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Sustainable Use of Biomass in a Low-Carbon Canada

December 6, 2012

DISCUSSION GUIDE

Acknowledgements

Carbon Talks is a project of the Simon Fraser University Centre for Dialogue in association with the Beedie School of Business, the School for Public Policy and the School for International Studies. The goal of Carbon Talks is to advance Canadian global competitiveness by shifting to a low-carbon economy.

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PROJET TROTTIER POUR L'AVENIR ÉNERGÉTIQUE
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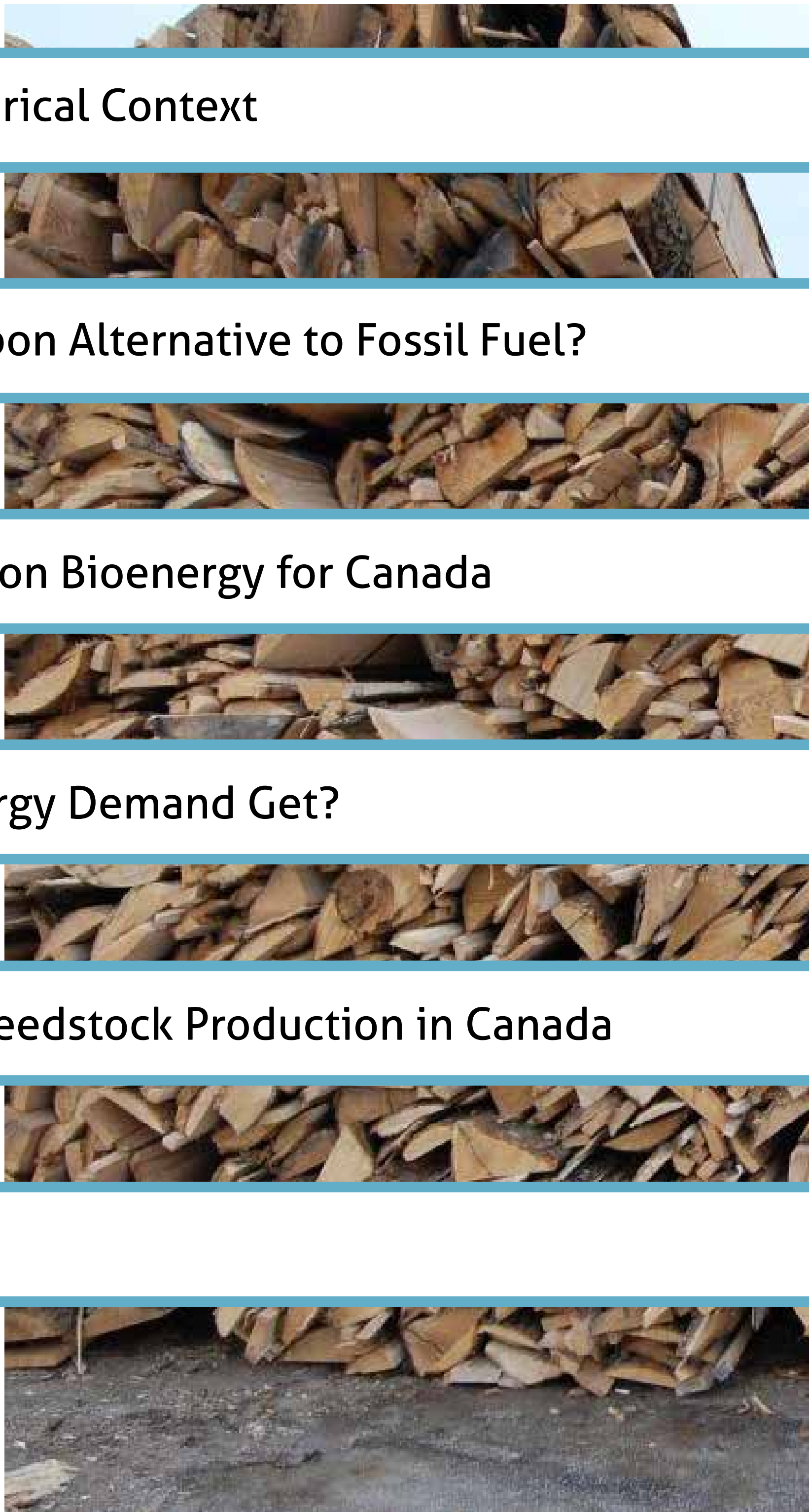
In this Discussion Guide



Introduction and Historical Context

The Trottier Energy Futures Project (TEFP) has identified a number of distinct challenges that form part of the overall objective of achieving a sustainable, low-carbon energy future for Canada. One of them is the development and growth of bioenergy as a low-carbon substitute for fossil fuel. This paper opens a discussion on the sustainability issues that would arise in a low-carbon energy scenario in which Canada's annual demand for biomass feedstock for various energy applications grew from its current level of about 35 million dry tonnes of biomass feedstock for energy (85% from wood, the rest from agricultural residues) to as much as 100 to 200 million tonnes.

In this guide, bioenergy refers to all the various ways of using biomass feedstocks to deliver heat, power, and liquid fuels. Biomass feedstocks include plant materials, algae, manure, waste oils, animal fats, food, and farm wastes that can be burned, gasified, or converted to liquid fuels. The multitude of biomass feedstocks and related pathways to liquid and gaseous fuels are illustrated in Figure 1. Each feedstock has its own carbon ratio, sustainability issues, and mix

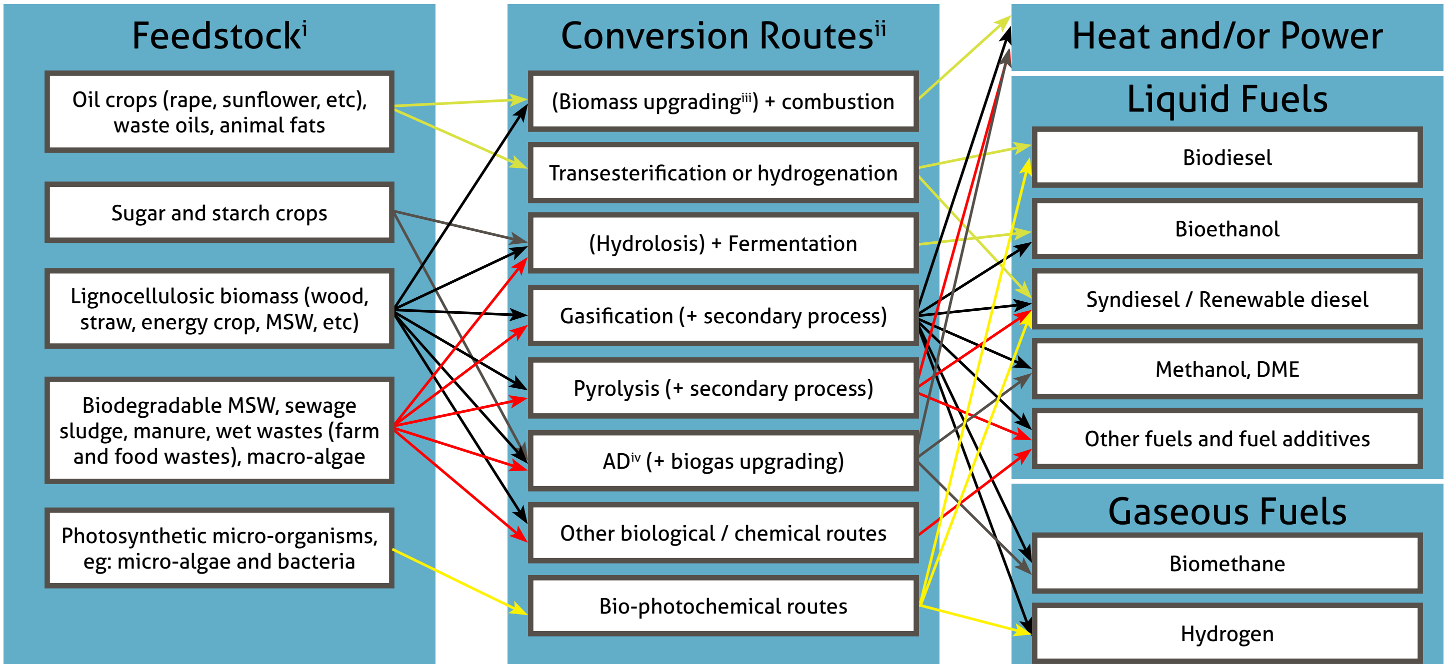


Figure 1 - Bioenergy Feedstocks and Conversion Pathways[1]

i - Parts of each feedstock, e.g. crop residues, could also be used in other routes
ii - Each route also gives co-products
iii - Biomass upgrading includes any one of the densification processes (pelletisation, pyrolysis, torrefaction, etc.)
iv - AD = Anaerobic Digestion

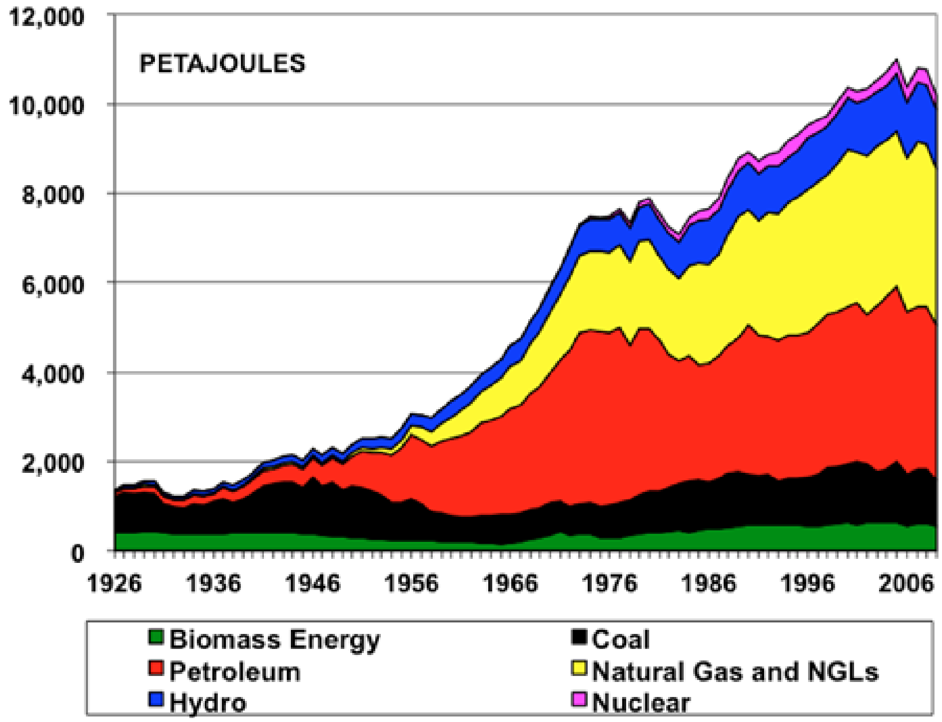


Figure 2 - Primary Energy in Canada, 1926-2009

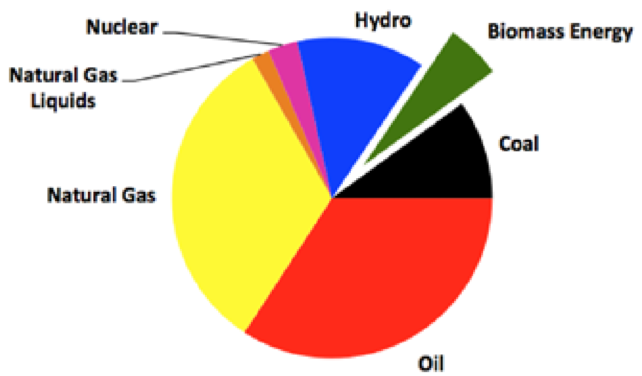
of pathways to produce fuels and electricity, making bioenergy the most complex and multi-faceted of the low-carbon energy sources.

As recently as 1930, biomass still accounted for nearly a third of total national energy use, second only to coal, which provided about 50% (Figure 2). At that time, bioenergy was used mainly in the form of wood to provide space and water heating to homes, businesses, and factories. By the end of the Second World War, oil's share of total energy had overtaken biomass fuel. Bioenergy's absolute and percentage contribution to Canada's energy supply continued to decline throughout the 1960s and 1970s, as petroleum, natural gas, and hydropower came to dominate growth in Canada's energy use. After the oil price shocks of the 1970s, biomass feedstocks enjoyed a resurgence in the pulp and paper industry (wood wastes and spent pulping liquor) and the residential sector (wood burning in modern, high-efficiency stoves and furnaces in some parts of the country). In recent years, there has also been renewed interest and growth in other bioenergy applications, including:

- Power generation from municipal solid waste, landfill methane, and wood fuel
- Biogas generation for heat and power
- Ethanol and biodiesel production from a variety of sugar- and starch-based crops and animal fats.

Today, biomass supplies 5-6% of Canada's domestic primary energy, about half the contribution made by coal, and considerably larger than the share provided by nuclear generation (Figure 3). Total bioenergy use in Canada has been relatively stable at around 600 PJ for the past 20 years. Pulp and paper mills use the equivalent of about 25 million oven-dry tonnes (Odt) of wood-based energy every year, residential wood burning another five million Odt. Corn and wheat for the production of ethanol and biodiesel account for less than five million tonnes of agricultural feedstock per year, but volume has been growing rapidly in recent years (Figure 4). Canadian biofuel production has increased to more than 1.3 billion litres of ethanol, using some three million tonnes of grain feedstock[2], and to more than 190 million litres of biodiesel, requiring some 180,000 tonnes of animal fats and canola feedstock.[3]

Figure 3 - Domestic Primary Energy in Canada, 2009



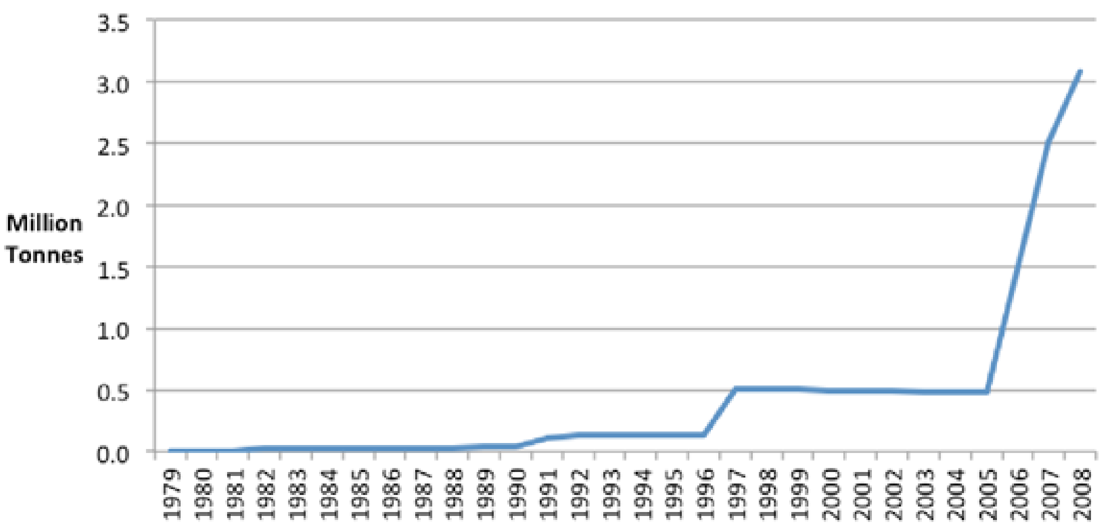


Figure 4 - Biomass Use for Biofuels, 1978-2008

1 - Ausilio Bauen et al., "Bioenergy – a Sustainable and Reliable Source: A Review of Status and Prospects", International Energy Agency (2009), which in turn attributes the graphic to www.e4tech.com.
2 - "Ethanol Production Efficiency", Ottawa: Natural Resources Canada (2012).
3 - Robin Tilsworth and Jessica Martin, "Canada Biofuels Annual, Policy" (2010).

Biomass as a Low-Carbon Alternative to Fossil Fuel?

The carbon dioxide emitted from bioenergy is considered “biogenic,” so it is not counted as a net greenhouse gas (GHG) emission. To the extent that the feedstocks and pathways identified in Figure 1 can be developed in Canada in ways that ensure low life cycle emissions of greenhouse gases, bioenergy could play a critical role in achieving a sustainable, low-carbon energy future.

However, while the carbon dioxide emitted when a biofuel is burned is biogenic, the task of harvesting biomass feedstock and converting it to biofuel often requires significant use of fossil fuels, and sometimes fertilizers, through processes that do emit greenhouse gases. Emissions from bioenergy production typically fall into two broad categories:

- Upstream emissions from producing biomass feedstocks and converting them into useful energy commodities
- Emissions from land use changes when soils, forests, or other carbon-sequestering biomes are disturbed.

So the net GHG benefit of using bioenergy depends in part on which fossil fuel (and how much of it) is being displaced, and on the choice of process fuel to produce the bioenergy:[4]

- When corn crops are dedicated for energy production, the fertilizer and fuel required to grow, transport, and process the corn are net emissions that would not otherwise have occurred. Life cycle GHG emissions from current technologies for producing ethanol from agricultural feedstock in Canada are 40-62% lower than gasoline.[5] Bioethanol can also be made from woody (or cellulosic) biomass, and the less GHG-intensive feedstock and conversion technologies could result in life cycle GHG emissions that are up to 75% lower than current agricultural feedstocks and related processes.[6]
- Market demand for biofuels may also shift economic activity to favour biofuel production over other land uses, leading

Biogenic Carbon Dioxide

When organic matter such as wood or plant matter (or fuels produced from those sources) is burned, the carbon content is released to the atmosphere as carbon dioxide. This CO_2 is not counted as an anthropogenic greenhouse gas (GHG) emission because it would eventually have been released under natural conditions; it is considered biogenic, rather than anthropogenic.

The carbon in the plants and trees from which these products are made is the result of the photosynthetic capture of carbon from the atmosphere, and in the natural carbon cycle it is returned to the atmosphere when the plant dies and decays (aerobically) on the earth’s surface. For this reason, international climate change conventions do not include direct carbon dioxide emissions from biomass burning, organic waste incineration, or renewable biofuels in the definition of “anthropogenic emissions”. However, fossil fuels are often used in the production of biofuels like corn-based ethanol, and the resulting emissions must be counted as part of the net GHG impact of bioenergy.

to significant increases in GHG emissions. This risk can be mitigated by appropriate agricultural management practices, such as perennial crop intensification and livestock production on degraded lands.[7]

- Agricultural residues for energy production are generally considered less greenhouse gas-intensive than dedicated biomass crops for energy, since any upstream emissions from the cultivation process are already attributed to the food system.
- Converting land from young forest with high rates of carbon sequestration to energy crop production shifts the calculation of net atmospheric emissions. Wood burning also leads to significant carbon monoxide and particulate emissions that affect human and ecosystem health for the surrounding region.[8] Black carbon emissions could also increase climate effects.[9] Biomass combustion produces lower sulphur dioxide emissions than coal, but higher SO2 emissions than natural gas.[10]

4 - IPCC, "Chapter 2 Bioenergy", (2011).
5 - Len Coad and Marta Bristow, "Ethanol 's Potential Contribution to Canada's Transportation Sector", Conference Board of Canada, November 2011.
6 - R. Samson et al., "Analyzing Biofuel Options: Greenhouse Gas Mitigation Efficiency and Costs", prepared by REAP-Canada for BIOCAP Canada Foundation, Ste. Anne de Bellevue, QC (2008).
7 - D. T. Arvizu et al., "IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation", ed. O Edenhofer et al., Cambridge, United Kingdom and New York, United States: Cambridge University Press (2011). p.99.
8 - Nicolas Mainville, "Fuelling a BioMess: Why Burning Trees for Energy Will Harm People, the Climate and Forests" (Montreal, 2011), http://www.greenpeace.org/canada/Global/canada/report/2011/10/ForestBiomess_Eng.pdf.
9 - IPCC, "Chapter 2 Bioenergy".
10 - Mainville, op. cit.

Sustainable, Low-Carbon Bioenergy for Canada

The technology of biomass production and utilization is the focus of intensive research and development and innovation around the world, as nations and economies seek to supplement or displace fossil fuel use. Low-carbon energy future scenarios invariably include an expanded role for bioenergy in a number of forms:

Solid Fuel: Modern fuel burning technology is much cleaner and more efficient than in the past, leading to a possible role for solid biomass in power plants, industrial and commercial boilers, and building heating systems. Solid biomass fuel, probably in the form of pellets, could become a more important energy commodity, and is already traded internationally.

Liquid Fuel: While automobiles and other forms of personal transportation may be increasingly electrified, long-haul freight transport will likely continue to require liquid fuels with high energy density. Expanded biofuel use in transport is a common theme in most low-emission future scenarios, including all the ultra-low carbon scenarios reviewed by the Trottier Project.[11] On a per-joule basis, liquid fuels for transportation are valued more highly than almost any other form of energy, including electricity, with a host of feedstocks and conversion technologies at various stages of research and development.

Biogas: Biogenic methane from sewage treatment plants, landfills, and engineered waste treatment facilities is already commercially available and widely used, and farm biogas generators are very common in some countries. Bioenergy development could also include large-scale gasification of wood and other cellulosic feedstocks to produce biomethane and other hydrocarbons. Biogas will be a viable source of low-carbon heat and power where the feedstock is plentiful, the end use application is nearby, and biogas generation helps address other issues like waste disposal or odour management. Canada produces nearly 13 million tonnes of waste per year, the largest volume per capita of the 17 OECD countries,[12] and there is significant potential to generate more biogas from organic waste.

11 - The low-carbon studies we reviewed in detail were for Australia, Canada, Finland, France, Germany, Sweden, the United Kingdom, and the United States.
12 - Conference Board of Canada, “Municipal Waste Generation” (2011), http://www.conferenceboard.ca/hcp/details/environment/municipal-waste-generation.aspx

How Big Could Bioenergy Demand Get?

As noted earlier in this paper, bioenergy production in Canada has been fairly stable at about 600 PJ, representing 5-6% of the country's total primary energy supply. However, for Canada to achieve an 80% reduction in its energy-related greenhouse gas emissions by 2050, the transportation sector must move away from fossil fuels. In urban centres, where most passenger transport involves shorter trip lengths, electric vehicles (EVs) are a viable alternative. For longer hauls between cities, current EV technologies are not adequate to move goods and passengers. So the need for energy-dense fuels will persist, and if that need is met by biofuels, their production will rise significantly, even with much higher vehicle efficiencies.

Figure 5 shows one illustrative scenario of biomass feedstock requirements to provide transportation fuels. In this scenario, developed by the Trottier Energy Futures Project, automobile fuel efficiency triples by 2050, truck fuel efficiency doubles, and by 2040, all automobiles are electric (with carbon-free electricity supply). Bioethanol and biodiesel both show strong growth until the late 2020s, when accelerating electrification of automobiles triggers a decline in total biofuel demand. Eventually, continuing economic growth leads to higher biofuel demand, but by 2050 that demand consists mostly of biodiesel for trucks and other freight transportation vehicles. In this scenario, long-haul goods movement requires more than 60 million tonnes of biomass per year by 2050, on top of any ongoing bioenergy requirements for pulp and paper, electric power production, or wood and biogas fuel (currently about 25 Mt per year). This is only one, illustrative scenario; primary biomass requirements could be half as much or twice as much with different assumptions about vehicle efficiency, the extent to which personal vehicles become electrified, and the growth of freight transportation.

This leads us to what may be the most important question about the future of bioenergy use in Canada:

How much biomass feedstock can Canada produce in a manner that is environmentally, economically, and socially sustainable?

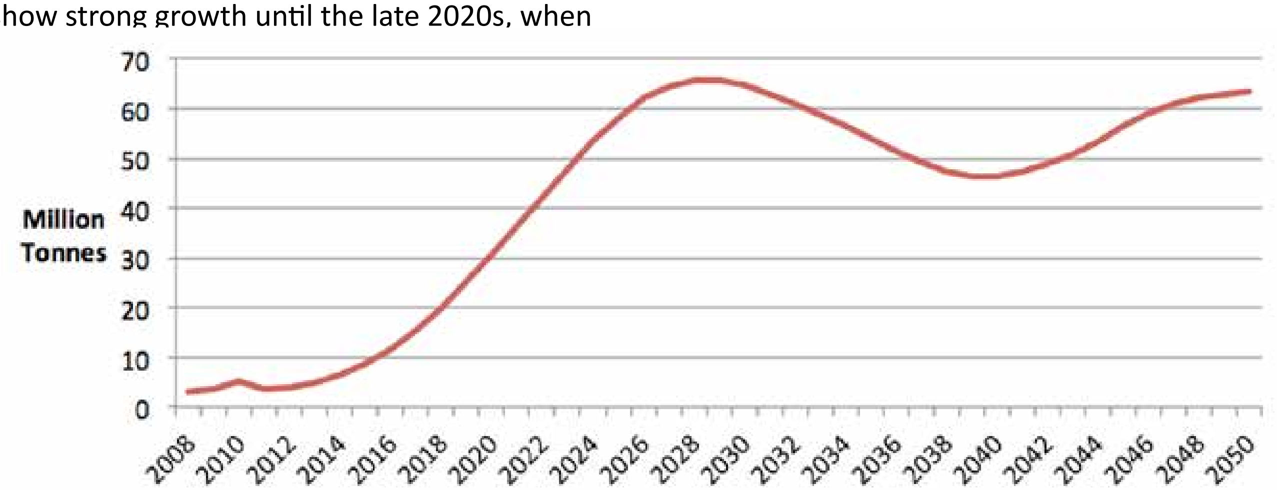


Figure 5 - Potential Biomass Feedstock Requirements to Provide Transport Fuels in a Low-Carbon Future for Canada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What is the Sustainable Level of Biomass Feedstock Production in Canada?

Bioenergy, particularly biofuels, will almost certainly be a central component of any plausible low-carbon energy scenario. Preliminary analysis shows that a low-carbon future could require much more bioenergy than Canada has ever produced.

It is crucial to understand how much of the various biomass feedstocks can be grown and produced in a sustainable manner over the long term, and how much of that primary biomass could be available for energy applications.

This is not only, or perhaps even primarily, a technical question. The question of sustainability has environmental, social, and economic dimensions. It involves the farm and forest communities and industries that would be affected by increased reliance on bioenergy. It intersects with all the other products and amenities our forests and farms provide, and it must be answered as part of a larger strategy for restoring and maintaining the health and resilience of our forest and agricultural ecosystems. Table 1 synthesizes a variety of published estimates of possible production levels for different biomass feedstocks, with the following caveats:

- Estimated potential production levels and underlying assumptions vary widely among published sources, and there is considerable uncertainty associated with all the sources. The table calculates total potential output of 7.6 exajoules (EJ) of primary energy from biomass feedstocks, but the data support a range from 3.0 to 12.0 EJ, depending on assumptions about everything from silviculture practices to the impact of insects and forest fires on wood supplies.
- With some exceptions like annual allowable cut limits, the estimates in the table do not reflect any attempt in the source literature to determine a sustainable level of production. This complex question is the central focus of the Carbon Talks dialogue on *Sustainable Use of Biomass in a Low-Carbon Canada* that the Trottier Energy Futures Project will convene in December 2012.
- The table summarizes estimates for Canada's annual primary biomass production potential, not the primary biomass available for energy. Competing uses include food, lumber, pulp and paper, chemical and pharmaceutical feedstocks, and a myriad of other applications. This assessment is just a first step in determining a role for biomass-based energy in the Trottier Energy Futures Project's low-carbon energy scenarios for Canada.

Feedstock	Total Tonnage	Heat of Combustion	Pathways
Food crops: Hay, wheat, corn, barley, canola, corn feed, flaxseed, oats, soybean, beans and peas, rye, mixed grains, other	108.8 million dried tonnes[13]	1,695.0 PJ[14]	First-generation biofuels production
Agricultural residues: Stover, husks, silage	70.0 million recoverable dried tonnes[15]	1,170.3 PJ[16]	Second-generation biofuels production
Energy crops: Switchgrass, cordgrass on marginal croplands	98.5 million dried tonnes[17]	1,585.1 PJ[18]	Second-generation biofuels production
Roundwood	132.2 million dried tonnes[19]	2,094.5 PJ[20]	First- and second-generation biofuels; gasification; fuelwood; wood pellets; combined heat and power (CHP); combustion or fossil fuel co-firing to produce electricity
Primary forestry residue[21]	27.8 million recoverable dried tonnes[22]	439.8 PJ[23]	First- and second-generation biofuels; gasification; fuelwood; wood pellets; combined heat and power (CHP); combustion or fossil fuel co-firing to produce electricity
Landfill gas	1.4 million tonnes[24]	96.9 PJ[25]	Direct combustion
Municipal solid waste: Combustible disposed waste	17.0 million dried tonnes[26]	249.9 PJ[27]	Direct combustion; thermochemical or biochemical conversion
Municipal solid waste: Combustible diverted waste	6.3 million dried tonnes[28]	114.9 PJ[29]	Thermochemical or biochemical conversion
Municipal biowaste	0.63 million dried tonnes[30]	9.1 PJ[31]	Direct combustion; anaerobic digestion to biogas for heat and electricity
Livestock waste	12.5 million recoverable dried tonnes[32]	187.2 PJ[33]	Direct combustion; anaerobic digestion to biogas for heat and electricity
TOTAL PRIMARY ENERGY POTENTIAL		7,642.7 PJ	

Table 1 - Estimated Annual Primary Biomass Production Potential, Canada

Questions for Discussion

How big could the primary supply of biomass for energy be in 2050?

- What is the gross production of biomass in Canada?
- What are the ecological limits to sustainable production?

How much biomass could be available for energy applications, given:

- Competing uses
- Impacts on other sectors
- Social license issues and limits to growth
- Fundamental economic constraints
- Environmental impacts
- Other factors?

How might these limits be addressed or affected by:

- Emerging technologies?
- Changes in cultivation practices or industrial processes?
- Land use decisions and constraints?
- Concerns about emissions or other environmental impacts?
- Other factors?

In the different sectors and communities where bioenergy production would scale up in a low-carbon energy scenario:

- How will greater demand for biomass feedstocks shift production priorities and affect communities that have grown up around biomass for food and fibre? What are the foreseeable benefits and pitfalls of these changes?
- What are the competing demands for fveedstock in each major production sector (agriculture, forestry, energy from waste)?
- How (and within what limits) can forest and agricultural biomass be developed in a way that enhances the sustainable prosperity of those ecosystems, in harmony with other established production chains?
- Are there opportunities to balance competing demands for the land and water required to support bioenergy production at a level that is consistent with a low-carbon energy future?

Are there best practices or pilot projects, in Canada or internationally, that can help shape our understanding of the sustainable limits on bioenergy production?

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The Trottier Energy Futures Challenges

In its search for pathways to a low-carbon, sustainable energy system, the Trottier Energy Futures Project is taking a close look at the various chains of value creation that give rise to the demand for energy services and, ultimately, for fuels and electricity. We have used this framework to identify 11 key elements of the challenge of achieving a sustainable, low-carbon future. We are using this expanded framing to build a deeper understanding of how Canadians can get the energy services and amenities they want and need, with radically lower greenhouse gas emissions.

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13 - Derived from a three-year average of harvest totals from Statistics Canada's "Field Crop Reporting Series" (2011).

14 - Assumes the same carbon content for Canadian crops as given by: Wood, S., and D. Layzell, "A Canadian Biomass Inventory: Feedstocks for a bio-based economy" BIOCAP (2003) p. 20. Assumes that direct combustion of one tonne of carbon produces 35.76 GJ (Wood and Layzell, 2003, p. 23, footnote 8).

15 - Derived from three-year average from Statistics Canada's "Field Crop Reporting Series" (2011). Assumes the same conservative straw-to-grain ration presented by Wood and Layzell (2003) p. 20. Assumes that 80% of residue can be sustainably recovered for all crops but soy (20%) (Wood and Layzell, 2003; Klass, D., Biomass for Renewable Energy, Fuels and Chemicals. (Academic Press, San Diego, California: 1998).

16 - Assumes carbon content of 45% and 35.76 GJ from direct combustion of one tonne of carbon (Wood and Layzell, 2003, p. 23, footnote 7).

17 - Milbrant, A., and R.P. Overend, "Assessment of Biomass Resources from Marginal Lands in APEC Economies", NREL (2009), p. 29.

18 - Assumes carbon content of 45% and 35.76 GJ from direct combustion of one tonne of carbon (Wood and Layzell, 2003).

19 - Total volume of annual allowable cut (AAC) in Canada (2009): 246,000,000 m^3 (National Forestry Database, "Wood Supply: Background" (2012) http://nfdp.ccfm.org/supply/background_e.php). Assumes 0.96 t /m^3 and 44% water content in wet wood (Ralevic and Layzell, 2006), thus 132.2 million dried tonnes.

20 - Assumes one tonne of carbon in 4.2 m^3 of wet wood and 35.76 GJ from direct combustion of one tonne of carbon (Wood and Layzell 2003).

21 - Primary forestry residue includes bark, branches, or unfit lumber that is typically left in the forest during harvest. Secondary forest residue refers to waste products from pulp mills and sawmills.

22 - Residue left in the forest equates to 30% of total roundwood of 132.2 MOdt (footnote 19, Ralevic and Layzell, 2006), 70% of which can be sustainably recovered (David Suzuki Foundation, "Smart Generation: Powering Ontario with Renewable Power").

23 - Assumes carbon content of 44% and 35.76 GJ from direct combustion of one tonne of carbon (Wood and Layzell 2003).

24 - In 2009, approximately one-quarter of methane gas was captured, totalling 349,000 tonnes. 100% capture would equate to approximately 1.4 million tonnes.

25 - Assumes a methane conversion rate of 14.4 tonnes/TJ.

26 - Total tonnage from Statistics Canada, "Human Activity and the Environment: Waste Management" (2012): 25.9 million tonnes. Assumes that 85% is combustible, and that combustible material has 22% average moisture content (Wood and Layzell 2003).

27 - Carbon content of 41% for dried combustible material, and 35.76 GJ from direct combustion of one tonne of carbon (Wood and Layzell 2003).

28 - Total tonnage from: Statistics Canada, "Human Activity and the Environment: Waste Management" (2012): 8.5 million tonnes, including 6.9 million tonnes of combustible material. Assumes 10% moisture content (Wood and Layzell 2003).

29 - Carbon content values taken from Wood and Layzell (2003, p. 29). Assumes 35.76 GJ from direct combustion of one tonne of carbon.

30 - Canadian population on sewers: 28,455,184 (Environment Canada, "Municipal Waste Water Indicator", http://www.ec.gc.ca/indicateurs-indicators/defaultasp?lang=en&n=2647AF7D-1). Assumes average 0.97 kg of wet waste per day, equal to 0.063 kg of dry waste (Klass, 1998).

31 - Assumes carbon content of 40% (Klass, 1998) and 35.76 GJ from direct combustion of one tonne of carbon (Wood and Layzell 2003).

32 - Number of head of cattle, poultry, pigs, and sheep from Statistics Canada's Agricultural Division (2012) Catalogue no. 23-012-X; 23-010-X; 23-015-X; 23-011-X. Dried kg/head/day from Klass (1998).

33 - Energy content of waste and percentage recoverable from Ralevic, P., and D. Layzell, "An Inventory of the Bioenergy Potential of British Columbia," BIOCAP (2006).

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