BIOMASS INNOVATION

Canada's Leading Cleantech Opportunity for Greenhouse Gas Reduction and Economic Prosperity

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About the Climate Change & Emissions Management Corporation

CCEMC was created by the province to support Alberta in the successful transition to a future with lower greenhouse gas emissions. By funding the next generation of innovative and clean technology, CCEMC helps Alberta build an open, sustainable economy that attracts investment, facilitates diversification, expands market access and delivers improved environmental outcomes. As of September 2015, CCEMC has committed $349.8 million to 109 projects with a total project value of $2.2 billion.
www.ccemc.ca

About Alberta Innovates Bio Solutions

Al Bio is a Government of Alberta corporation dedicated to investing in research and innovation for the benefit of the province's agriculture, food and forestry sectors.
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Executive Summary

Canada has a tremendous opportunity to build upon its inherent strengths and take a cleantech leadership position in the production of bioenergy and bioproducts produced from sustainable biomass. This document, which identifies why biomass should be the cornerstone of Canada's greenhouse gas (GHG) reduction and economic growth policies, is intended to initiate a dialogue between policy makers, large GHG emitting sectors, and biomass feedstock and technology suppliers that will result in deployment of Canada's biomass resources to reduce GHG emissions. Reasons for pursuing biomass cleantech innovation include:

- **Biomass can reduce GHG emissions from Canada's largest and fastest growing sources**
  Canada's unique GHG profile, dictated by a large landmass, northern climate, resource-based economy, and the 3rd lowest electricity GHG intensity in the G20, means deployment of electricity-based renewables, such as wind and solar, will not address the largest and fastest growing sources of emissions including oil and gas extraction and processing, heavy duty transportation, and process/space heat. Deployment of biomass can.

- **Biomass can be economically utilized in Canada's existing carbon-based infrastructure**
  Biomass is the only source of renewable carbon that can be used within the existing fossil-fuel infrastructure, including coal-fired power plants, oil sands operations, transportation fuel distribution systems, the vehicle fleet, natural gas pipelines, heavy industry (steel, cement, fertilizer) facilities, and residential and commercial building heating systems. This avoids stranding valuable assets and can enable market access for Canada's other natural resource products including oil, gas, chemicals, metals, and minerals.

- **Biomass creates far more jobs than other renewables and builds upon human resource strengths**
  Projects that utilize biomass can create 10 times more operating jobs than wind and solar on an energy output basis. In addition, production of bioenergy and biofuels economically complements the production of higher-value products such as food, lumber, pulp, biochemicals, and bioproducts that produce significantly more jobs than energy on a feedstock input basis. Many of the skills developed by workers in the oil and gas, chemicals, pulp and paper, utility, and food processing sectors are in demand by bioenergy, biofuel, and biochemical producers.

- **Biomass provides significant economic development opportunities for Indigenous peoples**
  Indigenous peoples can play a major role in the development and management of bioenergy and bioproduct projects as providers of traditional knowledge of ecosystems, suppliers of biomass, operators of facilities, exporters of bioproducts, and consumers of bioenergy – particularly in remote and isolated communities.

- **Biomass provides immense cleantech innovation and technology development opportunities**
  Deployment of commercial biomass conversion technologies can create sustainable livelihoods today and form the basis for a biotechnology and cleantech innovation-based bioeconomy, replete with high-quality bioproducts research, technology development, and commercialization jobs. Management of Canada's extensive biomass resources also offers vast potential for linking high tech industry development with resource management via big data, GIS, drones, and remotely-operated/autonomous machinery and vehicles. These cleantech, high tech, and biotech innovations can become high-value exports for Canada.

- **Canada has more biomass per capita than any other country on Earth**
  No other country has the combined forestry, agriculture, and urban biomass resources of Canada and others recognize the climate mitigation value of Canada's biomass resources by importing large volumes for use in heating, electricity generation, and transportation. As described in this report, domestic residues ('wastes') alone could provide 20% of Canada's yearly energy supply.

Meeting Canada's Greenhouse Gas and Economic Development Goals

"Canada has an opportunity to become the world leader in the use and development of clean and sustainable technologies and processes that utilize biomass"

Canada is facing significant economic and environmental headwinds, partially due to the country's reliance on currently low-priced resource commodities and the greenhouse gas (GHG) emissions associated with recovery, extraction, processing, and utilization of those resources. Fortunately, Canada has an opportunity to become the world leader in the use and development of clean and sustainable technologies and processes that utilize biomass to reduce GHG emissions while improving the performance of the Canadian economy. **This document describes how biomass – forest, agriculture, and municipal waste resources – can be effectively used to meet GHG reduction targets and why it should be a central part of Canada's climate change mitigation plan.** Canada has an unparalleled opportunity to utilize biomass to meet its climate leadership goals while creating a large number of jobs and enabling market access for the country's other natural resources including oil, gas, chemicals, metals, and minerals. Biomass is the bridge that links traditional resource and heavy industry sectors with cleantech and biotechnology. Not only are many of the skills developed by workers in the oil and gas, chemicals, pulp and paper, utility, and food processing sectors in demand by bioenergy, biofuel, and biochemical producers, but development of new technologies and processes that convert biomass into high-value bioproducts for domestic and foreign markets requires highly-qualified biotechnology and engineering personnel. In addition, Indigenous peoples can play a major role in the development and management of bioenergy and bioproduct projects as holders of traditional knowledge of ecosystems, suppliers of biomass, operators of facilities, exporters of bioproducts, and consumers of bioenergy.

What is Biomass?

Biomass is the only renewable source of carbon. It can be converted into transportation fuels, heat, electricity, chemicals, and materials. The most abundant forms of biomass are wood, agricultural residues (e.g., straw and manure), and organic municipal waste. Canada has more biomass per capita than any other country on Earth.

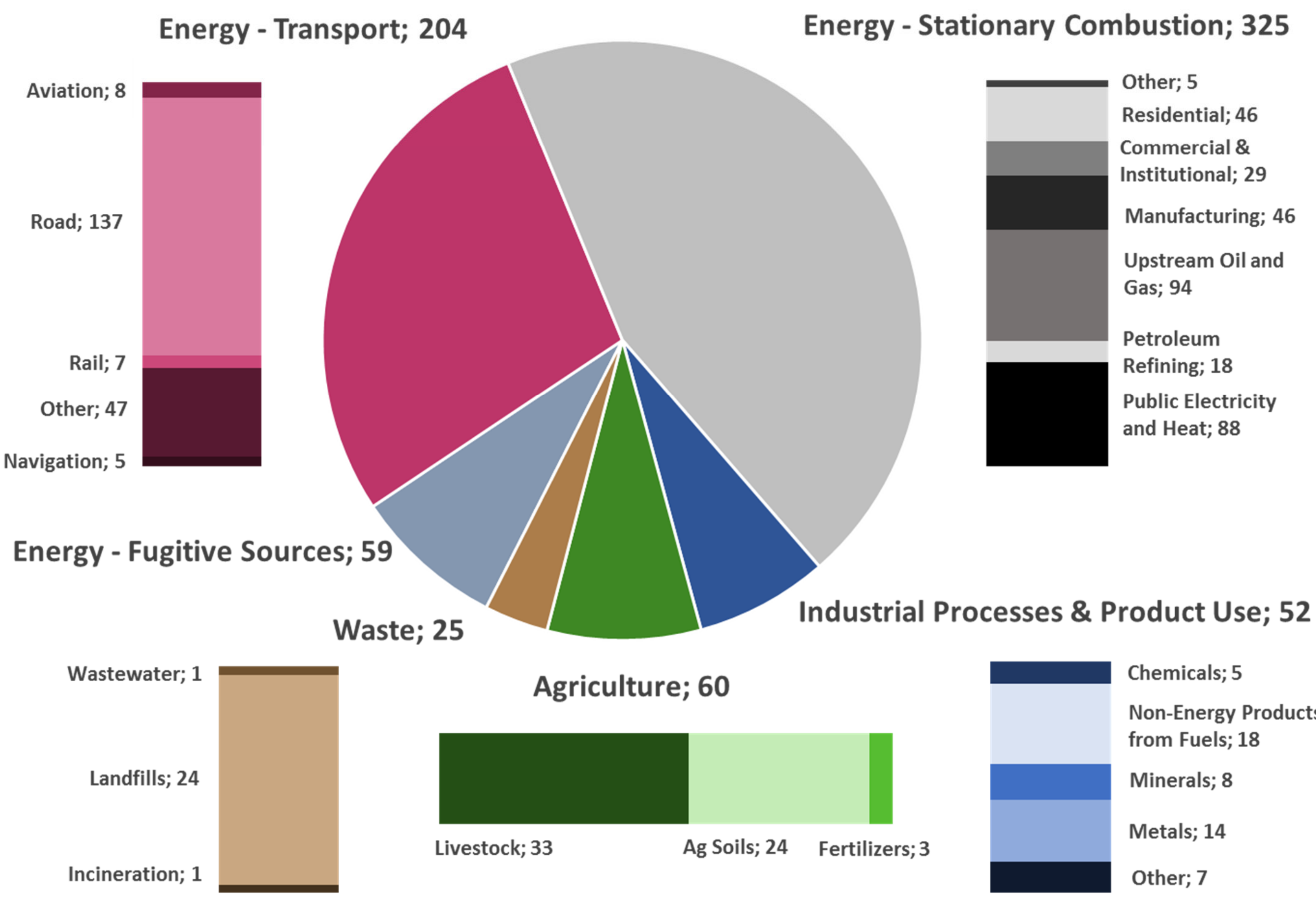
Many of the technologies that would allow biomass to be utilized to reduce GHG emissions are commercially available and already deployed in Canadian or foreign jurisdictions. In many cases, existing infrastructure – coal-fired power plants, transportation fuel distribution systems, oil refineries and bitumen upgraders, cement and steel plants, natural gas pipelines, and building heating systems – can accommodate biomass products, thus avoiding stranding assets while attaining significant GHG reductions. This is not typically the case with other renewables. However, development of a sustainable economy based upon biomass – a bioeconomy – does not need to be limited to existing technologies. Deployment of commercial technologies to reduce GHG emissions and create operations and resource management jobs today could be leveraged to form the basis for a biotechnology/ cleantech innovation-based economy, replete with high-quality research, technology development, and commercialization jobs, tomorrow. As this paper will demonstrate, no other clean technology option can effectively address Canada's unique GHG profile while building upon the country's strengths in resources – both human and physical. Many other countries yearn to have the biomass resources of Canada and while Canadian biomass is already exported in large volumes (e.g., >1.6 million tonnes of wood pellets per year) to help other countries meet their GHG targets, the domestic potential has been largely ignored. In order for Canada to be a leader in climate change mitigation, the country's economic structure necessitates that biomass form the cornerstone of plans that reduce GHG emissions while reshaping the Canadian economy for the better.

Canada's Greenhouse Gas Targets

Along with 194 other nations, Canada recently signed the Paris Agreement, which "sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2°C."[1] This is a follow-up to the Copenhagen Accord, in which Canada pledged to reduce GHG emissions from 2005 levels by 17% by 2020.[2] In order to meet this pledge, emissions will need to be reduced by 119 Million tonnes CO_2 equivalent (Mt CO_2 eq) – from 726 Mt CO_2 eq in 2013 to 607 Mt CO_2 eq.[3] If Canada is to play a leadership role in climate change mitigation, it is essential to establish a credible plan for reducing GHG emissions that recognizes the country's unique emissions profile and mitigation options.

As can be seen in Figure 1, the electricity sector ('Public Electricity & Heat'), a dominant source of emissions for many countries, only accounted for 12% of national emissions in 2013. A complete elimination of electricity grid-related emissions will not allow Canada to meet its Copenhagen Accord pledge. The single largest, but also one of the fastest growing, emissions sub-category is Road Transportation. Overall Transportation Sector emissions grew by 31% between 1990 and 2013, but growth in Freight emissions, at 59% (62 Mt CO_2 eq in 2013), far exceeded that of Passenger Emissions at 24% (97 Mt CO_2 eq in 2013). However, the Sector with the largest and fastest growing emissions profile is Oil and Gas, which reached 179 Mt CO_2 eq in 2013, propelled by a 313% (15 to 62 Mt CO_2 eq) increase in Oil Sands emissions between 1990 and 2013. Clearly, addressing Transportation and Oil Sands emissions will be necessary to meet Canada's climate change commitments.

Figure 1. Canada's Greenhouse Gas Emissions in 2013 (Million Tonnes CO_2 eq)[3]



Canada's Unique Greenhouse Gas Situation

Canada is a geographically large northern country with an economy heavily reliant upon natural resource sectors such as oil, gas, mining, and forestry. In fact, Canada's most recent greenhouse gas National Inventory Report – 1990-2013 – states "…[Canada] is one of the highest per capita emitters, largely as a result of its size, climate (i.e., climate-driven demands) and resource-based economy".[3] Biomass is a renewable option that can address Canada's unique GHG challenges, including:

"Biomass is the only renewable option that can address all of Canada's unique GHG challenges: size, climate, and a resource-based economy"

1. **Transportation (Canada's Size).** As the only renewable transportation fuels that can be utilized in the existing fuel infrastructure, liquid biofuels will need to play an increasingly important role in reducing transportation GHG emissions. This is particularly true for the two fastest-growing sources of transportation GHG emissions, heavy duty trucking (diesel) and aviation (kerosene), due to the low likelihood of fleet electrification. Biofuels are also the most likely option for decarbonisation of rail and marine transportation in Canada due to fuel energy density requirements, unlikelihood of electrification, and the ability to increase renewable content over time.

2. **Space Heat (Canada's Climate).** Biomass is often the most efficient and cost-effective means of space heating with renewables. Approximately 50% of the Canadian population does not use natural gas as their primary source of heat and must rely upon heating oil, propane, electricity, or firewood for thermal energy.[4] Ground source heat pumps have a high upfront capital cost while electrical heat can be expensive. Biomass boilers, furnaces, and stoves operating on wood pellets, wood chips, and/or firewood have been widely deployed in the institutional, commercial, and residential sectors in Europe, the U.S., and parts of Canada.

3. **Process Heat, Renewable Carbon, and Baseload Electricity (Canada's Economy).** Natural resource recovery, extraction, and processing often requires significant amounts of process heat. An example is the large amount of natural gas utilized in the oil sands to recover bitumen and upgrade it to synthetic crude oil. This is Canada's fastest-growing source of GHG emissions and several of the largest point-source emitters of GHG emissions in Canada are oil sands upgraders. A second example is cement production. Outside of highly site-specific geothermal, biomass is the only renewable option for process heat.

   Heavy industry production processes can also require a carbon source for chemical reactions that release CO_2, such as conversion of iron ore into steel (the three largest GHG emitters in Ontario are all steel plants). The only method for reducing these emissions, outside of carbon capture and storage, is to use the only renewable source of carbon: biomass.

   Finally, intermittent renewables, such as wind and solar, do not provide the constant, invariable electricity required by large resource extraction and processing operations. As a deployable fuel, biomass can be used to ensure Canada's industry is supplied with reliable and renewable electricity.

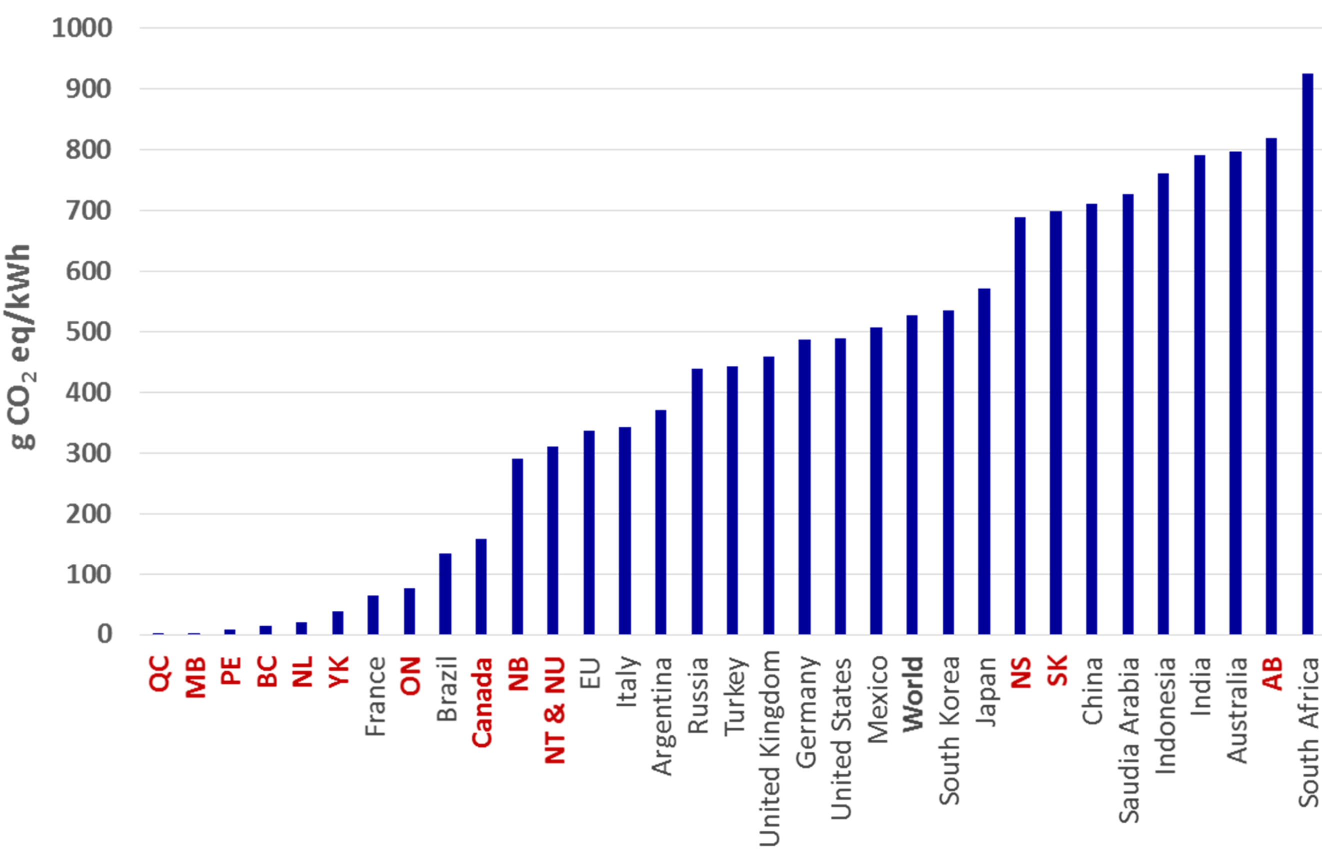
Greater Than 100% GHG Reduction?

Biomass that is degraded anaerobically (in the absence of oxygen), such as decomposition in a landfill, releases methane (CH_4), a GHG 25 times more impactful than CO_2. By using biomass as a fuel, these methane emissions can be avoided and fossil fuel consumption reduced. This is one way that bioenergy and biofuel use can reduce GHG emissions by greater than 100% from a fossil fuel baseline. The other is by combining bioenergy with carbon capture and storage (BECCS) or utilization.

The sector that has received the greatest attention for renewables deployment is electricity generation. In most countries, electricity generation is the largest source of GHG emissions and therefore the most logical target for reductions.[5] However, in Canada, the GHG intensity of electricity (emissions per unit of electricity) is lower than all the G20 except for France and Brazil (**Figure 2**). Canada has a substantially lower electricity GHG intensity than countries with a high penetration of wind and solar electricity such as Germany.[5] This is because Canada has a high proportion of electricity generated from hydroelectricity (similar to Brazil) and has significant nuclear generating capacity in Ontario (similar to France), the country's largest electricity market. Canada does not have a large electricity GHG intensity problem compared to the rest of the world. Canada has regional GHG intensity problems in Alberta, Saskatchewan, Nova Scotia, and to a lesser extent, in New Brunswick and the Northwest Territories/Nunavut. Deployment of additional renewables such as wind and solar in Québec, Manitoba, British Columbia, and even Ontario, without exports to Alberta, Saskatchewan, and Nova Scotia, will not address Canada's primary electricity generation GHG challenge.

"Intermittent renewables, such as wind and solar, cannot address baseload electricity GHG intensity challenges"

Figure 2. GHG Intensity of Electricity in Canadian Provinces & Territories and the G20[5,6]



Unlike Ontario, which was able to phase out coal-fired electricity generation due to the presence of baseload nuclear and large hydroelectricity, combined with a significant reduction in demand post 2008, Alberta and Saskatchewan utilize coal-fired generation as baseload. Intermittent renewables such as wind and solar cannot effectively displace stable coal-fired generation and a market penetration for these technologies beyond 30% is unlikely in the short- to medium-term due to grid stability requirements.[7] A 30% reduction in electricity GHG intensity in Saskatchewan and Alberta still leaves the provinces above U.S. and German intensity levels and therefore wind and solar will not solve the challenge of high electricity-associated GHG emissions in these provinces. Beyond nuclear, the only renewables that can displace coal generation as baseload electricity supply and maintain a stable grid are large hydro, geothermal, and biomass. Both large hydro and geothermal are highly site-specific and development opportunities in Alberta and Saskatchewan are limited. This leaves biomass as the only baseload, deployable renewable electricity option in these jurisdictions. Biomass is also the only renewable that can be utilized in the existing infrastructure (i.e., coal-fired power plants). It is anticipated that the electricity GHG intensity of Nova Scotia and New Brunswick will be reduced once the Maritime Transmission Link from Newfoundland is completed.[8] Therefore, substitution of coal with renewable biomass in thermal generating stations in Alberta and Saskatchewan must be the primary focus of GHG reduction efforts in the electricity sector in Canada. A second priority may be co-generation of electricity and heat (CHP) from biomass in some of Canada's 300 remote communities that are reliant upon diesel.

Meeting Electricity Demands

In general, it is expensive and inefficient to store electricity. This means that electricity supply must meet electricity demand instantaneously. The **baseload** is the amount of electricity that is generally always in demand. This contrasts with **peaking** demand, which rises and falls over the course of the day and seasonally. Since electricity supply must always meet demand, generation must also be increased and reduced. Biomass, like fossil fuels and large hydro, is **deployable** and generation can be ramped up or down. This is not the case for intermittent renewables, such as wind or solar, or nuclear. Biomass can also serve as baseload, thus displacing coal or gas generation – something not possible with wind or solar.

Biomass Utilization in Existing Infrastructure

Biomass is the only source of renewable carbon. Almost all products that are produced from fossil fuels, including electricity, heat, fuels, chemicals, plastics, and materials, can also be produced from biomass such as wood and straw. This means that infrastructure developed for utilization of fossil fuels can also consume biomass in raw or modified ('intermediate') form. The economic benefit of substituting biomass for fossil fuels in existing infrastructure is that companies avoid 'stranding assets' and can leverage previous investments, thus ensuring the affordability of renewables adoption while retaining (or expanding) the existing workforce. The following are examples of biomass utilization in existing infrastructure using currently available technology that is deployable at commercial scale.

- **Co-Firing Biomass in Coal-Fired Power Plants** – GHG emissions from coal-fired power plants can be significantly reduced by blending biomass with coal. Wood pellets are a common biomass fuel, but it is also possible to utilize urban waste, waste wood, wood chips, or agricultural residues (e.g., straw). Conversion of large coal-fired power plants to biomass has been completed in Canada, the U.S., and Europe.[9,10]
- **Liquid Transportation Fuels** – Renewable diesel and biodiesel can be blended with petroleum diesel, and ethanol and renewable gasoline can be blended with petroleum gasoline, in the existing liquid road transportation fuel distribution infrastructure. Biofuels avoid fleet replacement, which is necessary with electrification. Ethanol already accounts for 10% of the U.S. fuel supply and U.S. consumption of ethanol exceeds Canada's total gasoline consumption.[11,12] Bio-based jet fuel is the only renewable substitute for Jet A-1, the dominant jet fuel, and is available commercially.[13]

- **Process Heat for Cement Production** – Due to the combustion of fossil fuels to meet the significant heat demands of cement production, many of Canada's top 100 largest point sources of GHG emissions are cement plants.[14] Biomass is already being used to displace coal in at least two cement plants in Canada.
- **Renewable Natural Gas (RNG) in Pipelines** – RNG, which is chemically similar to natural gas, can be produced from a variety of organic feedstocks and blended with natural gas for utilization by industrial, commercial, and residential consumers. RNG upgrading and injection into pipelines is commercial in other jurisdictions.[15]
- **Biochar for Steel Production** – Large integrated steel producers, including the three large plants in Ontario, require a source of carbon for reduction reactions to convert iron ore into steel. Biochar (charcoal) produced from wood can displace the coke produced from coal at existing integrated steel plants. Large-scale commercial steel production using biochar is already practiced extensively in Brazil.[16]
- **BioCrude in Upgraders and Oil Refineries** – Low-oxygen 'biocrude' produced from liquefaction of solid biomass (e.g., waste wood) can be blended with bitumen prior to upgrading to synthetic crude oil or with oil prior to refining. Lipids, such as vegetable oils and animal fats, can also be converted into hydrocarbon fuels in existing refineries (several refineries have already been retrofitted to operate on inedible plant oils).[17]
- **Building Space Heating** – Building heating systems, whether hydronic (water/steam as the heat carrier) or forced-air (air as the heat carrier), that were installed with fossil fuel combustion as the heating source can be retrofitted to utilize biomass-based heat. The scale can range from individual residences to large district energy systems heating entire cities. Electricity from intermittent renewables cannot serve this purpose.[18]

Biomass as a Job Creation Opportunity

Biomass creates by far the most long-term, operating jobs of any renewable energy: up to 5.5 per MW vs. 0.2-0.7 per MW for PV solar and on-shore wind.[19] Modern bioenergy, including liquid biofuels, biopower, and biogas, currently employs more people worldwide than any other type of renewable energy.[20] This is because bioenergy requires a physical fuel for production; the majority of jobs are in feedstock supply operations and management.[19,20] These figures do not account for the fact that bioenergy economically complements the production of higher-value non-energy bioproducts, such as agricultural crops, lumber, solid wood, and pulp. Production of higher-value products typically requires significantly more labour than energy production and high-value co-products are a unique aspect of bioenergy when compared to other renewables.

As witnessed by Ontario's experience with the Green Energy Act, solar and wind companies can shift the location of manufacturing operations rapidly if taxpayer- or consumer-funded policy supports are reduced. Some companies that located production in Ontario have now withdrawn from the province and there is a risk that this will continue.[21] Germany, a leader in wind and solar deployment, has also lost much of its solar equipment manufacturing sector.[20,22,23] Above-market pricing for renewable electricity (e.g., solar) using equipment manufactured in other jurisdictions increases energy prices for consumers and reduces the competitiveness of electricity-consuming domestic industry while benefiting foreign renewable energy equipment manufacturers.[24] This highlights the importance of a policy focus on operating, long-term sustainable domestic jobs.

Many of the skills required to plan, build, and operate bioenergy and bioproduct operations are similar to those needed in Canada's oil and gas, mining, and chemicals industries. Given the downturn in fossil fuel prices and resulting unemployment, bioenergy and bioproducts offer an attractive alternative. There is also an immense opportunity to link resource management and utilization with high tech (ForestTech, AgTech) in the form of remote sensing and mapping, big data, GIS, drones, and remotely-operated/autonomous vehicles and equipment.

Cost Competitiveness

The economic performance of bioenergy, biofuels, and bioproducts depends upon the price of competing products. When the price of oil was US $147 per barrel in 2008, or when the price of natural gas was above US $12.00 per Gigajoule (GJ) in 2005 and 2008, bioenergy alternatives could be produced for much lower cost than those fossil fuels.[27] With oil trading below US $40 per barrel and natural gas near US $2.00 per GJ at the beginning of 2016, it is difficult for biomass to compete with these fuels on a simple cost basis in the absence of carbon pricing and/or other policy supports. However, bioheat, bioelectricity, and biofuels are typically produced in tandem with higher-value primary products, such as lumber, pulp, grains, animal feed, chemicals, and materials, which makes production of lower-value bioenergy commodities from the residues of these primary products economically viable. A 'bio-refinery', akin to an oil refinery where small-volume, high-value chemicals are co-produced with large-volume, low-value fuels, is one potential model. The economics of bioenergy and biofuels can also be attractive due to the utilization of existing fossil fuel infrastructure/equipment and avoidance of capital costs associated with new generating facilities (gas plants, wind and solar installations) or equipment (vehicle fleet).

Energy Price: Biomass Vs. Fossil Fuels

A dry tonne of biomass has an energy content of 15-19 Gigajoules (GJ). A barrel of oil has an energy content of 6.1 GJ and a cubic meter of natural gas has an energy content of 0.0373 GJ.[25,26] Oil priced at US$40 per barrel has an energy price US$6.56 per GJ. The equivalent price for delivered biomass is $98-125 per dry tonne. Natural gas at US $2 per GJ has an energy price equivalent of US $30-38 per dry tonne of biomass. It should be noted that high moisture content biomass feedstocks will have a lower conversion efficiency than oil or natural gas for most thermal processes due to the need to expend energy evaporating water. However, conversion of biomass to fuels and chemicals via biological conversion is not typically negatively impacted.

Despite current microeconomic challenges for some bioenergy and bioproducts, there are reasons to consider policy support (e.g., loan guarantees, capital support, feedstock assistance, blending incentives) beyond carbon pricing. Research on the impact of ethanol production on the liquid transportation fuel sector shows that the availability of a bio-based alternative to the dominant fossil fuel product results in reduced volatility of fuel pricing.[28] Essentially, two competing products in the marketplace that are produced from completely different feedstocks limits price spikes that occur in a single monopolistic product situation. In addition, one of the primary reasons for the higher cost of biomass compared to fossil fuels is the cost of labour associated with operation of feedstock supply chains and biomass conversion facilities. Labour expenditure has significant knock-on macroeconomic benefits – particularly when products or services can be exported.

Bioenergy for Economic Development in Remote and Indigenous Communities

A good example of how policy support for biomass utilization can be justified due to macroeconomic benefits is development and operation of heat and power plants in remote communities. Most of Canada's remote communities rely upon imported diesel fuel for electricity generation and heating oil/propane for some of their heat demands. This situation results in a transfer of funds out of the community that provides little to no knock-on economic development within the community. In contrast, production of heat and power from locally-sourced biomass results in significant job creation, positive economic feedbacks within the community, and improved environmental sustainability. Bioenergy can also support the operation of high-value solid wood products facilities that provide communities with revenue from exports and can employ many local workers.

Biomass at Large and Small Scale

Biomass can be used to reduce GHG emissions at a range of scales from household (e.g., biomass heat, transportation biofuels) to heavy industry. As an example of how biomass can be utilized to reduce GHG emissions at existing facilities, the following is a list of Canada's 25 largest GHG emitters, their 2013 emissions, and potential options for reducing associated GHG emissions (including products).

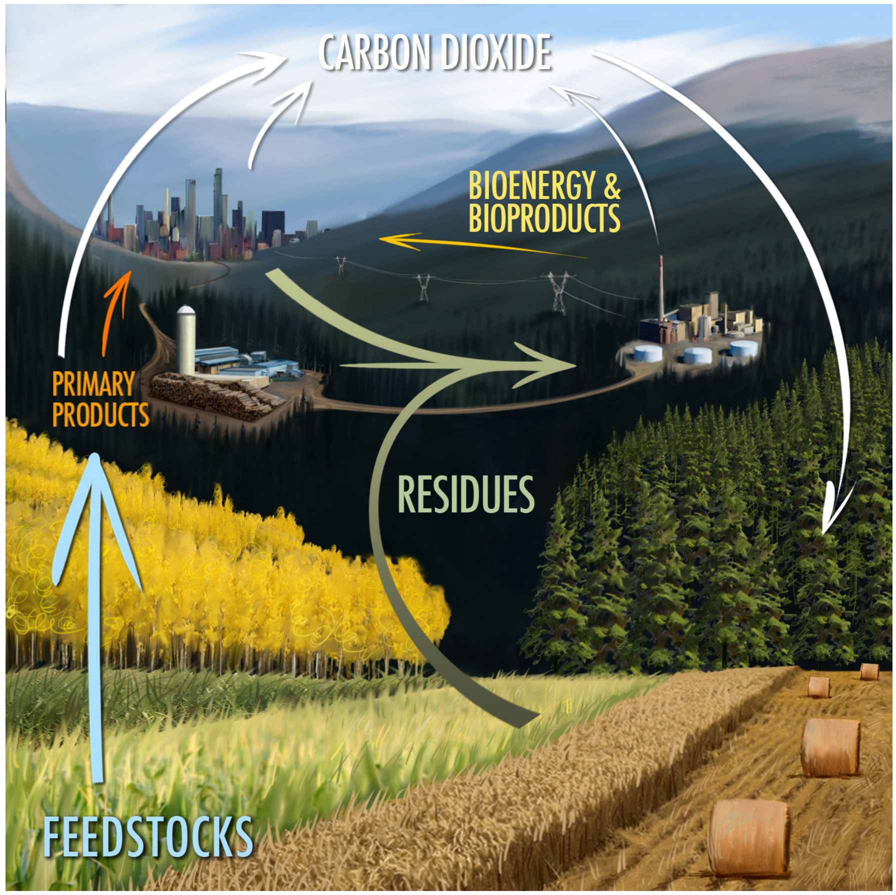
Figure 3. Canada's 25 Largest Point-Source Greenhouse Gas Emitters (2013)[14]

Facility Name	Company	Location	Facility Type	2013 GHG Emissions ('000 t CO_2 eq)	Biomass Options
Mildred Lake and Aurora North Plant Sites	Syncrude	Fort McMurray, AB	Oil Sands Upgrader	12,549	RNG, BioCrude, Biohydrogen
Sundance Thermal Electric Power Generating Plant	TransAlta	Duffield, AB	Coal-Fired Power Plant	12,182	Co-firing Biomass
Genesee Thermal Generating Station	Capital Power/TransAlta	Warburg, AB	Coal-Fired Power Plant	8,998	Co-firing Biomass
Suncor Energy Oil Sands	Suncor Energy	Fort McMurray, AB	Oil Sands Upgrader	8,414	RNG, BioCrude, Biohydrogen
Keephills Thermal Electric Power Generating Plant	TransAlta/Capital Power	Duffield, AB	Coal-Fired Power Plant	7,609	Co-firing Biomass
Boundary Dam Power Station	SaskPower	Estevan, SK	Coal-Fired Power Plant	5,605	Co-firing Biomass
Dofasco Hamilton	ArcelorMittal Dofasco	Hamilton, ON	Integrated Steel Plant	5,149	Biochar, Bio CHP
Sheerness Generating Station	ATCO/TransAlta	Hanna, AB	Coal-Fired Power Plant	4,810	Co-firing Biomass
Firebag	Suncor Energy	Fort McMurray, AB	In Situ Oil Sands Project	4,703	RNG, Bio CHP
Cold Lake	Imperial Oil	Grande Centre, AB	In Situ Oil Sands Project	4,605	RNG, Bio CHP
Horizon Oil Sands Processing Plant and Mine	Canadian Natural Resources	Fort McMurray, AB	Oil Sands Upgrader	4,539	RNG, BioCrude, Biohydrogen
Battle River Generating Station	ATCO	Forestburg, AB	Coal-Fired Power Plant	4,426	Co-firing Biomass
Long Lake Project	Nexen	Fort McMurray, AB	In Situ Oil Sands Project	4,139	RNG, Bio CHP
Poplar River Power Station	SaskPower	Coronach, SK	Coal-Fired Power Plant	3,970	Co-firing Biomass
Scotford Upgrader	Shell Canada	Fort Saskatchewan, AB	Oil Sands Upgrader	3,329	RNG, BioCrude, Biohydrogen
Lingan Generating Station	Nova Scotia Power	Lingan, NS	Coal-Fired Power Plant	3,319	Co-firing Biomass
Irving Refinery	Irving Oil	Saint John, NB	Oil Refinery	2,995	RNG, BioCrude, Biohydrogen
Wolf Lake and Primrose Plant	Canadian Natural Resources	Wolf Lake, AB	In Situ Oil Sands Project	2,994	RNG, Bio CHP
NOVA Chemicals Plant (Joffre)	NOVA Chemicals	Red Deer, AB	Ethylene & Chemicals Plant	2,897	Bioethylene
Belledune Generating Station	New Brunswick Power	Belledune, NB	Coal-Fired Power Plant	2,801	Co-firing Biomass
Essar Steel Algoma Inc	Essar Steel Algoma	Sault Ste. Marie, ON	Integrated Steel Plant	2,776	Biochar, Bio CHP
TransCanada Pipeline, Alberta System	Nova Gas Transmission	Fairview, AB	Natural Gas Pipeline	2,673	RNG
Shand Power Station	SaskPower	Estevan, SK	Coal-Fired Power Plant	2,333	Co-firing Biomass
Foster Creek SAGD Bitumen Battery	Cenovus	Bonnyville, AB	In Situ Oil Sands Project	2,193	RNG, Bio CHP
Lake Erie Works	U.S. Steel Canada Inc.	Haldimand County, ON	Integrated Steel Plant	1,863	Biochar, Bio CHP

Biomass as a Greenhouse Gas Emission Reduction Option

The use of fossil fuels releases carbon from ancient pools that cannot be replenished. Biomass, however, is considered a low-GHG source of energy and carbon because it contains carbon extracted from the atmosphere during annual plant growth cycles (**Figure 4**). Therefore there is ***no net addition of carbon to the atmosphere when biomass is used for fuels, energy, chemicals, or other materials***. In fact, wood and other solid biomass is the best long-term carbon storage option at present, as wood used to make buildings, furniture, and durable objects ('Primary Products') can store carbon for hundreds of years. During this time, multiple rotations of forest can be grown on the same land – each one extracting carbon from the atmosphere and storing it as plant material. ***All biomass must be sourced on a sustainable basis in order to be considered renewable*****.** Canada is the world leader in sustainable forest certification (46% of certified forests are in Canada)[29] and the same sustainability rules that apply to harvesting forests for solid wood products and pulp also apply to all other uses of biomass. Therefore, by law, it is not possible to overharvest publicly-owned forest lands in Canada for biomass. Canada's current forest harvest is far below the harvest volume deemed sustainable by Chief Foresters and Governments. Agricultural residue biomass is the inedible portion of annual crops, such as wheat and barley straw or corn stover and manure. A portion can be removed without negatively impacting sustainability of agriculture. Ensuring soil organic carbon and moisture levels are maintained by removing an appropriate amount of residue is essential to the long-term productivity of soils.

Figure 4. Biomass Feedstocks and the Carbon Cycle



Is Biomass Carbon Neutral?

Biomass is not 'carbon neutral', as fossil fuels are typically used in the harvest, transportation, and processing of feedstock. These reduce the net GHG reduction compared to fossil fuel baselines. However, many life cycle analyses show a GHG reduction of 70-95% from baseline when agricultural residues or forest biomass are used as the feedstock for energy and fuels.[30,31] The reduction is more significant when coal or oil, rather than natural gas, is replaced. In addition, utilization of waste biomass can result in a GHG reduction greater than 100% from baseline due to the avoidance of methane emissions (*see Breakout Box on page 6*).

Biomass Availability in Canada

Canada is home to 8% of the world's forests and ranks first among developed countries for forested land per capita (fourth globally).[32] It is the largest per capita cereals producer and ranks third globally for arable land per capita behind Australia and Kazakhstan.[32] No other country has the combined per capita forestry and agriculture resources of Canada. In addition, Canada's cropped area has actually been decreasing over time, meaning the country has a significant potential to develop biomass crops – plants such as oilseeds, grasses, or woody species, grown exclusively for bioenergy and bioproducts – on lower-grade agricultural land.

"No other country has the combined per capita forestry and agriculture resources of Canada"

Given the immense size of Canada and the diversity of its ecosystems, inventorying the existing and potential future biomass resources of the country is challenging. However, several studies have highlighted the significant potential to increase the utilization of biomass in Canada. In a 2003 report for Industry Canada, it was estimated that residue/'waste' streams from agriculture, forestry, and urban sectors could provide 1.5-2.2 Exajoules (EJ) of energy or 14-21% of current primary energy supply in Canada (10.6 EJ).[33] This is ***equivalent to 2-3 times the amount of coal (0.7 EJ) or 40-60% of the natural gas (3.6 EJ) supplied domestically in 2013***.[34] These figures do not account for the potential of biomass crops or increases in forest productivity possible via more active management. An inventory of crop residues in Canada by Agriculture and Agri-Food Canada and academic researchers found an average volume availability of 48 million dry tonnes per year, which has an energy content of almost 0.8 EJ.[35] This is similar to the maximum annual potential for forest harvest residues of 46 million dry tonnes identified by UBC researchers in 2010,[36] although the 26% drop in timber harvest in Canada since 2004, largely as a result of the drop in pulp and paper demand, has reduced the volume of harvest residues. The reduction in timber harvest for lumber and pulp is challenging for the forest industry but presents an opportunity to use the available biomass for GHG-reducing activities. Over 40 million dry tonnes of biomass could be harvested annually from Canada's forest while respecting existing sustainable harvest level regulations.[37] In addition to forestry and agricultural resources, Canadians produce approximately 25 million tonnes of municipal waste every year. This waste is an energy resource of 0.2-0.3 EJ.[38] By combining forestry, agricultural, and municipal biomass feedstocks, utilization of 2 EJ, or 120 million dry tonnes, of biomass is an achievable goal that could reduce Canada's GHG emissions by 125 million tonnes CO_2 eq or more from the current level (assuming an 80% GHG reduction from baseline). To put this in perspective, the United States currently consumes 50% more energy from biomass (3.2 EJ) than this target.[34]

"Utilizing two exajoules, or 120 million dry tonnes, of biomass is an achievable goal that could reduce Canada's GHG emissions by 125 million tonnes CO_2 eq or more and allow the country to meet its Copenhagen Accord target."

What is Two Exajoules of Biomass?

Assuming an average of 17 GJ per dry tonne of biomass, **2 EJ is equal to 120 million tonnes of dry biomass**. While this is a significant quantity, it pales in comparison to the billion tonnes of biomass (17 EJ) identified as reasonably available in the United States by the U.S. Department of Energy.[39] Canada's current bioenergy use is 0.5 EJ, or 5% of total energy supply, which is equal to the natural gas energy used in oil sands operations (the primary reason for the relatively high GHG intensity of bitumen and synthetic crude oil).[40]

Key Final Points

- Biomass and biological systems are critical to reducing Canada's greenhouse gas emissions
- Biomass addresses Canada's primary GHG challenges: Transportation, Climate, and a Resource Economy
- Biomass is the only source of renewable carbon and, unlike renewables such as solar and wind, can be used to produce transportation fuels, products, and materials
- Biomass products can be utilized in much of Canada's existing energy and heavy industry infrastructure
- Projects that utilize biomass create long-term, operating jobs that cannot be easily offshored
- Bioenergy complements production of high-value, job-creating bioproducts
- Biomass can be the basis for innovation in the CleanTech, BioTech, and AgTech/ForestTech sectors
- Canada has a competitive advantage in biomass supply compared to other nations

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