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Potential to use biomass for bio-energy in Ontario

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The availability and abundance of vegetable and animal biomass in Ontario has been estimated on the basis of data available through agricultural censes and other resources. Data has been collected and analyzed to estimate the potential to produce electricity using biomass as fuel. During this study the focus was to identify potential biomass from several origins and its prospects to produce electricity in Ontario. It was estimated that biomass could provide 1.25% of the current electricity demand in Ontario.

I. Introduction

Increasing concern about environmental damage due to excessive use of fossil fuels for generating electricity has focused attention on finding and improving techniques to use biomass as a fuel for efficient energy generation. Biomass is defined as organic matter that is recently derived from living organisms and can be converted into energy. Biomass includes crop residues, forest residues, wood wastes, saw dust, manufacturing scraps, the organic component of municipal solid wastes, and animal wastes. The aim of this paper is to assess and analyze prospects to use biomass for producing “bioenergy” in the form of electricity in Ontario.

Bioenergy is any form of useable energy that is produced from biomass. Using biomass as source of energy has several benefits including that it can be green house gas neutral, and combustion of biomass typically emits fewer oxides of sulphur and nitrogen than other fuels. Biomass energy technology may reduce bio-waste disposal problems, may help generate income from waste, and help create jobs in rural areas.

Biomass typically has a relatively low heating value. Franco and Giannini (2005) reported that biomass is generally a fuel with heating value in the range 8-25 MJ/kg, compared to 25-30 MJ/kg for coal, 40-45 MJ/kg for oil and 50-55 MJ/kg for natural gas. Residues from crops, wood, and animal wastes have different heat values, heating values of shelled corn, straw, and wood can be seen in following table 1.

Franco and Giannini (2005) conducted chemical analysis of common biomass fuels and found that sulphur and nitrogen content are less than 0.03% and 0.9 % respectively. These levels are very low compared to the percentage of carbon and hydrogen in biomass. Table 2 shows the chemical composition of different biomass fuels and also reveals that papers and sugar cane begasse offer high heating value.

Table 1.Heating values of crop residues (Source: OMAFRA, 1997)

Crop residue	Shelled corn	Straw	Wood
Heating value (MJ/kg)	16.20	15.20	18.50

Biomass combustion releases a variety of chemical pollutants. The air quality impacts of burning biomass are generally considered less harmful than those associated with coal, but more harmful than those associated with natural gas (Evrendilek and Ertekin, 2003).

Solid biomass can either be directly combusted to produce energy, or it can first be turned into liquid or gaseous fuel. Incineration (direct combustion) and gasification processes are main thermo-chemical conversion methods for biomass. Gasification is the conversion of solid fuels into gaseous form while retaining most of the energy in the original fuel. This is achieved by exposing the solid fuel to controlled temperature and oxygen levels. Incineration is combustion of organic material in under conditions of excess oxygen and high temperatures. Briquetting is a technology in which low density biomass is compressed into high density biomass in the form of small briquettes and this technology facilitates the transportation of biomass. Quaak, Knoef and Stassen (1999) give a range for briquette bulk density of 150-200 kg/m^3 for straw shaving and 600-900 kg/m^3 for solid wood.

Table 2.Chemical composition of different biomass fuels. (Source: Franco and Giannini, 2005)

Biomass & composition	Rice hulls	Rice straw	Sugar cane bagasse	Wood and wheat straw	Paper	Municipal solid waste
C (%)	38.8	38.2	48.6	47.5-52.5	48	39.7
H (%)	4.7	5.2	5.9	4.2-5.9	6.6	5.8
O_2 (%)	35.5	36.3	42.8	37.9-41.5	36.9	27.25
N_2 (%)	0.5	0.9	0.16	0.27-0.65	0.14	0.80
S (%)	0.05	0.2	0.04	0.03-0.12	0.07	0.35
Cl (%)	0.12	0.6	0.03	0.01-0.13	-	-
Ash (%)	20.3	18.7	2.44	2.5-8.2	8.3	26.1
Heat value (MJ /kg)	15.84	15.09	18.99	15.9-20.5	20.78	15.54

China has made advancements in this technology and they are producing commercial briquetters and gasifiers. India is using biomass to produce electricity on a limited scale and now Europe is also trying to improve and promote this technology. A biomass burning power station at Mannheim, Germany burns wood waste, ranging from timber cutting waste to scrap furniture and railway sleepers. The power station output energy is 20 MW, and annual output energy is 100,000 MWh. One of the aims of the UK government is to stimulate a new rural industry comprising energy crops that are grown specifically for burning and also encouraging energy crops to be planted (Wood, 2004).

Commercialization of these technologies in Canada faces some barriers and problems. Technology that uses fossil fuels is advanced and Canada has significant fossil fuel reserves. The capital costs of a biomass plant per kW of capacity are higher than for systems that use fossil fuels. Sources of biomass are scattered and no large scale supply chains exist to connect farmer's fields to power plants. There is a lack of knowledge about biomass technologies among stake holders, especially regarding technical aspects, business strategies and the means to make biomass cost effective.

Despite Ontario's huge power appetite, the government has been under pressure to close the giant coal fired electricity generating plants that have been supplying a quarter of Ontario's electricity (Willie, 2007). According to its energy strategy, called the Integrated Power System Plan, Ontario will cut coal "in the earliest practical time frame." The province will rely heavily on renewable energy, prop up its deteriorating nuclear plants, and make much more efficient use of its energy resources (Willei, 2007).

Power plant capacity and transportation of biomass have the most significant impacts on the cost of electricity production using biomass. Electricity production cost would rise by approximately $4.5 MW/h when the biopower plant capacity was reduced to 10 MW, but fall by about $3 MWh-1when power plant capacity was increased to 50 MW (Gan & Smith, 2006).

The estimated capacity for producing energy from biomass is often based on mature, direct-combustion boiler/steam turbine technology. An average size existing biopower plant is 10-25 MW (the largest approach 75 MW). Efficiency of biopower plants varies 10-40% (Franco and Giannini, 2005). The maximum available delivery distance, achieved through using more efficient transport systems like bundling technology would have important implication for commercial utilization of logging residues in electricity production (because the increase in transport distance would influence the procurement area accordingly to the square law dependence). However, not much gain in logging residues utilization would be obtained if the maximum delivery distance increases from 150 to 200 km (Gan & Smith, 2006).This information indicates that size of biopower plants as well as biomass collection distance determines the cost of electricity production.

To promote the use of biomass conversion in a more profitable way, an interesting strategy seems to be the use of biomass joined with natural gas, using a high efficient energy conversion system like combined power plants (Franco and Giannini, 2005). In the following sections, the amount of biomass available for electricity generation will be estimated, followed by the potential electrical energy production.

II. Estimate of biomass in Ontario

A. Crop residues

Specific data on crop residues in Ontario was not found, so estimates were made based on statistics on the amount of land area under different crops, which is available from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA, 2006). Annual production of different crops was estimated by using average annual yield for wheat, soybean, grain corn, barley, mixed grain, dry field beans, oats, rye and canola. So estimate for crop residues was made for all above crops and their heat value was calculated using 15-18 MJ/kg of biomass as in Table. 3. The final sum of estimated heat values for crop residues is 4.87×10^{10} MJ/year.

Table. 3. Estimate of crop residues in Ontario (OMAFRA, 2006)

Crop	Area (000) acres	Estimated annual production (AP) (000) tons	Estimated crop residues (CR) (000) tons	Estimated heat value from crop 10^6 MJ
Wheat	1,231	1,674 @ 1360kg/acre	753 @ 45% of AP	13,560
Soybean	2,155	2,586 @ 1200kg/acre	776 @ 30% of AP	11,637
Grain corn	1,577	6,308 @ 4000kg/acre	1261 @ 20% of AP	18,924
Barley	221	287 @ 1300kg/acre	114 @ 40% of AP	1,838
Mixed grain	173	208 @ 1200kg/acre	62.4 @ 30% of AP	936
Dry field beans	153	153 @ 1000kg/acre	46 @ 30% of AP	689
Oats, rye and canola	213	256 @ 1200kg/acre	77 @ 30% of AP	1,153

B. Wood and its residues

The majority of biomass resources in Ontario are comprised of wood, wood wastes and agricultural and forest wastes. In some countries forest residues represent more than 70% of the potential dry biomass (Van Belle et. al., 2003). Sustainable supply of wood and its residues/wastes in the long run is an important concern in bioenergy development. An estimate wood biomass available has made based on available information. It was estimated that the average heating value for wood is 18MJ/kg. Table 4 shows estimates of available wood residues in Ontario. So, total estimated wood residues in Ontario are 9.906 million tons, and estimated heating value from wood residues at 18MJ/kg is 1.78×10^{11} MJ/year

C. Waste from livestock

In Asian countries, animal waste remained popular fuel for centuries. In developing countries, most of the dairy farms are located in the suburb of large cities. Disposal of dairy animal waste is challenge for the farmers so poor people living in the vicinity prefer using animal waste as fuel for cooking because it is very cheap as compare to all other fuels.

Intensive animal feeding operations create large amounts of animal waste that must be safely disposed to avoid environmental degradation. Improper disposal leads to contamination of water supplies and poses serious health risks to humans (Soyuz et al., 2005).

Table 4. Estimate of available residues of wood (Source: Bradley, 2007)

Form of wood	Mill residues	Harvest residues	Forest residues	Roadside tree residues
Availability (000) tons	121	6,712	1,576	1,497

Table 5. Waste produced by livestock and poultry (Source: Smil, 2001)

Animal/Bird	Poultry birds	Pigs	Beef cattle	Dairy cattle
Waste (kg/year/head)	8	300	900-1200	1200-2000

(OMAFRA, 2006) revealed that there are significant numbers of livestock in Ontario. The annual waste produced by common livestock was estimated and is included in Table 6. Heating value of manure on a dry ash free basis is estimated at 8,500Btu/lb (19.771 MJ/kg) (Saqib et al., 2006). 18 MJ/kg was used as an average value for animal wastes to estimate heating values. Table 4 summarizes the expected heating values by type of livestock.

Table 6. Potential heating value of animal wastes in Ontario

Livestock/birds	Heads (000)	Estimate of annual waste (000) tons	Estimated heat value 10^6 MJ@ 18 MJ/kg
Dairy cows	330	528 @1600 kg/head	9,504
Beef cows	337	337 @1000 kg/head	6,066
Calves, sheep & lambs	900	270 @300 kg/head	4,860
Pigs	3,951	1,185 @300 kg/head	21,330
Poultry	47,657	381 @8 kg/head	6,858

Estimated annual waste from animals Ontario is 2.701 million tons with total potential of energy from it is 4.8618 × 1010 MJ/year.

III. Discussion

Ontario has the potential to produce 15.69 mega tons of dry biomass per year, with 65% from forest, 18% from animal waste, and 17% from crop residues. In the forest residues 68% is produced just from forest harvest residues, in animal waste 78% from pigs, dairy cows and poultry, similarly in crop residues 40% is produced from grain corn. Figure 2 indicates the proportion of different biomass produced in Ontario. In addition to all other energy activities if special attention to manage forest harvest residues, waste of pigs and dairy cows, and grain corn can produce successful results.

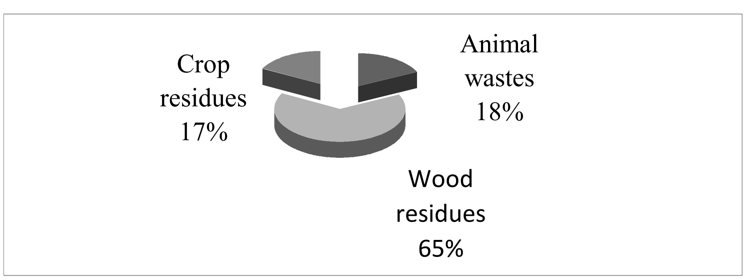

Figure 2. Summary of sources of available biomass

Leaving crop residues on agricultural lands after harvest play an important role in controlling and protecting soil against water and wind erosion. Crop residues acts as a blanket and must be spread evenly to prevent problems during seeding. At least 20% residue cover is required for a conservation tillage program (OMAF, 2005). Conventional use of crop residues/surplus is incorporation into the soil as organic matter, spreading in the field as mulch, feed for animals, combustion for heating and cooking, and as raw material for some factories (for example in production of paper, ethanol etc.). Collection and storage is also a challenge any how 5 to 10% of total crop residue can be considered as available for use to produce bioenergy.

Animal waste reported in this paper is total waste produced by the animals either in the sheds or in the fields. Collection of waste from sheds is viable as farmers are already doing this job to clean the sheds and spread it into the field as organic matter. Animals stay in the field during grazing while in the sheds for having feed, milking and shelter from intense weather conditions. So 5 to 10% of total animal waste might be safely available for use to produce bioenergy.

About 55% of the 4 billion m^3 of wood used annually by the population of the world is directly to meet daily energy needs for heating and cooking, mainly in the developing countries of the remainder, 40% ends up as industrial process residues that are viewed either as waste material for disposal, or as a potential source of renewable energy (Richard, 2002)

In some areas (e.g. British Columbia, Ontario, Quebec, Prince Edward Island, New Brunswick) forest industries supply wood waste (known as hog fuel), wood chips, and pellets to nearby industrial and residential consumers and non-utility electrical generators. In addition wood is the principal heating fuel for more than 100,000 Canadian homes and a supplemental (though largely decorative) heating source in several million others. Total production of mill residues in Ontario is 2.602 million tons while table 3 shows 0.121 million tons which is surplus and available. Total production of bark piles is 12 million tons while reported in the table is 6.7 million tons which is reported to be available. Similarly collection of left over in the remote areas could also be taken into account. So it can be assumed that 10 to 20 of wood residue could be used to bioenergy.

If we assume 5% of crop residues, 5% of animal wastes, and 10% wood residues are surplus and consistently available every year in Ontario. This assumption is made keeping in view availability as well as ease of collection, 10% of wood residues have been assumed as major portion of the wood residue is harvest residue and it seems viable to manage during shifting of harvested wooden logs. This results in annual potential bio-energy production in Ontario of 6.25×10^9 kWh (5% of 4.87×10^{10}MJ) + (5% of 4.8618×10^{10}MJ) + (10% of 1.78×10^{11}MJ) = 2.25×10^{10} MJ = 6.25×10^9 kWh, noting that 1 MJ=0.2778 kWh). As mentioned earlier, efficiencies of bio-power plants are not very high. Assuming bio-power plants are 30% efficient, the net annual potential of bio-energy in Ontario using biomass as fuel will be 1.87×10^9 kWh.

IV. Conclusion and Recommendations

It was found that there is potential to generate 1.87×10^9 kWh of electricity from biomass annually in Ontario which is 1.25% of Ontario present consumption. It is also found that major potential biomass sources include corn stover, residues of wheat and soybeans, the waste of pigs, dairy cows and poultry, and forest harvest residues. A detailed study should be carried out for successful utilization and tapping of these resources. It is also important to revise legislation and develop integrated rural electric energy plan in order to utilize locally produced electric power based on biomass as fuel.

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