as activities related to hunting and trapping. Energy used in this sector is for farm production and includes energy use by establishments engaged in agricultural activities and in providing services to agriculture. Agriculture energy use is included in total secondary energy use for Canada.

Air conditioning (Climatisation): Set of operations aimed at comfort by creating and maintaining predetermined conditions of temperature, relative humidity, speed and purity of air.

Air exchanger (Échangeur d'air): A device allowing the transfer of air from one area to another.

Air-to-air heat pump (Thermopompe air-air): A system that provides heat by removing it from the outside air and transferring it to indoor air. The process is reversed to provide cooling.

Alternate fuel (Carburant de remplacement): Every fuel other than conventional fuel (i.e. gasoline and diesel) that is used for motor vehicle transportation. The most common alternative fuels in Canada are propane, compressed natural gas and a blend of ethanol and gasoline.

Apartment (Appartement): This type of dwelling includes dwelling units in apartment blocks or apartment hotels; flats in duplexes or triplexes (i.e. where the division between dwelling units is horizontal); suites in structurally converted houses; living quarters located above or in the rear of stores, restaurants, garages or other business premises; caretakers' quarters in schools, churches, warehouses, etc.; and private quarters for employees in hospitals or other types of institutions. The *Survey of Household Energy Use* (SHEU-2003) only includes apartments located within a building with fewer than five storeys.

Appliance (Appareil ménager): Energy-consuming equipment used in the home for purposes other than air conditioning, centralized water heating and lighting. Includes cooking appliances (gas stoves and ovens, electric stoves and ovens, microwave ovens, and propane or gas grills); cooling appliances (evaporative coolers, attic fans, window or ceiling fans, and portable or table fans); and refrigerators, freezers, clothes washers and dishwashers. Other appliances include small ones such as televisions, video cassette recorders, digital video disc players, radios, computers and toasters.

Attic (Grenier): The accessible space between roof rafters and ceiling joists.

Automatic defrost (Dégivrage automatique): Automatic elimination of frost deposits that may have formed on the inside walls of a freezer.

Auxiliary equipment (Équipement auxiliaire): With the exception of auxiliary motors (see Auxiliary Motors), "auxiliary equipment" includes stand-alone equipment powered directly from an electrical outlet such as computers, photocopiers, refrigerators and desktop lamps. It also includes equipment that can be powered by natural gas, propane or other fuels, such as clothes dryers and cooking appliances.

Auxiliary motors (Moteurs auxiliaires): Refers to devices used to transform electric power into mechanical energy in order to provide a service, such as pumps, ventilators, compressors and conveyors.

B

Ballast (Régulateur): A device used with a fluorescent-type lamp to provide the necessary starting and operating electric conditions.

Basement (Sous-sol): The usable part of a building that is located partially or completely beneath the outside ground level.

Biomass (Biomasse): Includes wood waste and pulping liquor. Wood waste is a fuel consisting of bark, shavings, sawdust and low-grade lumber and lumber rejects from the operation of pulp mills, sawmills and plywood mills. Pulping liquor is a substance primarily made up of lignin and other wood constituents and chemicals that are by-products of the manufacture of chemical pulp. It can produce steam for industrial processes when burned in a boiler and/or produce electricity through thermal generation.

Bitumen (Bitume): A very heavy crude oil or tar consisting of a naturally occurring viscous mixture, mainly hydrocarbons heavier than pentane that may contain sulphur compounds and other minerals. In its natural viscous state, bitumen is not recoverable at a commercial rate through a well.

Boiler (Chaudière): A pressurized system in which water is vaporized to steam by heat transfer from fuel combustion. Steam thus generated may be used directly as a heating medium or converted to mechanical energy.

Btu (British thermal unit) (Btu [British thermal unit]): The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Built-in oven (Four encastré): A domestic appliance placed in a closed compartment with a supply of heat, used for cooking food. In contrast to the kitchen stove, the built-in oven is neither mobile nor equipped with surface heating elements (burners).

C

Capacity utilization (Utilisation de la capacité): The rates of capacity use are measures of the intensity with which industries use their production capacity. It is the ratio of an industry's actual output to its estimated potential output.

Carbon dioxide (CO_2) (Dioxyde de carbone): A compound of carbon and oxygen formed whenever carbon is burned. Carbon dioxide is a colourless gas that absorbs infrared radiation, mostly at wavelengths between 12 and 18 microns. It behaves as a one-way filter, allowing incoming visible light to pass through in one direction, while preventing outgoing infrared radiation from passing in the opposite direction. The one-way filtering effect of carbon dioxide causes an excess of the infrared radiation to be trapped in the atmosphere; thus it acts as a "greenhouse" and has the potential to increase the surface temperature of the planet (see Greenhouse Gas).

Ceiling fan (Ventilateur de plafond): A motorized fan installed on the ceiling and used to force the circulation of air in a given direction.

Census Metropolitan area (Région métropolitaine de recensement): As defined by Statistics Canada, a Census Metropolitan Area (CMA) is a very large urban area (know as urban and rural fringes) that have a high degree of social and economic integration with the urban core.

Central air conditioner (Climatisateur central): Powered by electricity, this device removes heat from an indoor living space to maintain comfortable conditions during hot, humid weather and conveys it to the outdoors. Designed to cool a house, the large compressor and outdoor coil are located outdoors and are connected by refrigerant lines to an indoor coil mounted in the furnace. The same duct system is used for both heating and cooling air distribution.

Clothes dryer (Sécheuse): Appliance used to dry clothing by evaporation accelerated by applying heat and rapid air movement. The air is usually heated by electricity or natural gas.

Clothes washer (Laveuse): An appliance for washing laundry, composed of a washtub, an agitator and a system for draining used water. An opening at the top or front of the appliance provides access to the washtub.

Coal (Charbon): A combustible mineral substance (carbonized vegetable matter).

Cogeneration (Cogénération): The simultaneous production of electric power and another form of useful energy (such as heat or steam) from the same fuel source. The heat or steam (that would otherwise be wasted) can be used for industrial process or other heating and/or cooling applications.

Coke (Coke): A hard, porous product made from baking bituminous coal in ovens at high temperatures.

Coke oven gas (Gaz de cokerie): A complex gas (containing hydrogen, methane, light oil, ammonia, pitch, tar and other minerals) released during coke production.

Combined heat and power (CHP) generation (Production combinée de chaleur et d'électricité [CCE]): *See* Cogeneration.

Compact fluorescent lights (Lampe fluorescente compacte): General term applied to smaller-diameter fluorescent lights.

Compact stereo (Minichaîne stéréo): A compact stereo is a one-component stereo system that is not capable of being easily carried or moved about because of its size or design (no built-in handles or carrying straps).

Company average fuel consumption (CAFC) (Consommation moyenne de carburant de

l'entreprise [CMCE]): The Government of Canada encourages improvements in the fuel efficiency of the Canadian new vehicle fleet by setting voluntary annual company average fuel consumption (CAFC) goals for vehicle manufacturers and importers.

Component stereo system (Chaîne stéréo): A component stereo system has two or more components. Each component has its own electrical plug. The components and speakers operate together to produce sound. Components may include an amplifier, audio-video receiver, CD player, tape player, record player and radio tuner.

Condensation (Condensation): A physical reaction wherein water vapour molecules unite to form water droplets that attach themselves to the interior surface of a window.

Condensing clothes dryer (Sécheuse à condensation): A clothes dryer where all the steam created by the drying process is cooled and condensed back into water. This water is then collected in a reservoir inside the machine. It is a vent-less clothes dryer.

Conversion loss (Perte de conversion): The energy lost during the conversion from primary energy (petroleum, natural gas, coal, hydro, uranium, wind, biomass and solar energy) into electrical energy. Losses occur during generation, transmission and distribution of electricity, and include plant and unaccounted-for uses.

Cooktop (Plaque chauffante): Appliance not attached to an oven, used for cooking food (the kitchen stove is a one-piece appliance containing an oven and a cooktop).

Cooling degree-day (CDD) (Degré-jour de réfrigération [DJR]): A measure of how hot a location was over a period, relative to a base temperature. In this handbook, the base temperature is 18.0°C and the period is one year. If the daily average temperature exceeds the base temperature, the number of cooling degree-days for that day is the difference between the two temperatures. However, if the daily average is equal to or less than the base temperature, the number of cooling degree-days for that day is zero. The number of cooling degree-days for a longer period is the sum of the daily cooling degree-days for the days in that period.

Cooling degree-day index (Indice des degrés-jours de réfrigération) : A measure of how relatively hot (or cold) a year was when compared with the cooling degree-day (CDD) average. When the CDD index is above (below) 1, the observed temperature is warmer (colder) than normal. The CDD normal represents a weighted average of the 1951-1980 CDDs observed in a number of weather stations across Canada. Its value, which varies from year to year because of the flow of population, was 170 CDDs in 2004.

Crawl space (Vide sanitaire): A ventilated, open, low space between the ground and the lowest storey of a building.

D

Dishwasher (Lave-vaisselle): An appliance designed to wash dishes automatically. Water is sprayed over dishes either by fixed jets aimed at a rotating basket or by rotating jets.

Distance travelled (Distance parcourue): An estimation of the number of kilometres (km) travelled per vehicle during a given period. The term "distance travelled" is often interchanged with "number of kilometres travelled."

Double-paned window (Fenêtre à vitrage double): A window containing two panes of glass separated by an air space.

Dwelling (Logement): A dwelling is defined as a structurally separate set of living premises with a private entrance from outside the building or from a common hallway or stairway inside.A private dwelling is one in which one person, a family or other small group of individuals may reside, such as a single house or apartment.

E

Economies of scale (Économies d'échelle): Occurs when there are advantages to large-scale production for a firm. Long-run average costs fall as production levels increase, reducing the per unit cost of the output.

Electric baseboard (Plinthe électrique): An electric heat-emitting appliance located at ground (or ceiling) level. This appliance may be made of cast iron or flanges.

Electric radiant heating (Chauffage radiant électrique): Radiant heat sources warm objects within their range without necessarily having to heat up the surrounding space. Two types of electric radiant heating are portable infrared heaters and electric radiant heating cables installed in a floor or ceiling.

Electricity (Perte de conversion de l'électricité): A form of energy emanating from electric charges at rest or in movement.

End-use (Utilisation finale): Any specific activity that requires energy (e.g. refrigeration, space heating, water heating, manufacturing processes and feedstock).

Energy efficiency (Efficacité énergétique): This term refers to how effectively energy is being used for a given purpose. For example, providing a similar (or better) level of service with less energy consumption on a per unit basis is considered an improvement in energy efficiency.

Energy intensity (Intensité énergétique): The amount of energy used per unit of activity. Examples of activity measures are households, floor space, passenger-kilometres, tonne-kilometres, physical units of production and constant dollar value of gross domestic product.

Energy source (Source d'énergie): Any substance that supplies heat or power (e.g. petroleum, natural gas, coal, renewable energy and electricity).

ENERGY STAR® qualified product (Produit homologué ENERGY STAR®): As an international symbol of energy efficiency, the ENERGY STAR mark helps consumers identify which appliances on the market are the most energy efficient in their class. Administered in Canada by Natural Resources Canada, the ENERGY STAR symbol is used mainly to identify products offering premium performance levels in energy efficiency. The ENERGY STAR symbol can be found on product packaging, literature and advertising and on the products themselves. In some cases, you may also find it on the EnerGuide label. The following criteria are used to determine if an appliance qualifies for the ENERGY STAR mark:

- A standard-size **refrigerator** must exceed the minimum energy performance standard established by the Government of Canada by at least 10 percent in 2003, and at least 15 percent in 2004. A standard-size **freezer** must, in 2003, exceed these standards by at least 10 percent. Compact refrigerators and freezers must exceed these same standards by at least 20 percent.
- A standard-size **dishwasher** must exceed the minimum energy performance standards established by the Government of Canada by at least 25 percent in 2003. Only standard-size dishwashers can qualify for the ENERGY STAR mark.

- A **clothes washer** must use from 35 to 50 percent less water and at least 50 percent less energy per load than conventional washers.
- A **television** must use 3 watts or less when turned off, i.e., use 75 percent less energy than conventional televisions, which consume up to 12 watts when turned off.
- A **video cassette recorder** must use 4 watts or less when turned off, i.e., use 70 percent less energy than conventional video cassette recorders, which consume up to 13 watts when turned off.
- A **DVD player** must use 3 watts or less when turned off, i.e., use 75 percent less energy than conventional DVD players, which consume up to 10 watts when turned off.
- A **system stereo** must use 2 watts or less when turned off, i.e., use 70 percent less energy than conventional stereo systems, which consume up to 7 watts when turned off.
- A **room air conditioner** must exceed the minimum energy performance standards established by the Government of Canada by at least 10 percent in 2003. A **central air conditioner** must exceed these standards by 20 percent.
- A **forced-air furnace** must have an annual fuel utilization efficiency rating of 90 or higher. A f**urnace (boiler) with hot water or steam radiators** must have an annual fuel utilization efficiency rating of 85 or higher.
- A **furnace (boiler) with hot water or steam radiators** must have an annual fuel utilization efficiency rating of 85 or higher.

F

Factorization method (Méthode de factorisation): A statistical method, based on the Log-Mean Divisia Index I (LMDI I) approach, is used to separate changes in energy use into five factors: activity, structure, weather, service level and energy efficiency.

Fireplace (Foyer): The space reserved in a wall or chimney mantle in which a heating apparatus can be installed and equipped with a chimney flue.

Floor space (area) (Surface de plancher [superficie]): The area enclosed by exterior walls of a building. In the residential sector, it excludes parking areas, basements or other floors below ground level; these areas are included in the commercial/institutional sector. It is measured in square metres.

Fluorescent lighting (Lumière fluorescente): A lighting unit that emits light by the excitation of a gas (such as neon) enclosed within a sealed tube or bulb. The terms "neon tube", "neon" and "fluorescent tube" are all used to designate the source of fluorescent light.

Fossil fuel (Combustible fossile): Any naturally occurring organic fuel, such as petroleum, coal and natural gas.

Foundation (Fondation): A structure of masonry, reinforced concrete or steel that supports and immobilizes support units and structural members of a frame. It is designed to evenly distribute all loads that are transmitted to it toward or under the ground. The word foundation includes basement, crawl space and slab on grade (concrete). It is the base on which a house rests.

Freezer (Congélateur): Appliance designed to freeze products at a temperature of approximately -15°C. The process of freezing involves removing heat from products to lower their temperature to a point where most of the water they contain is solidified. This is a separate appliance and is not part of a refrigerator. It is built as either a vertical model (with a door that opens outward) or a chest-style model (with a lid).

Fuel (Carburant): Refers to gasoline, fuel mixtures, diesel and propane, and to fuels used on farms. Vehicles that use a fuel other than gasoline represent only a small percentage of private vehicles.

Full cord (standard) (Corde de bois [standard]): The English standard measure equivalent to a pile of wood measuring 1.2 m x 1.2 m x 2.4 m (4' x 4' x 8'); that is, 3.4 m^3 (128 cu. ft.). The term "bush cord" is sometimes used to designate the full cord.

Furnace (boiler) with hot water or steam radiators (Fournaise [chaudière] avec radiateurs à eau chaude ou à vapeur): A heating system with a pump that distributes water heated by a boiler through a network of pipes in the dwelling to radiators in the rooms. The radiators release the heat from the water into the room.

Furnace with forced air (hot air vents) (Fournaise avec bouches d'air chaud): A furnace that distributes heat by using a motor-driven fan to circulate heated air through the duct system of a dwelling. The heated air is delivered to different rooms through air vents.

G

Garage (Garage): A shelter or space, generally enclosed, designed to accommodate vehicles other than horse-drawn vehicles.

Geothermal system (Système géothermique): A geothermal system is a heat exchanger that uses the earth or ground water or both as sources of heat in the winter and as the "sink" for heat removed from the building in the summer. The system provides heat by removing it from the earth through a liquid, such as ground water or an antifreeze solution, which is upgraded by the heat pump and transferred to indoor air. The system provides cooling by reversing the process.

Gigajoule (Gigajoule): One gigajoule equals 1×10^9 joules (see Petajoule).

Greenhouse gas (GHG) (Gaz à effet de serre [GES]): A greenhouse gas absorbs and radiates heat in the lower atmosphere that otherwise would be lost in space. The greenhouse effect is essential for life on this planet, since it keeps average global temperatures high enough to support plant and animal growth. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs) and nitrous oxide (N_20). By far the most abundant greenhouse gas is CO_2, accounting for 70 percent of total greenhouse gas emissions (see Carbon dioxide).

Greenhouse gas intensity (Intensité en gaz à effet de serre): The amount of greenhouse gas emitted per unit of energy used.

Gross domestic product (GDP) (Produit intérieur brut [PIB]): The total value of goods and services produced within Canada during a given year. Also referred to as annual economic output or, more simply, output. To avoid counting the same output more than once, GDP includes only final goods and services – not those that are used to make another product. GDP figures are reported in constant 1997 dollars.

Gross output (GO) (Production brute [(PB)]): The total value of goods and services produced by an industry. It is the sum of the industry's shipments plus the change in value due to labour and capital investment. Gross output figures are reported in constant 1997 dollars.

H

Halogen light bulbs (Lampe à halogène): Incandescent lights containing halogen gases, which burn very hot while providing an intense white light.

Heat gain (Gain de chaleur): Heat gained by a building from the operation of appliances. These heat gains reduce the space heating load in the winter and increase the space cooling load in the summer.

Heat loss (Perte de chaleur): Represents the amount of energy released as heat by an appliance or piece of equipment while it is in operation.

Heat pump (Thermopompe): A heating and cooling unit that draws heat from an outdoor source and transports it to an indoor space for heating purposes; or inversely, for cooling purposes.

Heating degree-day (HDD) (Degré-jour de chauffage [DJC]): A measure of how cold a location was over a period, relative to a base temperature. In this handbook, the base temperature is 18.0°C and the period is one year. If the daily average temperature is below the base temperature, the number of heating degree-days for that day is the difference between the two temperatures. However, if the daily average temperature is equal to or higher than the base temperature, the number of heating degree-days for that day is zero. The number of heating degree-days for a longer period is the sum of the daily heating degree-days for the days in that period.

Heating degree-day index (Indice des degrés-jours de chauffage): A measure of how relatively cold (or hot) a year was when compared with the heating degree-day (HDD) average. When the HDD index is above (below) 1, the observed temperature is colder (warmer) than normal. The HDD normal represents a weighted average of the 1951-1980 HDDs observed in a number of weather stations across Canada. Its value, which varies from year to year because of the flow of population, was 4476 HDDs in 2004.

Heavy truck (As referred to in the *Energy Efficiency Trends in Canada* report)(Camion lourd): A truck with a gross vehicle weight that is more than, or equal to, 14,970 kg (33,001 lb.). The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight.

High efficiency back-up furnace (Fournaise d'appoint à haut rendement): A furnace with additional heat exchange surfaces used to supplement a heat pump. These extract most of the heat remaining in the combustion by-products through a condensing heat-exchange process.

Horsepower (hp) (Horsepower): A unit of power commonly used for vehicle engines, equal to 75 metre kilograms-force per second; equal to 735.49875 watts.

Hot water tank (Réservoir d'eau chaude): A thermally insulated tank with automatic controls designed to produce and hold hot water.

Hours of operation (Heures d'exploitation): The time when the building is open for normal operation, not including the time when only maintenance, housekeeping of security staff may be in the building.

Household (Ménage): A person or a group of people occupying one dwelling unit is defined as a household. The number of households will, therefore, be equal to the number of occupied dwellings.

Household size (Taille du ménage): The number of people per household.

Housing stock (Parc de logements): The physical number of dwellings is referred to as the housing stock. As opposed to the number of households, which refers to the number of occupied dwellings, housing stock includes both occupied and unoccupied dwellings.

I

Idling (Marche au ralenti): Occurs when power is delivered by an engine but is not used for any useful work.

Imputation (Imputation): A statistical process that entails the replacement of missing values with a realistic value through analysis, using the information available about the unit in question.

Incandescent light (Incandescente): A term generally applied to lamps that generate light when an electric current heats a metallic filament to incandescence. The expression also applies to arc lamps.

Incandescent light bulb (Ampoule à incandescence): A glass globe containing electrodes within a vacuum, which produces electric light. More commonly called an ordinary light bulb.

Insulation blanket (Couverture isolante, Isolation du réservoir d'eau): Insulation that covers a hot water tank in order to conserve energy.

K

Kilometre (km) (Kilomètre [km]): A metric unit of distance, equivalent to 0.6214 of a mile.

Kilowatt-hour (kWh) (Kilowattheure [kWh]): The commercial unit of electricity energy equivalent to 1000 watt-hours. A kilowatt-hour can best be visualized as the amount of electricity consumed by ten 100-watt bulbs burning for an hour. One kilowatt-hour equals 3.6 million joules (*see* Watt).

L

Large car (Grosse voiture): A car with a gross vehicle weight of 1182 kg (2601 lb.) or more. The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight.

Large truck (as referred to in the *National Private Vehicle Use Survey*) (Gros camion): A truck with a gross vehicle weight of more than, or equal to, 14,970 kilograms (30,001 lb.).

Light truck (Camion léger): A truck of up to 3855 kg (8500 lb.) of gross vehicle weight. The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight. This class of vehicles includes pickup trucks, minivans and sport utility vehicles.

Light truck and van category (Catégorie camion léger et fourgonnette): A category of light motorized vehicles - including minivans, pickup trucks, vans and other types of light trucks, such as utility vehicles - designed primarily to carry light goods, with limited capacity to carry passengers.

Light-duty vehicle (Véhicule léger): A car, motorcycle and light truck, including a van.

Liquefied Petroleum Gases (LPG) and Gas Plant Natural Gas Liquids (NGL) (Gaz de pétrole liquéfié [GPL] et liquides de gaz naturel [LGN] des usines de gaz): Propane and butane are liquefied gases extracted from natural gas (i.e. gas plant NGL) or from refined petroleum products (i.e. LPG) at the processing plant.

Louvred unit (Panneau persienné): A window-mounted air-conditioning unit that has accordion-style or louvred side panels installed between the unit and the window frame to prevent drafts.

Low-E coating (Couche à faible émissivité): Low-E (low-emissivity) coatings are highly reflective, transparent coatings applied to windowpanes to slow heat loss.

M

Medium truck (Camion moyen): A truck with a gross vehicle weight ranging from 3856 to 14,969 kg (8501 to 33,000 lb.). The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight.

Megajoule (Mégajoule): One megajoule equals 1 x 10^6 joules (*see* Petajoule).

Megawatt-hour (mWh) (Mégawattheure [mWh]): One megawatt-hour equals 1 x 10^6 watt hours (*see* Kilowatt-hour).

Methane (CH_4) (Méthane): A very potent greenhouse gas, as the release of one tonne of methane has the same GHG impact as 21 tonnes of carbon dioxide. It has an energy content of 20.3 MJ/m^3 (*see* Greenhouse Gas).

Microwave oven (Four à micro-ondes): An appliance that emits electromagnetic waves capable of agitating water molecules contained in food. The repeated friction of these molecules raises the temperature, enabling the food to cook rapidly.

Minivan (Mini-fourgonnette): A type of small van introduced in 1984 to carry up to seven occupants.

Mobile home (Maison mobile): A moveable dwelling designed and constructed to be transported by road on its own chassis to a site and placed on a temporary foundation (such as blocks, posts or a prepared pad). If required, it can be moved to a new location.

Model year (Année automobile): An annual period in which a national automotive industry organizes its operations and within which new models are announced. For example, if the "model year" is 2004, it begins September 1, 2003, and ends August 31, 2004.

Moisture detector (Détecteur d'humidité): A moisture detector is a sensor in a clothes dryer used to check the amount of moisture in the clothes and to terminate the dryer cycle automatically when the clothes are dry.

Multifactor productivity (Productivité multifactorielle): The ratio of output per unit of combined inputs (capital services and labour services).

N

Natural gas (Gaz naturel): A gaseous mixture of saturated hydrocarbons that is found in underground deposits, either alone or with petroleum. It is delivered directly to buildings by pipelines.

Non-louvred unit (Panneau non persienné): Wall-mounted air-conditioning unit that does not have accordion-style or louvred side panels around it.

North American Industry Classification System (NAICS) (Système de classification des industries de l'Amérique du Nord [SCIAN]): A classification system that categorizes establishments into groups with similar economic activities. The structure of NAICS, adopted by Statistics Canada in 1997 to replace the 1980 Standard Industrial Classification (SIC), was developed by the statistical agencies of Canada, Mexico and the United States.

O

Oil (Mazout): A flammable liquid derived from petroleum, which is dark brown or black and more or less viscous. It is used as fuel to produce heat and energy.

Outdoor lights with motion detector (Lumière extérieure munie de détecteur de mouvements): Outdoor lighting fixtures that turn on when the sensor detects movement and turn off automatically after a set period of time.

P

Passenger car category (Catégorie automobile): A category of light motorized vehicles, including convertibles, sedans, station wagons and hatchbacks, that are designed primarily to carry passengers.

Passenger-kilometre (Pkm) (Voyageur-kilomètre): An activity measure in the passenger transportation sub-sector describing the transportation of one passenger over a distance of one kilometre.

Penetration rate (Taux de pénétration): The rate at which a technology infiltrates the stock of buildings (e.g. number of refrigerators per household at a specified time).

Per capita (Par habitant): For each person.

Petajoule (Petajoule): One petajoule equals 1×10^{15} joules. A joule is the international unit of measure of energy – the energy produced by the power of one watt flowing for a second. There are 3.6 million joules in one kilowatt-hour (*see* Kilowatt-hour).

Petroleum (Pétrole): A naturally occurring mixture consisting of predominantly hydrocarbons in the gaseous, liquid or solid phase.

Pickup truck (Camionnette): A light motorized vehicle with an enclosed cab that usually accommodates two to three occupants and, in the rear, has an open bed with low sides designed to carry cargo.

Pillars (Piliers): Wood, concrete or metal columns that are driven into the ground and used to support a building and prevent it from sinking into the ground.

Pilot light (Veilleuse [foyer à gaz]): A small flame within a gas- or oil-burning unit that is allowed to burn continually to enable automatic ignition of the unit.

Portable electric heater (Radiateur électrique portatif): A heating unit that can be easily transported. The source of heat is an electrically heated resistance.

Portable stereo (Chaîne stéréo portative): A stereo that is capable of being easily carried or moved about (using built-in handles or carrying straps). A portable stereo is also a one-component stereo system. Walkmans and MP3 players are not considered to be portable stereos.

Primary energy use (Consommation d'énergie primaire): Represents the total requirement for all uses of energy, including energy used by the final consumer (*see* Secondary energy use), non-energy uses, intermediate uses of energy, energy in transforming one energy form to another (e.g. coal to electricity), and energy used by suppliers in providing energy to the market (e.g. pipeline fuel).

Private vehicle (Véhicule personnel): A light vehicle such as a passenger car, minivan, pickup truck, van and other types of light trucks or utility vehicles used for personal use, regardless of ownership status.

Production of electricity (Production d'électricité): The amount of electric energy expressed in kilowatt-hours produced in a year. The determination of electric energy production takes into account various factors, such as the type of service for which generating units were designed (e.g. peaking or base load), the availability of fuels, the cost of fuels, stream flows and reservoir water levels and environmental constraints.

Programmable thermostat (Thermostat programmable): Device that automatically controls the amount of heat or cold distributed within a room by reacting to room temperature. The programmable thermostat makes it possible to set the desired temperature of a room according to the time of the day.

Propane (Propane): A saturated, aliphatic, linear-chain hydrocarbon (C_3H_8) found in natural gas and petroleum and widely used as a fuel.

Pulping liquor (Liqueur résiduaire): A substance primarily made up of lignin, other wood constituents and chemicals that are by-products of the manufacture of chemical pulp. It can produce steam for industrial processes when burned in a boiler and/or produce electricity through thermal generation.

R

Refrigerator (Réfrigérateur): A movable chest in which the temperature can be reduced and controlled for the preservation of refrigerated foods. Most refrigerators are equipped with a second compartment for freezing foods.

Retrofit (Amélioration éconergétique): The improvement in the energy efficiency of existing energy-using equipment or the thermal characteristics of an existing building.

Roof space (Entretoit): The space between the roof and the highest floor of a house.

Roof air conditioner (Climatisateur individuel): Powered by electricity, this device removes heat from an indoor living space to maintain comfortable conditions during hot, humid weather and conveys it to the outdoors. Unlike a central air conditioner, no ductwork is required. All components are built into a single package that is mounted in a window opening or through the wall. It is a smaller version of a central unit and is intended to cool a small area, such as a room.

Rural area (Région rurale): Any area located outside an urban area is considered to be part of a rural area.

S

Secondary energy use (Consommation d'énergie secondaire): Energy used by final consumers for residential, agricultural, commercial, industrial and transportation purposes.

Sector (Secteur): The broadest category for which energy consumption and intensity are considered within the Canadian economy (e.g. residential, commercial/institutional, industrial, transportation, agriculture and electricity generation).

Service level (Niveau de service): Term used to characterize the increased penetration of auxiliary equipment in commercial/institutional buildings.

Single attached (dwelling) (Maison individuelle attenante): Each half of a semi-detached (double) house and each section of a row or terrace are defined as single attached dwellings. A single dwelling attached to a non-residential structure also belongs to this category.

Single detached (dwelling) (Maison unifamiliale): This type of dwelling is commonly called a single house (i.e. a house containing one dwelling unit and completely separated on all sides from any other building or structure).

Single-paned window (Fenêtre à vitrage simple): A window containing a single pane of glass.

Slab on grade (concrete) (Dalle de béton): A rigid, horizontal (or almost horizontal) concrete structure with a large horizontal surface in relation to its thickness, used as the foundation of a house.

Small car (Petite voiture): A car weighing up to 1181 kg (2600 lb.) of gross vehicle weight. The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight.

Space cooling (Climatisation des locaux d'habitation): Conditioning of room air for human comfort by a refrigeration unit (e.g. air conditioner or heat pump) or by the circulation of chilled water through a central- or district-cooling system.

Space heating (Chauffage des locaux): The use of mechanical equipment to heat all or part of a building. Includes the principal space heating unit and any supplementary equipment.

Sport utility vehicle (Véhicule utilitaire sport): A four-wheel drive vehicle that is not a pickup truck (e.g. Ford Explorer).

Standard Industrial Classification (SIC) (Classification type des industries [CTI]): A classification system that categorizes establishments into groups with similar economic activities.

Storey (Étage): The space contained between two consecutive floors or between one floor and the roof.

Storm window (Contre-fenêtre): A full-width window, either fixed or movable, installed on the exterior of a window for protection against inclement weather. It is usually equipped with a single pane to reduce air leakage.

Stove or kitchen stove (Cuisinière ordinaire): A single-unit appliance used to cook food, combining a cooking surface and an oven. The stove may be heated by wood, coal, oil, gas or electricity, or by different combinations thereof (such as a stove using both natural gas and electricity).

Structure (Structure): Structure refers to change in the makeup of each sector. For example, in the industrial sector, a relative increase in output from one industry over another is considered a structural change; in the electricity generation sector, a relative increase in one fuel over another is considered a structural change.

Supplementary heating (Chauffage d'appoint): A heating system that can be used in addition to a main heating system, as desired, and is flexible enough to respond to rapid variations in heating needs.

Swimming pool (Piscine): Any basin or tank that holds water and that is sufficiently large for swimming.

T

Terajoule (TJ) (Térajoule [TJ]): One terajoule equals 1×10^{12} joules (*See* Petajoule).

Tonne-kilometre (Tkm)(Tonne-kilomètre): An activity measure in the freight transportation sub-sector describing the transportation of one tonne over a distance of one kilometre.

Triple-paned window (Fenêtre à vitrage triple): A window containing three panes of glass separated by air spaces.

U

Urban area (Région urbaine): An area having a population of at least 1000 inhabitants and a population density of at least 400 inhabitants per square kilometre, as determined in the previous census.

V

Van (Fourgonnette): A vehicle with a capacity to carry from five to 15 occupants or a limited amount of cargo. Access is normally through side or rear doors.

Ventilation (Ventilation): The circulation of air through a building to deliver fresh air to occupants.

Vintage (Période de construction): The year of origin or age of a unit of capital stock (e.g. a building or a car).

W

Waste fuel (Combustible résiduaire): A name applied to any number of energy sources other than conventional fuels used in the cement industry. It includes materials such as tires, municipal waste and landfill off-gases.

Water devices (Dispositifs pour l'eau): Water devices include hot water tanks, water-saving shower heads, and tap attachments.

Water heater (Chauffe-eau): An automatically controlled vessel designed for heating water and storing heated water.

Water heating (Chauffage de l'eau): The use of energy to heat water for hot running water, as well as the use of energy to heat water on stoves and in auxiliary water heating equipment for bathing, cleaning and other non-cooking applications.

Watt (W) Watt[W]): A measure of power. For example, a 40-watt light bulb uses 40 watts of electricity (*see* Kilowatt-hour).

Wood stove (Poêle à bois): An enclosed heating unit for burning wood.

Wood waste (Déchets ligneux): Fuel consisting of bark, shavings, sawdust, low-grade lumber and lumber rejects from the operation of pulp mills, sawmills and plywood mills.

List of Abbreviations

$97 (97 $): Constant 1997 dollars

bbl. (baril): Barrel

CAFC (CMCE): Company Average Fuel Consumption

CANSIM (CANSIM): Canadian Socio-Economic Information Management System

CEUM (Modèle d'utilisation finale pour le secteur commercial): Commercial/Institutional End-Use Model

CIEEDAC (Centre): Canadian Industrial Energy End-Use Data and Analysis Centre

EC (EC): Environment Canada

EER (EER): Energy Efficiency Ratio

GDP (PIB): Gross Domestic Product

GHG (GES): Greenhouse Gas

GJ (GJ): Gigajoule = 1×10^9 joules

GO (PB): Gross Output

GWh (GWh): Gigawatt-hour = 1×10^9 Wh

km (km): Kilometre

kW (kW): Kilowatt

kWh (kWh): Kilowatt-hour = 1×10^3 Wh

L (L): Litre

LPG (GPL): Liquefied Petroleum Gases

m^2 (m^2): Square metre

m^3 (m^3): Cubic metre

MJ (MJ): Megajoule = 1 x 10^6 joules

Mt of CO_2e (Mt éq CO_2): Megatonnes of carbon dioxide equivalent = 1 x 10^6 tonnes

NAICS (SCIAN): North American Industry Classification System

n.e.c. (n.c.a.): Not elsewhere classified

NEUD (BNCÉ): National Energy Use Database

NGL (LGN): Natural Gas Liquids

NRCan (RNCan): Natural Resources Canada

OEE (OEE): Office of Energy Efficiency

PJ (PJ): Petajoule = 1 x 10^{15} joules

Pkm (Vkm): Passenger-kilometre

RESD (Bulletin): *Report on Energy Supply-Demand in Canada*

REUM (Modèle d'utilisation finale pour le secteur résidentiel): Residential End-Use Model

SEER (SEER): Seasonal Energy Efficiency Ratio

SIC (CTI): Standard Industrial Classification

TEUM (Modèle d'utilisation finale pour le secteur des transports): Transportation End-Use Model

TJ (TJ): Terajoule = 1 x 10^{12} joules

Tkm (Tkm): Tonne-kilometre

UEC (CUE): Unit Energy Consumption

W (W): Watt

Wh (Wh): Watt-hour