MaRS Market Insights

Digging in to Bio-based Innovation

MaRS is a member of

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1. Introduction

Bioenergy is big business. McKinsey expects the market for energy from biomass and biofuels to grow from $203 billion in 2008 to $544 billion in 2020[1] and account for a rapidly increasing share of the total energy market. Markets are also developing around co-products and bioproducts from biofuel production, including a variety of bio-based materials. Bioproducts are chemicals, proteins or polymers derived from the bioprocessing of renewable resources. When produced in large volumes, they form the building blocks for renewable fuels, biodegradable plastics, food additives and therapeutic compounds.[2]

Canada's bio-based activities are worth $87.8 billion of the country's gross domestic product (GDP); health and pharmaceuticals, bioindustrials and agriculture account for $55 billion, $20 billion and $11 billion of this value, respectively.[3] Together, bioenergy and bioindustrial companies account for 24.7% of Canada's bioeconomy companies.[4] These are the companies that develop biofuels as well as the technologies to develop biofuels, bioproducts and other related compounds. The industry is growing: there are 11% more Canadian bioeconomy companies today than there were five years ago. Approximately a third of the companies in Canada's overall bioeconomy are based in Ontario.[5]

The financial implications of this growth industry are huge. To get the most out of the bioeconomy, and to stimulate jobs and development in Ontario, further development of the industry must be done in an environmentally and socially responsible fashion.

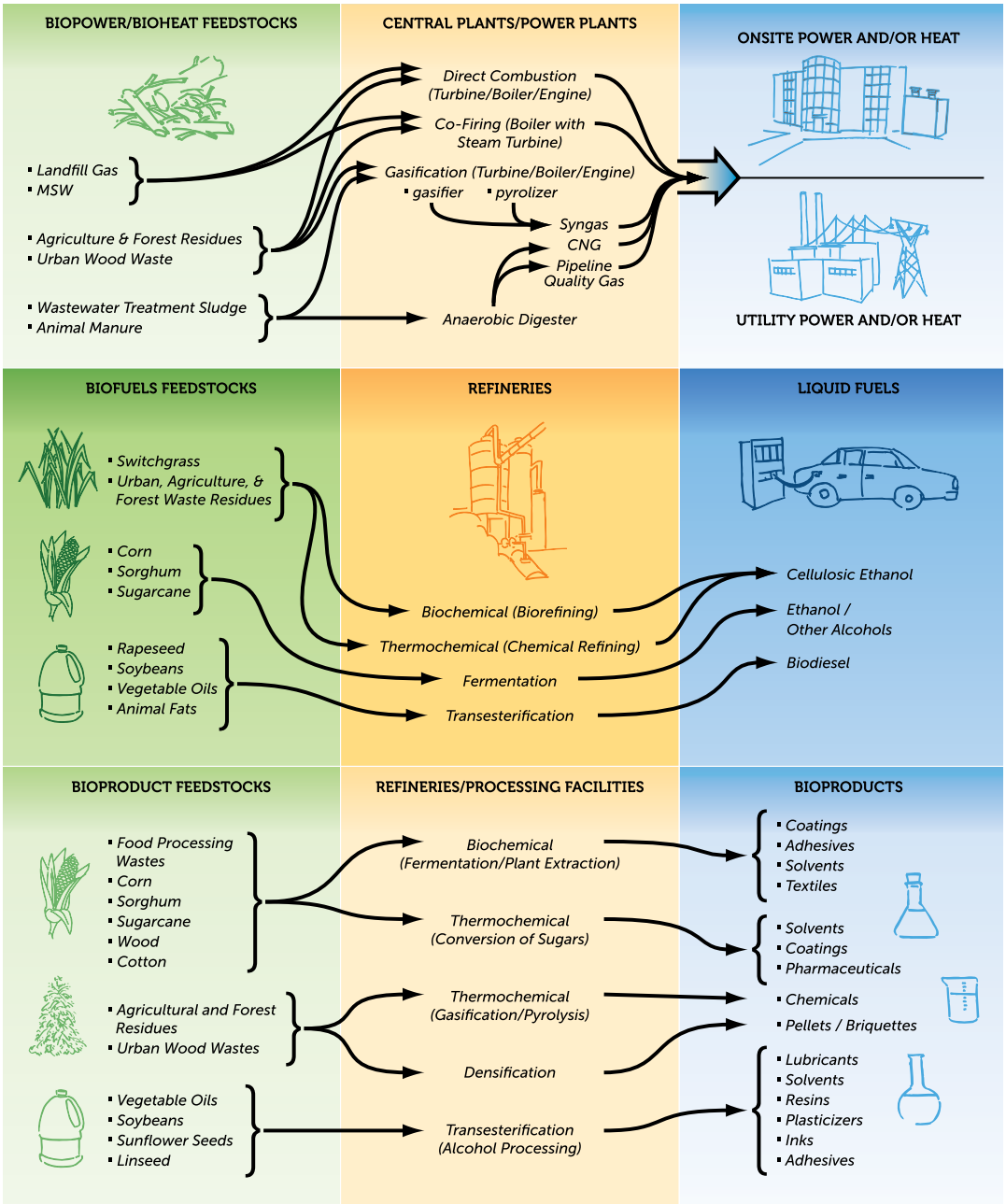
Bioproducts can be a pathway to hedge against higher fuel prices and depletions in supply, as well as to foster rural economic development and independence from fossil fuels. If harnessed appropriately, bioproducts can help mitigate climate change through the use of a carbon-neutral energy source and adapt to climate change through rural economic development opportunities and offering security of supply. In Ontario, bioproducts can increase the markets for farm and forest products, with the subsequent benefits spread across to farmers, communities (rural, urban and First Nations) and businesses.

This report explores the market opportunity found in various feedstocks and bioproducts, including biofuels, biochemicals, biopower and waste-to-energy plants. It begins by reviewing relevant research on potential feedstock supplies and industry logistics, policies, funding and investment opportunities in Ontario. The report profiles Ontario innovators and identifies the sector players.

2. Feedstock potential

Biomass is the biological material that comes from living or recently living plants, encompassing forestry, agricultural, aquacultural and waste sources. Ontario is rich in all these sources. These bioresources can become feedstocks for bioproducts. Biomass can be used directly for heating and electricity, or it can be refined through gasification, pyrolysis, torrefaction and LignoBoost; for the production of electricity, steam and heat; or for the development of bio-based products and materials, such as fuels, plastics, polymers and chemicals.

Figure 1: Biomass conversion technologies and feedstock sources



Source: United States Environmental Protection Agency and the National Renewable Energy Laboratory, State BioEnergy Primer, 2009.

Globally, most biomass collected for energy is used directly as fuelwood and only 10% is agriculture based, of which only 3% is purpose-grown energy crops.[6] These fuelwood quantities, used primarily for heating, cooking and lighting in developing nations, are similar in quantity to global industrial roundwood production for products (see Figure 2).

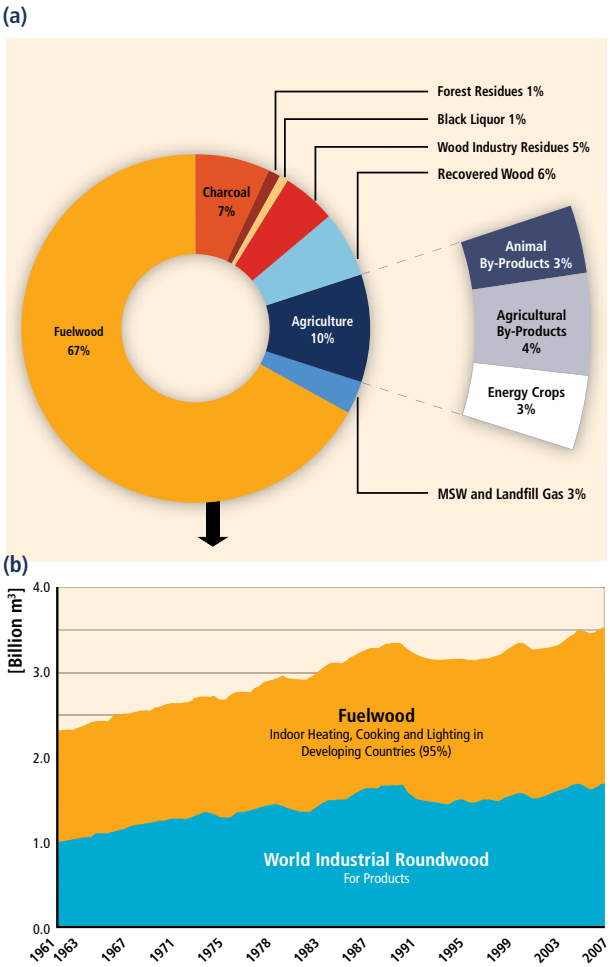
In 2011, Statistics Canada reported that of Canada's 208 firms that reported bioproduct activity (representing 43% of Canada's firms at the time of data collection), approximately 27 million tonnes of biomass (including renewable biomass from agricultural, forestry and marine/aquaculture sources) were converted into bioproduct sales of over $1 billion.[7] The primary biomass sources utilized were agricultural biomass, followed by forestry biomass, as seen in Figure 3.

Bio-feedstocks tend to be the most expensive operational input for biorefineries (plants producing fuels, products or chemicals), at about 70% to 80% of operational costs.[8] Depending on the refinery location, the transport of these feedstocks can be a huge cost and operational challenge, often more expensive than shipping the finished products (wood, for example, is a voluminous feedstock with higher mass than finished bioproducts).

Ontario industries that can provide significant feedstock supplies include forestry, agriculture, and waste and food processing (Ontario has the largest food processing industry in Canada). Aquaculture is another source, though for this paper it is included under agriculture. Newer feedstocks are cellulose, algae and lignin.

Bioenergy and bioproducts can create jobs and encourage rural development in the forestry and agricultural sectors. In northern Ontario, forestry dominates. In southwestern and southeastern Ontario, there is more focus on the agricultural and industry byproducts/waste utilization sectors, with the added benefit of having a close proximity to markets. To reach the potential for and to maximize upon the benefits of a bio-based economy, it is crucial to develop mutually beneficial partnerships with First Nations, Métis and Inuit communities to bring economic opportunity and autonomy to communities like these that are often remote. First Nations participation in the bio-based economy can lead to economic sustainability for these communities, while allowing for independence in

Figure 2: World primary biomass sources

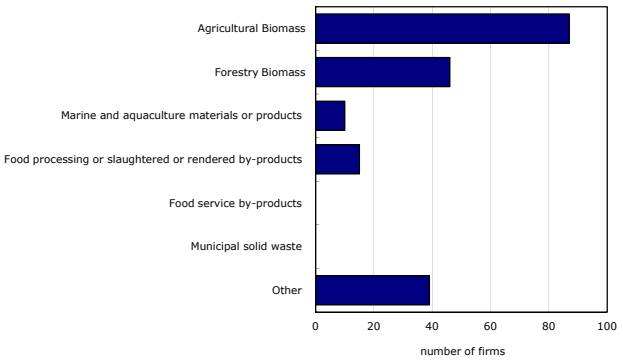


Source: Chum, H., et. Al. Bioenergy. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, 2011.

Biomass Inventory Mapping and Analysis

The Government of Canada developed the Biomass Inventory Mapping and Analysis Tool (BIMAT) to allow users to learn more about the availability of Canadian herbaceous and woody opportunity biomass as well as the spatial variability of the resource across Canada. This application provides Internet-based geographic information system (GIS) functionality to allow users to query and visualize biomass inventory data.

Figure 3: Canadian bioproducts firms by primary biomass source



Source: Chum, H., et. Al. Bioenergy. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, 2011.

and the opportunity to pursue projects to meet their energy and material needs.[9] [10] This is a human element of sustainability, wherein the benefits of a bio-based economy can be recognized, but employee well-being, treaty and land rights must also be acknowledged.

2.1 Wood and forest resources

Ontario's forests cover 66% of the provincial land mass and 82% of forests are owned by the Crown.[11] The Ministry of Natural Resources (MNR) is charged with stewardship, sustainable use and conservation of these resources. MNR defines forest biofibres as forest resources from Crown forests that are not normally being utilized for conventional forest products and that are made available under an approved forest management plan. Forest biofibre includes tree tops, cull trees or portions of trees, individual and stands of merchantable and unmarketable trees, and trees that may be salvaged as a result of a natural disturbance. It does not include residual byproducts such as wood shavings, sawdust, bark or wood chips produced during mill operations.[12]

According to MNR's Ontario Available Wood Report (2013), there are 11.5 million square metres—4.1 million square metres merchantable and 7.4 million metres unmerchantable—of potentially available wood supply in Ontario.[13] The Ministry of Northern Development and Mines (formally known as the Ministry of Northern Development, Mines and Forestry) estimates that 7.4 million cubic metres a year of unused wood is an available feedstock and that 2.9 million cubic metres of this amount is undersized or "unmerchantable"—that being treetops, branches and limbs.[14] It is this leftover wood or wood residues that tend to be used for the bioeconomy, not virgin forest stands. The forest industry used 12,582 kilotonnes of solid wood waste and 17,358 kilotonnes of spent pulping liquor for energy production in 2011.[15] Ensuring the sustainability of use is key to Ontario's success in this space.

Forest resources can be processed into logs, wood chips and pellets (byproducts of other industry that have higher calorific value due to compression and are easier to store) to use directly in end use, or to further process. Wood pellets, which most commonly utilize sawmill waste, are made through compacting or compressing waste wood, like sawdust. This is already a mature market. Wood pellet exports went up in North America by 50% from the first quarter in 2012 to the first quarter in 2013.[16]

Ontario Power Generation and the Pembina Institute completed a sustainability analysis of Ontario's forestry-based biomass and found that Ontario has a renewable supply of biomass available from logging residues and low-grade wood amounting to two million tonnes of wood pellets annually for electricity production.[17] This quantity of wood pellets is capable of producing 3.4 billion kilowatt hours of electricity annually—enough to power 285,000 homes while reducing greenhouse gas (GHG) emissions by 80% compared to using natural gas.[18] Pembina also calculated that over 3,500 full-time jobs could be created, 91% of which would be located in forest-dependent communities.[19] The report also suggests that harvesting and using biomass could contribute $590 million annually to Ontario's gross domestic product.[20]

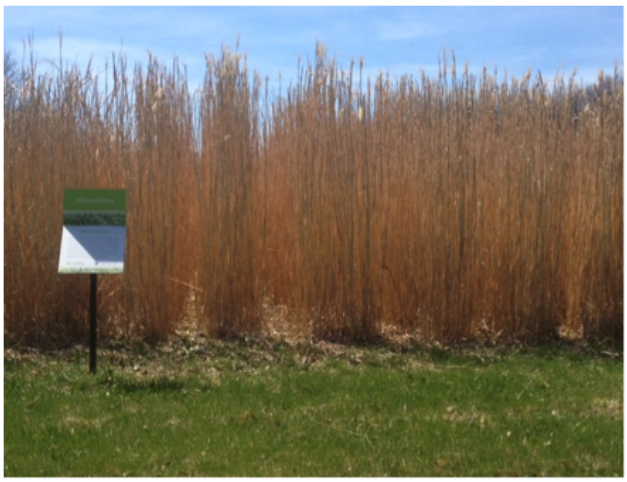
According to University of Toronto's Dr. Tat Smith, a leading expert in forest ecology and dean of the university's Faculty of Forestry, woody biomass market penetration depends on the following factors[21]:

- Energy market development and penetration
- Forest supply chain complexity and cost (and it is a complex supply chain)
- Confidence in feedstock inventory estimates
- Development status of major conversion technologies
- Sustainability considerations

The Forest Products Association of Canada and FP Innovations, in The New Face of the Canadian Forest Industry: The Emerging Bio-Revolution, found that the global market for bioenergy, biochemicals and biomaterials that can be extracted from trees will be approximately $200 billion by 2015.[22] Canada's forest sector is already producing bioproducts. Paper demand is down, resulting in less competition for wood resources and a forest industry that is interested in diversifying. The integration of new technologies into existing production can provide the competitive edge to Canada in this sector.

2.2 Agricultural resources

Agricultural feedstocks include crops such as corn for ethanol, oilseeds for diesel production and second-generation feedstocks such as switchgrass, as well as tree crops such as willow and aspen. Crop residues are also considered a feedstock and can provide additional crop value to farmers. Algae is yet another promising upcoming feedstock source.



Source: Lynda O'Malley, 2013.

Seventy per cent of Canada's land mass is suitable for growing crops.[23] In Canada, the number of farms and the acreage these farms cover has been decreasing from 276,548 farms in 1996 to 205, 730 farms in 2011. In 2011 Ontario had 51,950 farms covering 12.6 billion acres.[24]

During a similar time frame, oilseed and grain farming in Ontario increased from 13,776 farms in 2001 to 15,818 farms in 2011.[25] There are about 1.7 million cattle in Ontario whose manure waste could be used to produce 1.55 terawatt hour (TWh) or over 60% of total electricity consumed in the agricultural sector.[26]

In the joint report Assessment of the Business Case for Purpose-Grown Biomass in Ontario, prepared by the Western University Research Park at the Sarnia-Lambton Campus for Ontario Federation of Agriculture and Erie Innovation and Commercialization, the authors examined the business case for purpose-grown biomass specifically for heat and power generation in Ontario.[27] They argue that there is a viable business case in Ontario for purpose-grown biomass crops, with a margin comparable to cash crops and with the added benefits of soil improvement. They also determined that the acceptable farm gate price ranges from $104.4 per tonne (miscanthus) to $148. 7 per tonne (tall grass prairie).[28] They went on to estimate the price of pelletizing at $38.88 per tonne (including sub-total processing and financing costs).[29] In their words:

"The development of a biomass aggregation chain in Ontario is required to establish a purpose-grown crops industry. There are a few biomass aggregators or pellet mills in Ontario. However, most of these are relatively small with a processing capacity of 1 – 4 tonne/hr. Other supply chain components of growing the crops and transportation of biomass are already established to a certain extent. The total cost of biomass processing, i.e., pelletizing, is estimated at $38.88/tonne, which includes the sub-total processing cost of $23/tonne and a financing cost of $15.88/tonne. For this total processing cost, investing in a new agricultural pellet mill would provide a return on equity of 17.5%. A pellet mill with a capacity of 150,000 tonne/yr or 20 tonne/hr is considered the optimum size to draw purpose-grown biomass from a 100 km radius and was used for the processing cost estimations in this report. For the centralized heat and power generation system, which usually has a longer total transportation distance, the total cost of biomass transportation in Ontario is $40-50/tonne. For the distributed heat and power generation system, which has relatively shorter total transportation distance, the total cost of biomass transportation in Ontario is approximately $30/tonne. The total cost of miscanthus and switchgrass pellets to end users are $172.45/tonne and $203.75/tonne, respectively."[30]

Within the agricultural sector, algae biofuels hold great promise. SBI Energy, an industrial and energy market research publisher, estimates that the algal biofuels market will be worth $1.6 billion by 2015, representing a 43% growth rate between 2010 and 2015.[31] Algae, a single or multi-cellular organism that is composed of lipids, carbohydrates and protein, is a fast-growing and efficient biomass source, requires less land to produce a comparative fuel from compared to conventional biofuels, and uses carbon dioxide as an input. Its environmental footprint is large—it is a huge consumer of water, and innovators are having a hard time scaling up production. As a feedstock, algae has applications for biofuels, plastics, food additives, cosmetics and neutraceuticals.

Algae systems are still under development—productivity needs to improve and production costs need to decrease. The International Energy Agency estimates production costs to range from $1.2 to $7.9 per litre, equivalent to $200 to $1,200 per barrel of oil, and are projected to cost 26 cents per litre, equivalent to $60 per barrel of oil at an unstated point in the future.[32] Algae biofuels production is also expected to grow rapidly over the next decade and reach 61 million gallons per year with a market value of $1.3 billion by 2020. This represents a compound annual growth rate of 72%.[33] Collaboration with food additive and neutraceuticals can provide the cash flow needed to sustain the sector until demonstration plants develop into commercial scale biorefineries for algae production.

The Innovators

Converted Carbon Technologies (CCT) is a nutrient ingredient company that has developed an algae cultivation system, called BioSilo™, for the high volume production of algae biomass. Founded in 2008, CCT's initial focus was to cultivate algae biomass for clean energy. CCT changed its direction in 2010, taking this biomass, which is high in vitamins, minerals, antitoxins and omega-3, to target the multibillion-dollar functional food and beverage additive, and health and supplement markets. CCT's system has a small footprint and is modular in nature to allow scalable construction. Their system can cultivate a wide variety of algae species depending upon the requirements of their customers. CCT is currently preparing to move into an industrial facility while they seek capital to scale up their operations.

Toronto-based Pond Biofuels converts raw smokestack emissions from heavy industry into algal biomass. The company uses greenhouse gas emissions emitted by heavy industry as a feedstock for its process, whereby algae use carbon dioxide and sunlight to grow. Pond Biofuels' process produces bio-oil and biodiesel. In December 2012, Pond Biofuels partnered with US Steel Canada and Union Gas for a pilot project to test their process. Prior to this, they partnered with St. Mary's Cement, a cement and construction-related products manufacturer, on a pilot plant to tap into carbon dioxide from cement production as a feedstock for their algae production.

2.3 Food waste and food processing resources

This section covers food processing and municipal waste streams, with a focus on food and municipal solid waste (MSW). Waste as a feedstock includes:

- Forestry—trimmings, slash residue, sawmill residue;
- Agriculture—residues, manure, abattoir, produce;
- Food processing—produce gone bad, unusable food or drink, liquid waste streams, grocery store waste, used cooking oil; and
- Construction and demolition waste, landfill, sewage, wastewater, and urban green-space maintenance.

Ontario is home to Canada's largest food processing sector. It employs approximately 100,000 people across the province, and it is the third largest food processing sector in North America[34] with manufacturing revenues of more than $35 billion.[35] Globally, 1.3 billion tonnes of food waste is produced each year—54% of this waste happens before processing—and comes with a direct global economic cost of $750 billion annually.[36] The United Nations' Food and Agricultural Organization estimates the global volume of food wastage to be 1.6 gigatonnes of 'primary product equivalents,' while the total wastage for the edible part of food is 1.3 gigatonnes.[37] Total agricultural production (for food and non-food uses) is about six gigatonnes, which means nearly a third of all agricultural production ends up as waste. The United States generated around 250 million tons of MSW, of which about 87 million tons was recycled or composted. MSW generated per person peaked in 2000 and recycling has increased from 10% in 1980 to 34% in 2011. The US incinerates nearly 12% of all MSW.[38]

In Canada, the loss of solid food was more than 6.0 million tonnes between the retail level and the plate in 2007—the equivalent of 183 kg per person.[39] Another 2.8 billion litres of liquids, including milk and milk products, coffee, tea, pop and juices, were also wasted. These figures do not include losses at the production level or during food processing.[40] In addition, roughly 40% of food produced each year in Canada is not consumed, representing a loss of $27 billion.[41] Food wastes have significant environmental impact in the fuel and water inputs at various stages of production and processing. While much can be done to reduce food waste, it also represents a significant volume of material that can be recovered and converted into a useful product.

3. Bioproduct market opportunities

After collecting a feedstock, the components must be broken down to get at the chemical building blocks that will compose the product that is sought after.

Starch, sugar and cellulose are all plant-derived carbohydrates, produced through photosynthesis. Starch is the main source of stored energy in plants and is produced in plant cells. Structurally, plants are composed of cellulose, lignin and hemicellulose (in the form of lignocellulose mainly), and the percentages depend on the feedstock. Cellulose, like starch, is composed of glucose units, though many more and with much stronger bonds.

Starches and cellulose are in stored form, and breaking this form down to glucose—the accessible form—is key in biofuel and biochemical production. It is much easier to break down starch than cellulose. Cellulose is naturally harder to break down and few organisms in nature can do this job as a consequence. For example, human digestion uses enzymes to easily break down starch into glucose but cannot break down cellulose.

Technology developers have created various advanced processes to break down different feedstocks into one or more chemical components. Some developers have isolated an enzyme from a termite gut and harnessed it to break down cellulose, while others have developed an anaerobic digester to turn manure into gas. No matter the innovation, the next challenge for any developer is to get this innovation to market.

The following section discusses the market opportunities of biofuel, biochemical and biopower, including waste-to-energy technologies.

3.1 Biofuel market

Global biofuel use is projected to increase 25% by 2018 to 2.4 million barrels per day.[42] By comparison, the world consumes 90 million barrels per day of petroleum. In its Market Data: Biofuels report, Navigant Research, a market research firm, forecasts that global biofuels production will reach 61 billion gallons by 2023 from 33 billion gallons in 2013, and that biofuels will replace nearly 6% of global transportation fuel production from fossil sources while generating $70 billion in new revenue over the next decade.[43]

Global biofuels production is also anticipated to expand with a compound annual growth rate (CAGR) of 6% between 2013 and 2023—double the growth rate of fossil fuel based gasoline, diesel and jet fuel. [44] Leading this expansion will be advanced drop-in biofuels production, with a CAGR of 14% during the same time period. Drop-in fuels are those that are highly compatible with current infrastructure. Navigant predicts that the United States, Brazil and the European Union countries will remain the leading biofuels markets worldwide.

The commonality between these regions is the dedicated policy mechanisms, research dollars and co-technology development that occurs within these countries. Renewable fuel mandates have been the main mechanism to spur market growth in the biofuel industry to date. The result has been an increased demand for ethanol across Canada and the United States.

Case study: Biodiesel and ethanol energy production in the United States

About five per cent of the United States' total energy production is provided by bioenergy. The Energy Independence and Security Act of 2007 required that the Environmental Protection Agency's (EPA) Renewable Fuel Standard (RFS) program increase the volume of renewable fuel blended into transportation fuel from nine billion gallons in 2008 to 36 billion gallons by 2022; include diesel fuel; set requirements for different renewable fuels; ensure a net carbon savings; and require that the EPA apply lifecycle greenhouse gas performance threshold standards. Every November, the EPA sets the renewable fuel standards for the next year. The required applicable RFS volumes in the United States Clean Air Act for 2013, in billions of gallons, include:

- Cellulosic biofuel a1.0
- Biomass-based diesel ..... b+1.0
- Advanced biofuel..... a2.75
- Renewable fuel..... a16.55

a Ethanol-equivalent volume.

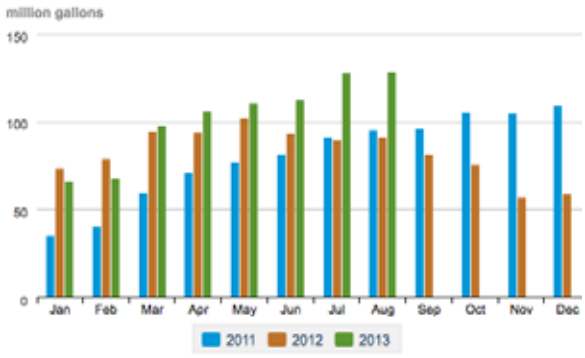
b Actual volume. The ethanol-equivalent volume would be 1.5 if biodiesel is used to meet this requirement.

Biodiesel

The EPA established a volume requirement of 1.28 billion gallons for biomass-based diesel for 2013 under the RFS program.

There were a total of 836 million pounds of feedstocks used to produce 111 million gallons of biodiesel in May 2013, coming from 116 biodiesel plants with an operable capacity of 2.2 billion gallons per year. This production in May was an increase from 106 million gallons in April 2013. Biodiesel production from the Midwest region was 67% of the US total.

Figure 4 United States monthly biodiesel production 2011-2013

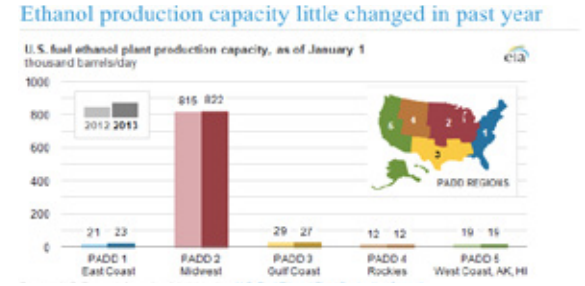


Source: US Energy Information Administration, 2013.

Ethanol

In terms of ethanol production, a total of 193 ethanol plants were in operation as of January 1, 2013, in the US, with a production capacity of 13.9 billion gallons annually. Most of this production capacity is located in the Midwest. Total nameplate capacity in the Midwest is 12.6 billion gallons per year (822,000 barrels per day). It is anticipated that the EPA will announce a decrease in RFS mandates for ethanol in 2014—cutting to 15.21 billion gallons for renewable fuels in 2014 instead of 18.15 billion gallons, one of three of the EPA's proposals to relax biofuel mandates.

Figure 5: United States fuel ethanol plant production capacity as of January 1, 2013



Source: US Energy Information Administration, 2013.

Bio-based industry support

The US has a network of support for bio-based technology at the federal and state levels. The US Department of Agriculture has loan guarantees for biorefineries through the Biorefinery Assistance Program and provides grants through the Repowering Assistance Biorefinery Program (for pre-2008 facilities), among others.

Figure 6: Ontario ethanol and biodiesel plant locations

Source: Chum, H., et. Al. Bioenergy. IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, 2011.

Canada has already made strides in ethanol production. In 2006, the country produced almost 600 million litres of ethanol; this totals to just over one per cent of the global production of 51 billion litres of ethanol in the same year.[45] In the western provinces ethanol is made from wheat, while in Ontario and Quebec ethanol is made from corn. This ethanol production requires about 0.5 metric tons (Mt) of wheat and 1.0 Mt of corn, representing 2% of the total production of 25.3 Mt of wheat and 11% of the total production of 9 Mt of corn for grain in Canada.[46]

At the federal level, Canada has a five per cent fuel mandate for ethanol content in gasoline and a two per cent mandate for biodiesel content in diesel. Ontario consumes 15.8 billion litres a year of gasoline and seven billion litres a year of diesel.[47] Ontario's production capacity for biodiesel (orange) and ethanol (green) can be seen in Figure 7 and plant details are found in the following tables. The figure focuses in on southern Ontario because there are no reported commercial plants in operation in northern Ontario. This can in part be explained by the tendency to locate plants for easy access to feedstock supply and a focus, at least for ethanol, on first-generation corn feedstocks (that utilize the starch content rather than the cellulosic content of corn).

Table 1: Ethanol production capacity in Ontario (in million litres per year [mmly])

GreenField Ethanol Inc.	Chatham	Ontario	Corn	195 mmly	Operational
GreenField Ethanol Inc.	Johnstown	Ontario	Corn	200 mmly	Operational
GreenField Ethanol Inc.	Tiverton	Ontario	Corn	27 mmly	Operational
IGPC Ethanol Inc.	Aylmer	Ontario	Corn	162 mmly	Operational
Kawartha Ethanol	Havelock	Ontario	Corn	120 mmly	Operational
Suncor St. Clair Ethanol Plant	Sarnia	Ontario	Corn	400 mmly	Operational

Source: Canadian Renewable Fuels Association, 2013.

Table 2: Diesel production capacity in Ontario (in million litres per year [mmly])

BIOX Corporation	Hamilton	Ontario	Multi-feedstock	66 mmly	Operational
Great Lakes Biodiesel	Welland	Ontario	Multi-feedstock	170 mmly	Operational
Methes Energies Canada Inc.	Mississauga	Ontario	Yellow grease	5 mmly	Operational
Methes Energies Canada Inc.	Sombra	Ontario	Multi-feedstock	50 mmly	Under Construction
Noroxel Energy Ltd.	Springfield	Ontario	Yellow grease	5 mmly	Operational

Source: Canadian Renewable Fuels Association, 2013.

Ethanol production in Ontario is not only used for fuel blends in gasoline, but is also an important building block chemical for the chemical industry. Renewables fuels, however, pose challenges for industry (Table 3).

Table 3: Renewable fuels specific issues

• Today's vehicle fleet is poorly equipped to use gas blends that are beyond 10% ethanol content.
• There is uncertainty around the lifecycle GHG reduction benefits of crop-based biofuels vs. gas/diesel. This is mostly related to land-use change.
• FAME mandates have raised concerns due to cold weather concerns because of the lack of availability of additives to improve the cloud point of biodiesel.
• Technical barriers and capital constraints have prevented further availability of advanced low GHG biofuels – in 2010 there was an estimated 6M gallons of cellulosic ethanol produced, far below the 100M gallons originally expected.
• Costs for crop-based biofuels remain high compared to the petroleum based counterparts.

Source: Ministry of Energy, 2010.

The Innovators

Woodland Biofuels is a cellulosic ethanol company that has developed technology for converting all forms of biomass into ethanol. Using waste biomass, the company uses gasification to produce synthetic gas or "syngas". Next, using a catalyst, they convert syngas into ethanol. Woodland Biofuels' technology utilizes waste materials as a feedstock and has the advantage of being able to convert various feedstocks into a consistent ethanol product.

Source: Lynda O'Malley, 2013.

Woodland's demonstration plant is located in Sarnia, Ontario, and has been built to scale up to a 20-million-gallon commercial plant. This plant was funded through multiple private investment funds—such as MaRS Cleantech Fund and Investeco Capital—and through the federal government's Sustainable Development Technology Canada, and the Ontario government's Innovation Demonstration Fund and Ontario Emerging Technologies Fund. To date, Woodland Biofuels has raised $30 million in capital.

The original idea behind Woodland was to help solve two big problems at once—dependency on fossil fuels and the environmental and energy security issues that dependency brings with it, and the growing problem of disposing of waste. Dependency on fossil fuels for energy and materials brings with it a wide variety of dangers. A significant danger is the impact on the cost of many products—including food—when oil prices spike. Woodland Biofuels expects to be able to produce ethanol from waste for less than half of what it costs oil companies to produce gasoline at today's oil prices. The company also expects to be able to compete effectively with the oil industry on a cost of production basis.

Woodland Biofuels' main challenge is taking their technology to the commercial scale. It has identified government as a key stakeholder that can help aid in commercializing these new technology in the sector. The company has found that industry investors have no incentive to finance technology that, once commercialized, has the potential to produce automotive fuel at half the current cost.

Based in Ottawa, Ensyn Technologies developed a pyrolysis technology that converts residual forestry and agricultural wastes into renewable fuels and chemicals through its Rapid Thermal Processing (RTP) technology. The company has built success upon developing innovations through partnerships. Ensyn and Fibria, Brazil's largest producer of paper and pulp, formed a joint venture in 2012 to develop cellulosic liquid products through a $20 million equity investment from Fibria. The company recently formed a development partnership with Pinova Holdings to develop specialty chemicals from a variety of renewable feedstocks. Other partnerships include Honeywell's UOP and Envergent, and Chevron Technology Ventures. The UOP partnership provides Ensyn with engineering design, support and guarantees for its RTP facilities. Both UOP and Chevron partnered with Ensyn to upgrade their RTP liquids to transport fuels. Strategic buyers and co-development partnerships are consistent trends in the bio-based innovations space and have enabled companies like Ensyn to get the capital and support needed to grow.

Altranex has developed a series of drop-in fuels, with its patented GreenKero process. Drop-in biofuels are those that are chemically indistinct from the fossil fuels they are replacing. They are the longer chain carbon atoms with bounded hydrogen atoms—C7 through C15 (the shorter for gasoline and the longer for kerosene and jet fuel). This allows for these fuels to "drop" right in to the current infrastructure—this is key: no additional infrastructure and associated costs are needed.

Through its process, the company creates Altra-K (cold climate diesel), Altra-JT (aviation fuel/kerosene), Altra DZL (diesel) and Altra-HF (heavy fuel oil). Altranex is currently working with GreenCentre Canada and MaRS Discovery District to further develop its technologies.

Biodiesel molecules are long chains of carbon atoms with bonded hydrogen, and are very similar to diesel already (except biodiesel has the ester group (oxygen) at the end. When biodiesel is made from vegetable oil, the molecule is shortened but the ester group remains, making it much less likely to solidify than a vegetable oil, but less likely than regular diesel. Diesel engines can burn biodiesel fuel without modifications because of this chemical similarity. With their cold climate diesel fuel, Altranex removes the oxygen from biodiesel, which brings the cloud point down to -30 degrees Celsius. Cloud point is an issue specific to biodiesel—in colder temperatures, biodiesel begins to solidify, giving it a cloudy look and damaging engines that use biodiesel.

3.2 Bio-based chemical and materials market

The chemical industry uses whatever feedstock is most available. Typically, chemicals are produced from fossil fuels: coal, natural gas and oil. As renewable, bio-based feedstocks become more available, there is now more opportunity to increasingly use bio-based feedstocks for chemical production: first, because co-products will increase; and second, because ethanol itself is not only a fuel, but also a chemical feedstock. Upcoming bio-based chemicals include methanol, succinic acid, monoethylene glycol and epichlorohydrin. Byproducts include glycerin, lignin (similar to black liquor, but which can be burned or put through a gasification process to produce further products), dry distillers grain and bio-oil during ethanol production, among others.

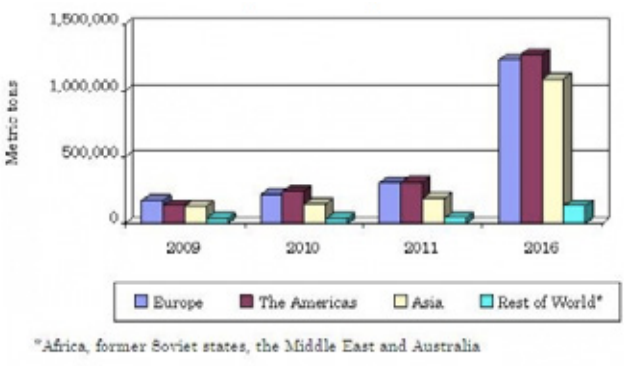
Glycerin and lactic acid have been at the forefront of the bio-based chemicals market. The global bio-based chemicals market had a CAGR of 19.5% between 2007 and 2011, with the total volume of chemicals reaching nine billion pounds in 2011.[48] This market is led by the United States and followed by China. The glycerin market was impacted by a quick acceleration of biodiesel production, which led to surplus glycerin and a fall in prices in 2009.[49] With glycerin at lower prices, innovators were able to use the chemical as a precursor for propylene glycol, epichlorohydrin and methanol. Lactic acid, on the other hand, is used in chemical and pharmaceutical industries. Polylactic acid (PLA) production is part of this market, within food preservation and nutrition.

Lignin is a promising upcoming material for biochemical production. The pulp and paper industry produces an estimated 50 million tonnes of lignin, while just two per cent of lignin is used commercially in products, and the rest is burned.[50] For this reason, among others, lignin has the potential to become the main renewable aromatic resource for the chemical industry in the future. In addition to being the only renewable source of industrial aromatics production, renewable lignin can be used in place of petroleum products to produce fuels, resins, rubber additives, thermoplastic blends, nutraceuticals and pharmaceuticals.[51]

Bioplastics can be derived from glucose, starch, cellulose or synthetics. Concerns over plastic waste and the rising cost of crude oil are driving growth for bioplastics. The global use of bioplastics was 0.64 million metric tons in 2010 and 0.85 million metric tons in 2011.[52] The use of bioplastics is expected to rise to 3.7 million metric tons by 2016, a CAGR of 34.3%.[53] IBISWorld, a market research firm, puts growth of the bioplastics manufacturing industry in the US at 4.3% from 2007 to 2012.[54]

The pull in this market is from downstream end users. Another driver is the desire of the forestry industry to diversify and develop products around byproducts (especially when the cost of doing so is less expensive than using as a fuel). Collaborations and partnerships will be key for the biochemical industry.

Figure 7: Use of bioplastics by global region, 2009–2016 in metric tons



Source: BCC Research, 2012.

Trivium Industries manufactures corn-based biodegradable and compostable cosmetic and pharmaceutical packaging in Welland, Ontario. Its product utilizes polylactic acid derived from corn; it is a bioplastic that fully decomposes in a commercial composting facility in under 180 days. The company's innovation is its Green Barrier© coating technology, which it is in the process of patenting. Its products are currently used in the cosmetic and food service industries. The company is developing new applications for their technology in collaboration with Brock University in Ontario.

Trivium Industries produces compostable bottles that are competitively priced with plastic bottles. On large orders, they can offer their bottles at almost the same cost. By using these compostable bottles, a company can attract environmentally conscious consumers or strengthen their brand by using a bio-based packaging if it has a natural or environmentally friendly product. The production for the compostable bottles uses less energy compared to conventional plastic production and avoids the harmful toxins associated with petroleum extraction and use.

A significant challenge for Trivium Industries in the past was accessing financing for its facility. To raise capital, the company purchased and renovated an 18,000 square foot industrial building, and rented it to two tenants—thereby creating a revenue stream to improve its investment appeal. The company expects full production by January 2014.

Trivium Industries is led by a young entrepreneur, David D'Angelo, a 22-year-old graduate from Brook University. David says he viewed his youth as a barrier in accessing finance—investors consider companies with young entrepreneurs as higher risk due to their age and often lack of the collateral banks seek. Funding for this age group often involves smaller amounts and with higher interest rates or equity stake. In 2013, MaRS Discovery District launched a Youth Investment Accelerator Fund (Youth IAF) to help young entrepreneurs access financing. The fund is designed to accelerate the commercialization of innovative technologies in Ontario. The majority of founders must be under 30 in the company to be eligible to receive funding of up to $250,000 from the Youth IAF. Learn more at www.iaf.marsdd.com.

The Innovators

Founded in 2008 and headquartered in Montreal, BioAmber is a publicly-traded sustainable chemicals company. Its proprietary technology platform combines industrial biotechnology and chemical catalysis to convert renewable feedstock into chemicals for use in a wide variety of everyday products including plastics, resins, food additives and personal care products. These renewable chemicals directly replace petroleum-based chemicals.

BioAmber has an exclusive license from Cargill to use a proprietary yeast organism to produce succinic acid. Concurrent with the company's ability to use the yeast in producing succinic acid, BioAmber entered into a development plan to improve the performance of the yeast. The company is now building the first and largest commercial bio-based succinic acid facility in the world in Sarnia, Ontario to utilize the new yeast and double production to 30,000 tonnes. The conversion of the Sarnia plant to utilize this specific yeast simplifies the production process, thereby removing some energy and capital costs. The plant is expected to create more than 50 high-value jobs.

Sarnia was chosen as the site for the plant because of its unique combination of proximity to one of the richest agricultural zones in Ontario and the fact that Sarnia is already home to a significant chemical industry. While a renewable chemical company, BioAmber is also a chemical company and the infrastructure and human resources skill-set in this area are already in place—access to energy, a carbon dioxide source, steam, utilities and systems to handle transport logistics—due to the city's petrochemical history. In addition, there are several wet mills in the area that use corn to make products, such as liquid dextrose, which is the feedstock for the plant. Sarnia also has significant community support already in place—namely from the Ontario Federation of Agriculture and the Sustainable Chemistry Alliance, both which are part of a network of organizations that support bio-based innovations.

Technologies like BioAmber's platform are costly to scale up. There are significant dollars invested in research and development, technology demonstration and infrastructure—the bricks and mortars of commercial production facilities. As a result, partnerships are important in these industries. BioAmber's $126 million facility is a joint venture with Mitsui & Co., a large Japanese trading house. BioAmber also has partnerships with LANXESS, NatureWorks, Cargill and Innolex, among others. BioAmber is jointly developing succinate-based plasticizers with LANXESS, a global leader in phthalate-free plasticizers. The goal is to develop and commercialize bio-succinic acid-based plasticizers that are both renewable and phthalate-free (used in toys, baby bottles, and other consumer products). Partnerships are important for creating markets for bio-based succinic acid. Bio-based succinic acid and its derivatives are expected to experience rapid growth over the next decade. The company has a solid market opportunity, estimated at $10 billion, and it has the people and partnerships in place to execute on this opportunity. BioAmber's recent initial public offering (IPO), low-interest loans from the provincial and federal governments, and Sustainable Development Technology Canada have significantly supported the implementation of the plant in Sarnia.

3.3 Biopower

Biopower is the generation of electricity and/or heat from biomass feedstocks. Navigant Research predicts that revenue from the global biomass power generation market will reach $11.5 billion annually by 2020, and that logistical issues in collecting, aggregating, transporting and handling biomass feedstocks will limit the commercial potential of biomass power generation.[55]

Ontario is currently phasing out coal, with the remaining facilities closing in 2014. The two northern coal plants were reviewed for suitability to convert into burning biomass feedstocks. The southern plants were reviewed as well and were not deemed suitable for this purpose. As of 2010, there are over 200 megawatts of grid-connected generating facilities using biomass (primarily wood waste) in Ontario, mainly operating as co-generation plants in forest sector industries.[56] These facilities typically co-fire with natural gas. Northland Power operates two combined cycle plants in Cochrane and Kirkland Lake, Ontario that are fuelled by natural gas and wood waste. Each year, these plants consume 200,000 tonnes of wood waste.[57] The Atikokan coal plant closed in 2012 and is currently undergoing conversion to run on biomass. The plant is expected to be completed in 2014 at the cost of $170 million and will run on pellets.[58]

Further, the forestry industry is Ontario's largest user of power.[59] Using forest materials for energy production can contribute to reducing energy costs in manufacturing processes, especially if locally-sourced feedstocks are utilized. The industry can also benefit from cost savings, while simultaneously reducing demand overall on Ontario's electrical grid.

Ontario's Long-Term Energy Plan (LTEP), developed by the Ontario Power Authority (OPA) at the behest of the Ministry of Energy and currently under review[60], provides an idea of potential local market size in Ontario by indicating how much grid capacity it will plan for various electricity generation sources. The estimated capacity for biopower by 2013 is 300 megawatts or 2 terawatt-hours, which is one per cent of Ontario's overall grid system capacity.[61] The OPA plan is to allocated 10,700 megawatts of overall future capacity to other renewables (this includes wind, solar and biopower, except hydro), which would account for 22% of overall system capacity.

To give some context, wind power and solar photovoltaics are estimated to hold 2,500 megawatts or 6% and 1,100 megawatts or three per cent capacity, respectively, for 2013.[62] Actual solar online is 700 megawatts. The province's Feed-In Tariff programs—smallFIT (over 10 kilowatts and up to 500 kilowatts) and microFIT (under 10 kilowatts)—pay a fixed price per kilowatt of power a renewable energy system produces. As of 2014, this program will be capped at 150 megawatts for smallFIT and 50 megawatts for microFIT, with a window of 900 megawatts in total planned renewable energy capacity from 2013 to 2018.[63] Prices are reviewed regularly and may be lowered to reflect lowered costs in doing business as these technologies and markets mature. For renewable energy projects over 500 kilowatts in size, the OPA is developing a competitive procurement process that will provide the mechanism to procure the planned renewable energy capacity set out in the LTEP.

The following table delves into the main issues and challenges associated with harvesting and utlizing biomass as a source of energy in Ontario.

Table 4: Biomass specific issues

• *Cost*: Biomass harvesting and transportation costs are higher than coal. Economies of scale may reduce this over time. A carbon-pricing regime would also mitigate the costs. Biomass can be used in conjunction with gas, which would lower costs and add operational flexibility.
• *Economic Development*: Impact will be highest in northern Ontario as the forestry sector expands.
• *Availability*: Annual fuel volumes are still uncertain. This will be refined through the Ontario Power Generation and the Ontario Ministry of Northern Development and Mines' (formerly known as the Ministry of Northern Development, Mines and Forestry) ongoing competitive process, but will ultimately provide an upper limit on the amount of electricity produced each year.
• *Demand*: Several factors including economic conditions, unseasonable weather, and conservation have lowered electricity demand in Ontario.
• *Competition*: Biomass can be used for many other products and power producers must compete against these other uses. There are policy issues around using farmland to grow energy crops
• *Transmission*: Transmission is constrained in northern Ontario. New investments will help to alleviate the problem, but transmission enhancements are large capital projects that take time to construct.

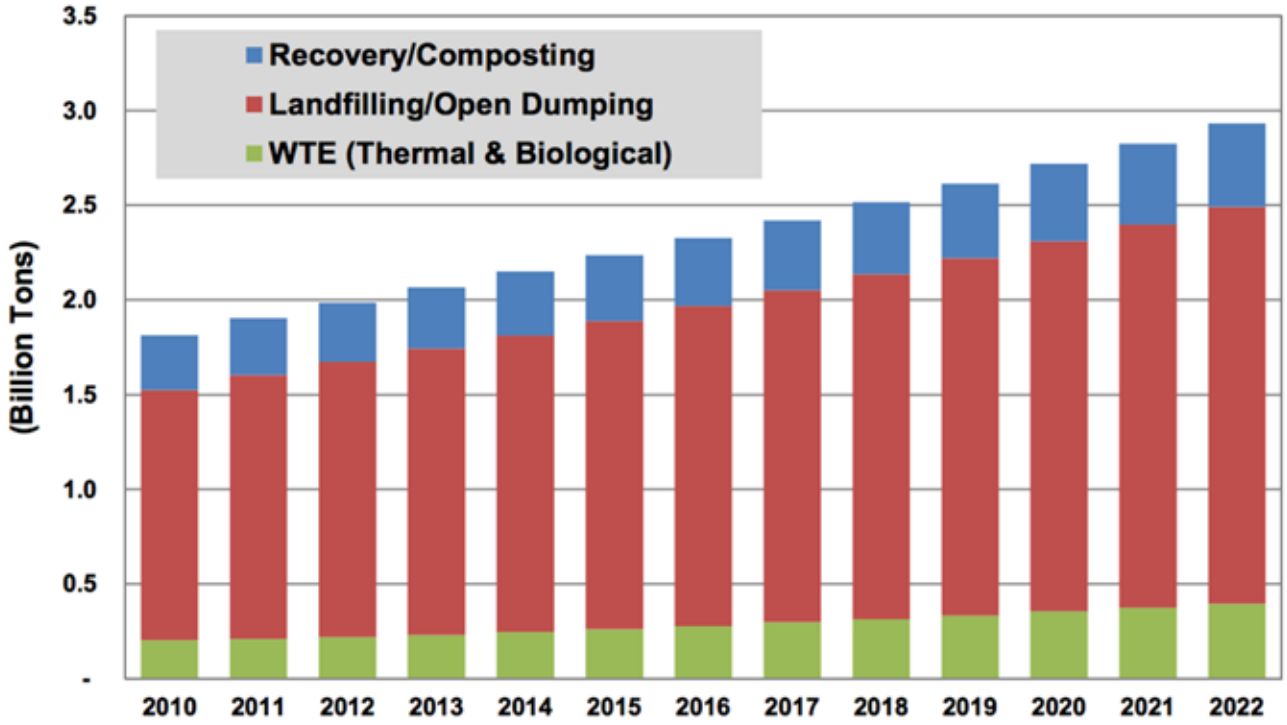
Source: Jennings, E. (2010). Ministry of Energy and Infrastructure, Bioenergy in Ontario: A presentation to the CanBio Conference. Retrieved from http://www.canbio.ca/events/ottawa10/jennings_e.pdf

3.4 Waste-to-energy market

Here, waste to energy (WTE) is defined as converting food, agricultural and forestry wastes into useful energy and products. This definition does not include non-bio-based wastes such as plastics, as they fall outside of the scope of this paper. WTE goes far beyond incineration, which is the most common form of WTE plant in the market.

WTE technologies include any technology that converts waste to heat and electricity; the three main technology segments include combustion, gasification and anaerobic digestion. Navigant Research predicts that the global market for thermal and biological WTE technologies will reach at least $6.2 billion in 2012 and grow to $29.2 billion by 2022.[64] The research firm also forecasts that WTE systems will treat at least 261 million tonnes of waste annually by 2022, with a total estimated output of 283 terawatt-hours of electricity and heat generation, up from 221 terawatt-hours in 2010.[65]

Figure 8: World municipal solid waste management by disposal method



Source: Navigant Research, Waste-to-Energy Technology Markets, 2012.

Canada currently has eight WTE facilities, which consume three per cent of our waste. By comparison, Asia has 301 facilities and Europe has 388.[66] In Ontario, only four municipalities use waste to energy.[67] There are numerous jurisdictions that have banned waste incineration, such as California and the United Kingdom.

The Recycling Council of Ontario's (RCO) has advised that reduction, reuse and recycling be used as the preferred methods of avoiding waste and conserving resources. Furthermore, it emphasizes that energy from waste, fuel substitution and incineration should be considered on a case-by-case basis only if[68]:

1. It is clearly demonstrated that all reduction, reuse, and recycling initiatives are maximized.
2. Any technique used to handle remaining residual materials is of net benefit to the environment and economically sound.
3. Energy from waste or fuel substitution initiatives meet or exceed stringently enforced environmental performance standards.
4. Incineration of solid non-hazardous waste includes energy recovery

Landfill sites are not likely to increase in Ontario due to permitting restrictions, as well as to community resistance to the smell, sight and increased traffic due to landfills. Often waste-to-energy technologies are associated with incineration, which is banned in many locations. New landfills are difficult to build because the required approvals for new facilities take a long time and are costly. Ontario has not permitted a landfill since 1999,[69] and many current sites are small and have filled up over the past 30 years.[70] Advanced waste conversion legislation has been helpful in other jurisdictions such as California and the United Kingdom, both of which have banned incineration.

The Innovators

CENNATEK Bioanalytical Services provides analytical support as well as research and development services to aid the commercialization of technologies that convert biomass into biofuels and bio-based specialty chemicals, plastics and lubricants. The company runs an analytical laboratory at the University of Western Ontario's Western Sarnia-Lambton Research Park in Sarnia, Ontario in support of the Bioindustrial Innovation Centre. Its services are primarily related to solid biomass characterization (including biomass pellet characterization), spray drying, biodiesel and second-generation ethanol production.

The company also invested its revenues generated from these services towards the development of BioLiNE, a demineralization process that converts agricultural waste and marginal vegetation into liquid fertilizer and high-quality biomass fibre. (Demineralization improves biomass usability and increases its fibre value.) The fibre is ideal for densification into fuel pellets or as feedstock for further processing into liquid fuels or chemicals. CENNATEK is currently attempting to secure matching funds for the $750,000 of public funding to commercialize its technology.

ZooShare Biogas Co-operative Inc. is a renewable energy co-operative that will take manure from the Toronto Zoo in Toronto, Ontario, convert it into gas through an anaerobic digester and then burn the gas in a 500-kilowatt biogas facility. ZooShare aims to sell this power to the grid through a 20-year contract with the Ontario Power Authority's microFIT program. ZooShare is using an innovating funding mechanism to finance their facility. The company sells community bonds with a five-to-seven-year term that offer an annual return of up to seven per cent. ZooShare was recently included in the Social Venture Connexion, an impact investing platform that connects social ventures, impact funds and impact investors.

Solutions4CO2 Inc. (S4CO2) is a Canadian company that develops innovative Waste to High Value Co-Product solutions for waste gas, water and biomass streams. S4CO2's integrated Waste to High Value Co-Product solutions include the Integrated Biogas Refinery[a] and Bio-Extraction Process[a].

Zero Waste Energy Systems Ltd. (ZWES) manufactures, delivers, operates and manages customer-specific and cost-effective waste recovery and waste-to-energy solutions. ZWES is a vertically integrated manufacturer of packaging and biomass handling, and conversion technologies for wet, dry and hazardous waste streams. The company offers opportunities in waste reduction and profitable energy production for both industry and governments.

Elementa Group's patented Elementa Process (EP) converts carbon-based matter into a synthetic gas ("syngas") with properties and utility values similar to those of natural gas. The syngas and resultant heat can be used to power turbines, engines or fuel cells for the generation of electricity, produce liquid fuels or hydrogen. The syngas can also be used as a natural gas replacement.

Elementa's process is a platform technology—it can convert a diversity of carbon-based materials into syngas, from which further fuels can be made, including hydrogen, biodiesel and methanol. The company's first application is to convert waste material (such as municipal solid waste and sewage sludge) through a steam reformation process in an oxygen-deprived environment to produce syngas.

Based in Niagara-on-the-Lake, Ontario, Elementa has a waste-to-electricity demonstration plant in Sault Ste. Marie, Ontario, which has been in operation since 2007. The company is in the final planning stages for a commercial-scale plant, and is moving into the finance and construction phases in 2014. This plant is set to process 50,000 tonnes of municipal solid waste a year and produce 9.5 megawatts of electricity from the syngas produced at the plant.

The Elementa process is uniquely different from other thermal process in that there is no oxidation, which means capital and operating costs are significantly lower while output is higher. These advantages enable Elementa to compete with conventional power generation sources (coal, nuclear and hydro) on a lifetime cost of electricity (LCOE)– a standard measure of measuring the true cost of electricity. The Elementa process can virtually eliminate the need for landfill. This is especially relevant to municipalities dealing with waste in Ontario, a province which has not permitted a landfill since 1999.

4. Advantages at a glance

Using more bioenergy and bioproducts has both advantages and disadvantages. The opportunities include economic development and jobs through new industries and the evolution of existing industries, a great benefit to northern Ontario for its woody biomass feedstocks and to the Sarnia region as a means to redevelop; increased energy security locally and for the province; and the most contested benefit, the reduction of greenhouse gas emissions. The challenges include the potentially negative environmental consequences of land-use change, sustainable land and forest use, and ensuring a net reduction in greenhouse gas emissions; feedstock and production facilities' access and path to market; and a consistent supply of biomass for targeted end use. The advantages described in Table 5 can play a role in accelerating market deployment of bio-based innovations.

Table 5: Ontario's bioenergy advantage

• Vast agricultural and forestry resources: Water, land and a favourable climate, resulting in an exceptionally diverse industry.
• Extensive research and development capacity: Twenty universities (17 of Canada's top 50), 24 colleges and a globally significant agri-innovation cluster
• Highly skilled workforce
• Network of innovation and commercialization support through established organizations and funding
• Availability of bio-based feedstock from agriculture and forest-based products and byproducts, as well as byproducts from the food processing sector
• Government policy supporting bioenergy and biofuels development and growth

Source: Ontario Ministry of Agriculture and Food, Ontario's Bio Advantage Sector Profile: Spotlight on BioEnergy. Retrieved from http://www.omafra.gov.on.ca/english/research/ktt/spot-bioenergy.pdf

5. Market drivers

The main broad market drivers for bio-based products revolve around environmental, energy and economic security themes. Environmental security stems from globally rising carbon dioxide emissions. Concerns over carbon dioxide and other greenhouse gas emissions from conventional fuels, as well as other pollutants from conventional fuels, are pushing governments to find alternative fuels and energy production processes.

In terms of energy security, independence is highly valued as well as the security that comes from having access to a diversity of energy resources that are not reliant upon international supply chains. As oil prices continue to rise, this diversity and independence in energy resources mitigates the cost impact that rising fossil fuel prices will have on society.

On the economic side, drivers globally include the opportunity for economic development in rural areas (especially when developed around a sustainable industry), as well as the opportunity to become a clean energy, technology and service exporter. Further opportunity to create value-added industries around resource processing and new opportunities for the forestry and agricultural sectors are also some of the factors that drive the market for bio-based products, particularly in Canada.

All of these drivers are interrelated. In the United States, fuel security and energy independence is a major driver. The US Department of Energy has determined that the end cost to the consumer of biofuels is the same as that of fossil fuels, except that there is more value to the domestic economy in ensuring that jobs and income are sourced within the country in the biofuel scenario. The price differential between imported crude oil as opposed to domestic biomass is $323 billion/year[71]—this amount stays within the US economy, rather than lost to the cost of production and transportation, and profits to host countries.

At a more hands-on level, market drivers include research and development investments, financing opportunities and funding programs and government policy and regulation. Government can help stimulate the bio-based economy through policies, financing and investment, standards, certification processes and mandates, among others. (Government, however, also supports competing fossil fuel industry through these same mechanisms.) Policies, such as those that drive renewable energy investments, are another key driver. Renewable fuel mandates, the Feed-In Tarriff and other incentive legislation for biopower projects, as well as carbon pricing, all drive market uptake. See Table 6 for an overview of policies and programs in Canada.

Government mandates are one of the stronger incentives driving the biopower market. In Ontario, the Feed-In Tariff program, operated by the OPA, offers incentives for renewable biomass, on-farm biogas, biogas and landfill gas projects. This program provides a fixed price per kilowatt-hour (kWh) produced on system sizes up to 500 kilowatt-hours, with targeted capacity additions of 900 megawatts for these projects by 2018[72]:

- All sizes of renewable biomass projects receive 15.6 cents per kWh; On-farm biogas under 100 kW is eligible for 26.5 cents per kWh, and those over 100 kW up to 250 kW are eligible for 21 cents per kWh;
- Biogas projects of all sizes are eligible for 16.4 cents per kWh; and
- Landfill gas projects of all sizes are eligible for 7.7 cents per kWh.

The OPA is developing a competitive procurement process for renewable energy projects over the size of 500 kilowatt-hours, and the Ministry of Energy has directed the OPA to review the Long-Term Energy Plan (LTEP). Earlier versions of the LTEP (2010) plan for 10,700 megawatts of renewable energy generation by 2018, excluding large hydro. This capacity would bring renewables supply to 22% by 2018 from an estimated 10% capacity by the end of 2013.[73]

Table 6: Relevant Canadian policy

Policy	Location	Focus areas	Details
Crown Forest Sustainability Act	Ontario	Forestry	Policy framework for sustainable forests from the Ministry of Natural Resources.
Environmental Protection Act, 1990	Ontario	Waste	This Act grants the Ministry of the Environment broad powers to deal with the discharge of contaminants that cause negative effects. Landfill sites and other waste management activities are subject to Part V of the Environmental Protection Act (EPA) and the regulations made under the Act. The EPA is the overarching piece of legislation that provides the basic legislative framework for waste management in Ontario.
Feed-In Tariff Program (smallFIT and microFIT)	Ontario	Electricity	Fixed price per kilowatt-hour of electricity a renewable energy system produces.
Forestry Directive, FOR 03 02 01, May 15, 2013	Ontario	Forestry	Forest biofibre allocation and use.
Grain Financial Protection Program (delivered by Agricorp on behalf of the Ontario Ministry of Agricultre and Food, Ministry of Rural Affairs [OMAFRA)	Ontario	Agriculture	The Grain Financial Protection Program protects producers who sell grains and oilseeds to licensed dealers and producers or owners who store grains and oilseeds at licensed elevators. The program has both a licensing and inspection component and a financial protection component. All dealers and elevator operators must be licensed and make payments to producers and owners within specified timelines.
Green Energy Act, 2009	Ontario	Electricity	Framework legislation to facilitate the expansion of renewable energy generation, encourage energy conservation and promote the creation of clean energy jobs.
Growing Forward 2, Agriculture and Agri-Food Canada, 2013 – 2018	Canada	Agriculture and Food	Growing Forward 2 (GF2) is a $3 billion investment by federal, provincial and territorial governments and the foundation for government agricultural programs and services over the next five years. GF2 programs will focus on innovation, competitiveness and market development to ensure Canadian producers and processors have the tools and resources they need to continue to innovate and capitalize on emerging market opportunities. The Agri-Innovation Program falls under this policy framework.
Long-Term Energy Plan	Ontario	Electricity	Sets capacity allocations for different electricity generators.
Ministerial Directives	Ontario	Energy	Ministry of Energy Directives to Ontario's public agencies like the Ontario Power Authority. These can be procurement directives, direction in planning, and so on.

Policy	Location	Focus areas	Details
Ministry of Northern Development and Mines (Formerly known as the Ministry of Northern Development, Mines and Forestry)	Northern Ontario	Forestry	Competition for unutilized Crown forest resources.
Ontario Power Generation, Thermal Fuel Conversion Program	Ontario	Biopower	Ontario Power Generation is phasing out its four coal-fuelled generating stations by the end of 2014. Thunder Bay's Atikokan Generating Station is being converted to run on biomass, while the others will be converted to natural gas with some opportunity to co-fire with biomass.
Renewable Transportation Fuels	Ontario	Ethanol	Five per cent ethanol content in gasoline since 2007. There is an incentive for cellulosic ethanol.
	Ontario	Diesel	FAME biodiesel is exempt from Ontario's 14.3 cents per litre diesel excise tax.
	Canada	Ethanol and Diesel	Five per cent renewable content in gasoline sales and two per cent renewable content in diesel and heating oil.

6. Access to finance

The main challenges for bio-based product technology developers are the inherent high capital expenditure requirements, access to a consistent feedstock supply and technology risk. Access to finance was identified as the number one barrier faced by startups with bio-based innovations interviewed for this paper.

Likewise, according to BIOTECanada, access to capital remains the number one challenge the biotechnology industry (which includes health, agricultural and industrial biotechnology sectors) faces as it seeks to bring new technologies into the global marketplace.[74] The length of the development process and risk involved with biotechnology products contributes to this challenge. On average, these technologies take seven to 10 years to develop and work through initial regulatory paths.[75] A lack of venture capital funds in Canada also results in companies seeking investment opportunities outside of the country. Government is one source of funding for companies aiming to launch a technology into the marketplace—often in an attempt to create jobs and boost the economy. Ontario and Canada have a suite of funding mechanisms to spur innovations, and Table 7 lists solely those that are geared towards to bioenergy and bioproducts innovations. Further sources of funding can be found through exploring the MaRS Funding Portal.

Table 7: Specific bio-based innovation funding

Fund or program	Jurisdiction	Focus	Details
The Ontario Ethanol Growth Fund, 2007 – 2017	Ontario	Ethanol	This 12-year, $520 million program was implemented to support the development of a domestic ethanol industry in Ontario.
Biomass Innovation Centre, Northern Ontario Bioeconomy Initiatives Program	Northern Ontario	Woody biomass	The purpose of this program is to create the foundation for biomass-related project development in northern Ontario. This project will provide five small- and medium-sized enterprises (SMEs) with consulting and research services that will position them for expansion and/or re-alignment in their sector.
GreenCentre SME Commercialization Fund	Ontario	Green chemistry	This fund is designed to support the commercialization activities of Ontario-based, chemistry-driven SMEs. GreenCentre covers up to 25% of project costs, with awards ranging from $50,000 to $150,000.
Canadian Agricultural Adaptation Program, Agriculture and Agri-Food Canada, 2009 – 2014	Canada	Agriculture	The purpose of this program is to facilitate the agriculture, agri-food and agri-based products sector's ability to seize opportunities, respond to new and emerging issues, and pilot solutions to new and ongoing issues in order to adapt and remain competitive. Funding is $163 million over five years and is available for eligible projects identified and carried out by the agriculture, agri-food and agri-based products sector.
Agri-Innovation Program	Canada	Agriculture	This five-year iniative offers up to $698 million under Growing Forward 2 and brings together the pre-commercialization and commercialization stages of innovation for agriculture and agri-food.

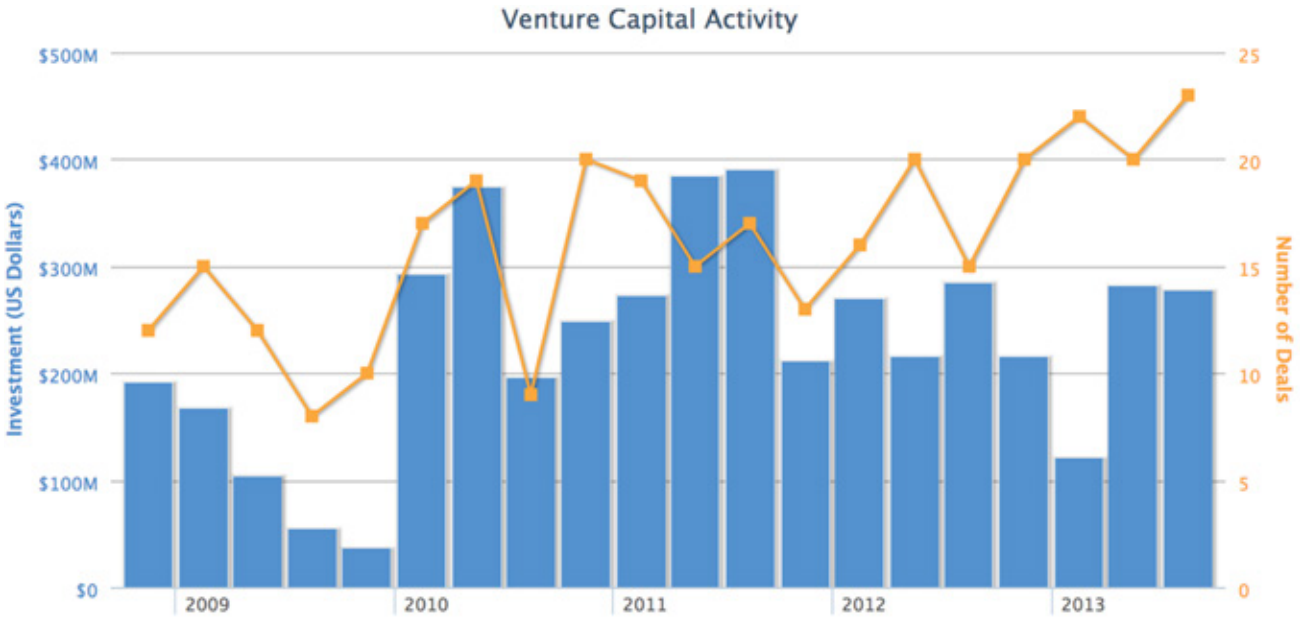
Fund or program	Jurisdiction	Focus	Details
Feed In Tariff Program (smallFIT and microFIT)	Ontario	Electricity	Price per kilowatt-hour that a renewable energy system produces.
Next Generation Biofuels Fund, Sustainable Development Technology Canada (SDTC)	Canada	Next generation biofuels (the general SDTC Tech Fund could assist other biomaterial companies).	The aim of this fund is to increase each project's chances of success going to market by helping them bridge the high capital expense (CAPEX) gap while, at the same time, helping them to scale their technology solution to a large, demonstration-scale plant.

7. Investment trends

Capital for bioenergy companies largely comes from government grants and loans, private equity and venture capital, as well as through initial public offerings (IPOs). Customers (end users) are another source of capital. The other source comes from companies when they reinvest their own profits. The capital injected into a company enables manufacturing, production and commercialization activities to occur. Investments can be made in three areas: technology improvement, commercialization (investing in biorefineries for production at scale) and revenues (end-user sales).

According to the Cleantech Group data, biofuels and biochemicals companies raised a disclosed $958 million in 2012—slightly down from $1 billion in 2011 though on par with recent years overall.[76] 2012 also had the highest deal count in the biofuels and biochemicals sector in the past five years. The Cleantech Group's statistics indicate that venture capitalists are still active, while the rounds are smaller. The average deal size was $23 million in 2012 compared to $28 million in 2011.[77]

Figure 9: Global venture investment in biofuels and biochemicals



Source: Cleantech Group's 13 Platform.

Timelines for cleantech technologies are longer and more expensive than many technologies, like those in the information and communications technology (ICT) sector. It can also take much longer to make sales. Cleantech companies are also dealing with entrenched industries that are resistant to change and new technologies. Within conventional industries such as the petrochemical industry there is a vested interest in current technologies, fuels and ingredient sources due to history and existing energy infrastructure. This reality also explains why drop-in technologies are so appealing to investors.

For early-stage investing, angel investors typically seek high and quick rates of returns on their investment. Bioenergy and biochemicals cannot offer this type of return as there are longer timelines to reach market penetration and to begin to make significant financial returns. In this case investors are investing in technologies that have worked in a laboratory but have not yet received enough cash to have a pilot or demonstration project that can capture customers.

Overall trends

- Developing algae as a feedstock is a growing trend, and conversion technologies for algae have garnered attention in the space. These technologies utilize carbon dioxide and wastewater waste streams. Challenges, however, remain in scaling up. The trend has entered into the food additive, nutraceutical and cosmetics industries.
- Unconventional, non-food-based feedstocks and conversion technologies are more appealing to investors due to concerns over food versus fuel and policy change risk.
- Production targets for advanced biofuels have not been met, for example, in the US production targets were reduced from 100 million gallons to 80 million gallons for 2013.
- The cost of fossil fuels remains low in the market due to a long history of subsidization and continued subsidization and in the absence of the correction of market failures such as pollution. Without accurate carbon pricing, biofuels and bio-based chemicals are not on a level playing field. Climate change and rising fossil fuel prices offer an opportunity for explosive growth in these technologies when the cost of oil reaches $100 per barrel.
- Mergers and acquisitions have shown a trend in large agriculture corporations' interest in expanding into feedstocks and a trend in plant acquisition by larger players in the corn ethanol and biodiesel space.
- There has been a lack of IPOs in general in this sector, aside from BioAmber in 2013. This lack of an exit strategy can leave investors wary. IPOs have not recently been an exit strategy for bioproduct companies.[78]

Feedstocks have been considered a bottleneck in the bioproducts industry.[79] To mitigate the risk of feedstock volatility, the ideal approach is to vertically integrate feedstocks into the company or to lock in feedstocks through a partnership or other means. Investors are reluctant to invest if they do not have assurance that a biorefinery has a secure supply of feedstock to convert into useful products. Further, investment in unconventional, non-food-based feedstocks and conversion technology that incorporates these alternative feedstocks also may assuage investor concerns.

Partnerships are another major trend in this sector. In the absence of capital, companies are partnering with different components of their supply chains. Canadian companies BioAmber and Ensyn Technologies have shown success within a partnership model. Ensyn's partnership with Fibria, a Brazilian pulp and fibre producer, includes the establishment of an equally owned joint venture for the production of cellulosic liquid fuels and chemicals in Brazil and a $20 million equity investment in Ensyn by Fibria. The investment will provide Fibria a six per cent stake in Ensyn as well as the right to improve its investment to nine per cent in the future. This positions Ensyn as a key partner for Fibria in cellulosic liquid fuels development. Fibria can also leverage its expertise in growing fibre to develop a value-added, non-food renewable fuels business complementary to its pulp production basis. For Ensyn, this type of partnership enables them to have secure access to feedstocks.

The MaRS Cleantech Fund is a new model of collaboration between MaRS Discovery District and the private sector. This privately-backed, $30 million provides early-stage funding to companies developing next-generation cleantech breakthroughs. They select capital efficient companies where an investment of $1-3 million will enable a company to reach a meaningful milestone within one to two years, and with strong intellectual property that provides a long-term defensible market position and large global opportunity.

8. Challenges are opportunities

The major challenges for bio-based innovation companies can be categorized as sustainability, technical and business-related. Sustainability challenges include ensuring sustainable harvests, the environmental footprint and biodiversity. Technical challenges include scaling up from a demonstration phase to a full-scale commercial manufacturing facility, consistent biomass quality and supply chain logistics. Business challenges include policy and trade policy, codes and standards, financing and incorporation into the existing value chain.[80]

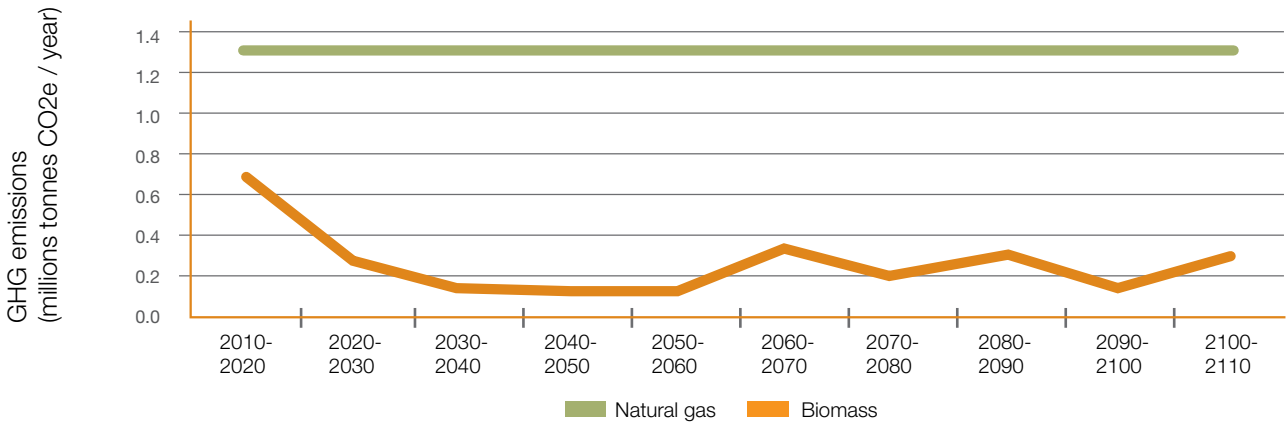
8.1 Sustainability

Sustainability is crucial to the success of the bioproducts sector. Global modern bioenergy use is 10 to 15 exajoules (EJ) per year and total bioenergy use is 50 EJ per year.[81] Other biomass production of industrial roundwood is approximately 15 EJ per year and major agricultural crops are approximately 60 EJ per year. The biomass required to meet Intergovernmental Panel on Climate Change (IPCC) scenarios by 2050 is:

- 440-600 parts per million carbon dioxide equivalent (ppm CO2eq) target: 80-150 EJ/year
- <440 ppm CO2eq target: 118-190 EJ/year

This represents a tenfold increase in biomass.

Figure 10: Generating electricity from biomass can reduce greenhouse gas emissions on average by 80% compared to natural gas



Source: Ontario Power Generation and Pembina Institute, Biomass Sustainability Analysis Summary Report, 2011.

In their sustainability analysis of Ontario's forestry-based biomass, Ontario Power Generation and the Pembina Institute concluded that Ontario-sourced wood pellets meet the United Nations Framework Convention on Climate Change (UNFCCC) definition of renewable biomass and that harvesting biomass for electricity production can be accomplished without depleting the forest resource over a 100-year planning horizon. They found that emissions are initially high due to the first harvest but then fluctuate over time as the forest resource transitions.

Environmental footprint

The environmental footprint includes carbon dioxide emissions; fertilizer, pesticide and herbicide use; and water consumption. These are all interrelated. The main concern over carbon dioxide neutrality stems from land-use change. Forest conversion and cropland expansion can result in habitat and biodiversity losses; soil depletion and degradation; an increase in carbon emissions; as well as waterway impacts from runoff contaminating waterways and groundwater resources, and changes in surface water flows (which in turn exacerbate the listed impacts). Further, there can be an overall increase in water use.

Water use can have a devastating impact in water-scarce areas, limiting where and what can be grown. Diverting water can stress water levels in groundwater and streams. However, there are opportunities to increase water use efficiency, such as capturing water during certain portions of the hydrological cycle (for example, rainwater harvesting), or using methods of growing that lead to more transpiration at the expense of evaporation and runoff. Water-efficient plants can be selected, as well as salt-tolerant plants. This can potentially help to prevent desertification or make inroads to reversing desertification in some cases. Still, many countries withdraw more water than that which can be renewed under current agricultural practices. There are competing uses for water such as fracking, drinking water and bottled water, unsustainable land use and industrial processes. A bioenergy strategy should include a complementary water innovation focus.

Food versus fuel

Taking land out of production for food and substituting for energy and materials crops is a major concern globally. There are fears that diverting corn for products rather than food can increase the price of this staple crop. In Ontario, new lands are not necessarily being put into agricultural production. Due in part to urban sprawl, farmers can often make more money in the long term through selling their land for non-agricultural purposes. [82] Total farm area in Ontario decreased 4.8% between 2006 and 2011 to 12.7 million acres.[83] Of this total farm area there was a small increase from 68% in 2006 to 70.5% in 2011 in crop land. Statistics Canada also found that increased prices for cash crops coupled with lower numbers of beef cattle and pigs led to a shift from forages and crops typically used for animal feed to cash crops. [84]

Growing crops for energy and materials may provide these farms with the opportunity to make more money for these crops, but also through the production of biogas with animal husbandry operations. The report, Alternative Technologies to Transform Biomass into Energy, prepared for the Ontario Federation of Agriculture, assessed the opportunity for Ontario's agricultural producers to participate in the bioeconomy.

Figure 11: Participation in bio-energy value chain for Ontario producers

Bio-Energy System	F	T	P	M&S	Recommended Approach/Investment
Anaerobic digestion	●	●	●	●	Lobby for better grid access and greater premium price for energy generated
Direct combustion	●	●	●	●	Minority Stakes to Joint Venture
Pyrolysis	●	●	●	●	Strategic Alliance to Minority Stakes
Gasification	●	●	●	●	Strategic Alliance to Minority Stakes
Bio-ethanol	●	●	●	●	Minority Stakes to Joint Venture
Bio-diesel	●	●	●	●	Minority Stakes to Joint Venture
Torrefaction	●	●	●	●	Strategic Alliance
Energy storage	●	●	●	●	Strategic Alliance to Minority Stakes
Bio-methane	●	●	●	●	Strategic Alliance to Minority Stakes
Hydrogen enriched natural gas	●	●	●	●	Strategic Alliance

F: Feedstock supply
T: Transportation of feedstock
P: Production of energy and co-products
M&S: Marketing and sales

● Full participation recommended
● Partial participation possible
● Participation needs further analysis

Source: Western Sarnia-Lambton Research Park, Alternative Technologies to Transform Biomass into Energy, 2012.

In the report, they recommended that generation of heat and power and production of co-products from agricultural biomass could provide additional income and a reasonable hedging against the raising energy costs for Ontario agricultural producers. They did caution that risks associated with bioenergy technologies must be carefully managed.

Sustainability certification

It may not make sense to try to replace all energy products with bioresources. We simply consume far too much as a society to be able to do so. If there production of oilseed and cereal crops with business-as-usual growth practices continue, it could add to the detrimental environmental impact of these land-use practices. However, it can be done differently. With water conservation and soil conservation growth methods, Ontario can ensure that more of the benefits than the negatives associated with growing biomass for food, fibre and products are captured. Another way to ensure sustainability is through sustainability certification. Sustainability standards are necessary to ensure that bio-based products are developed in an environmentally and socially sound way from production or collection of feedstock, in the products themselves and across the supply chain. These standards could prevent unsustainable practices while protecting companies that do not cut corners on sustainable production of bioresources.

According to the International Energy Agency Bioenergy Task 40 (International Sustainable Bioenergy Trade), 43 (Biomass Feedstocks for Energy Markets) and 38 (Greenhouse Gas Balances of Biomass and Bioenergy Systems), there are a number of biomass and biofuel sustainability certification schemes under development or that have been implemented around the world.[85] These schemes are applicable to various feedstocks such as forest and agricultural resources; various bioproducts, such as wood chips, pellets, fuels and power; as well as whole or segments of supply chains. Task 40 points out that there are some challenges with sustainability certification in its current state, giving the following examples:

- The proliferation of schemes has led to confusion among actors involved;
- Fear of market distortion and trade barriers;
- An increase of commodity costs;
- Questions on the adequacy of systems in place; and
- Uncertainty over how to develop systems that are effective and yet cost-efficient.

They concluded that moving towards a more harmonized global approach is an ideal solution to attain sustainability in biomass and biofuels production and trade, and offers a way to improve the effectiveness of certification systems so that benefits are spread beoth globally and locally.

Adapted from Berndes and Smith (2009)[86], these practices could improve sustainability:

- Increase lignocellulosic feedstocks grown on low-carbon pasture land that is less suitable for annual crops to decrease pressure on prime cropping land.
- Grow food, fibre and bioenergy crops in integrated production systems to mitigate displacement effects and to improve land-use productivity. The targeting of unused marginal and degraded lands can also mitigate land-use change emissions associated with bioenergy expansion.
- Utilize waste wood, such as wood extracted to prevent fires, wood derived from urban forestry management practices and woo from construction industries.
- Replace unsustainable annual crops with perennials; biomass plantations can also improve land productivity.

- Encourage the environmental service benefits of bio-crops, such as providing windbreaks and other erosion-prevention features.
- Utilize new innovations, such as using wastewater to reduce fertilizer requirements and water infrastructure expenses, can also increase sustainability.

8.2 Technical and business

Getting these products to market is key—through rail and shipping, pipelines and transmission. Biomass logistics are those that move biomass to various points in the supply chain and these logistics should be fully integrated into a business plan. Another issue to any biomass or bioproduct success is the ability to capitalize co-products; for example, ethanol production has a variety of outputs (ethanol itself, dry distillers grain, bio-oil and carbon dioxide).

Related to the development of co-products is the concept of clustering. Initially proposed as a concept by Michael E. Porter of Harvard University, clusters are geographic concentrations of interconnected businesses and institutions, service providers, supporting or co-ordinating organizations, and suppliers in a specific sector.[87] A clustering of innovation in the bioproducts space is key to capture cost reductions and market access through infrastructure sharing, sourcing feedstock supply, fostering co-product innovations and market development. The Canadian Bioenergy Association (CanBio) has narrowed in on this cluster concept in what they refer to as "Strategic Synergy Centers". CanBio advocates that an attempt should be made to identify a strategic bioproduct direction and then look for synergies with other bioproducts by addressing research and development gaps, rather than focusing broadly on all types of biotechnology and bioproducts in one cluster.

CanBio visualizes these clusters in rural areas where most of the forest and agricultural biomass is located. The overall goal of these centres is to faciliate financing and operating scenarios for bioproduct operations (energy, biofuels, biochemical and biomaterials) that are capable of competing with petrochemical product price points. The ultimate goal is to build the capacity of these companies to export to larger markets.[88] CanBio aims to work with the private sector and local and provincial governments to identify suitable locations and resources to encourage a network of these centres across Canada.

9. Who's who in bioproducts: Sector players

Across Ontario, a number of organizations are working to bring innovations to market, such as the Business Acceleration Program and the Regional Innovation Centres. Below are a number of key players divided up by region.

Southwestern Ontario

The Sarnia industrial complex is well situated to capitalize upon existing infrastructure, industrial players, an academic and research community, and access to US markets and waterways for access to feedstock supplies and end-use markets. Biorefineries are an integral part of the bio-based economy.

The Bioindustrial Innovation Centre (BIC) is designed to help bridge the gap between research and market in chemicals and energy production from biomass. Based in Sarnia, and located at the Sarnia-Lambton Campus Western University Research Park, BIC helps industry take renewable feedstocks, such as agricultural and forestry byproducts and wastes, and turn these feedstocks into energy and value-added chemicals for a variety of end uses. The centre is equipped with biotechnology laboratories and shared pilot plant facilities for gasification, pyrolysis, fermentation and bio-conversion technologies that convert renewable feedstocks into fuels, chemicals, products and materials.

Bioenterprise is a business accelerator located in Guelph that focuses on bringing agricultural-based innovations from across Canada to market. The accelerator helps commercialize agribusiness through a variety of services, including business plan, strategy and marketing development, preparation for investment and facilitating connections to capital.

In the Niagara region, Brock University houses the incubator, BioLinc. BioLinc is a business incubation facility that is dedicated to the promotion, enhancement, and commercialization of bioscience, biotechnology, and biomanufacturing discoveries that are taking place at the university.

North Ontario

The Biomass Innovation Centre, located at Nipissing University in North Bay, works to:

- Identify biomass supply opportunities in the forestry and agricultural sectors
- Support projects that transform biomass into fuels and high-value products
- Develop market capacity and demand for biofuels and biorefinery products

The centre works to accomplish these goals through training and educational outreach, technical marketing, advocacy activities and research. It is focused on bridging the information gaps between knowledge and application, and forestry feedstock and final markets.

Recently, the Biomass Innovation Centre commissioned a study to measure the potential for a bio-based industrial cluster to be located in the nearby area. They produced a list of recommended actions required to encourage bioindustrial development in the nearby region. The recommended actions for the Blue Sky Region (the most southerly region of northern Ontario) are:

1. Establish a biomass aggregator enterprise
2. Support an inventory and price index study on harvest and mill residues
3. Develop a campaign to promote the use of pellets in the region

4. Establish a working group on district energy for North Bay institutions
5. Create a bioenergy technology training program at Canadore College
6. Support an assessment of intermediate technologies
7. Engage with the biofuel and biochemical cluster in Sarnia
8. Support a feasibility study on cross-laminated timber production
9. Continue stakeholder engagement and information-sharing efforts by the Biomass Innovation Centre
10. Form a regulatory and policy advisory committee

These recommendations may be applicable to further regions in northern Ontario.[89]

Eastern Ontario

Based in Kingston, GreenCentre Canada is a commercialization centre focused on bringing green chemistry innovations across Canada, and particularly Ontario, to market. GreenCentre helps commercialize green chemistry innovations originating in academia and industry. It does this by collaborating with industry and offering intellectual property management, and technical and business services to help scale up and roll out green chemistry innovations into green processes and products. GreenCentre Canada has worked with universities from across Canada. It also manages a commercialization fund to support Ontario-based, small- and medium-sized enterprises working on chemistry-based products and processes that conserve energy, use resources and reduce pollution and waste. They are housed in Queen's University Innovation Park, a clustering of synergistic organizations and companies working on cutting-edge innovations.

Central Ontario

MaRS Discovery District is located in Toronto and works with a diversity of partners to accelerate and amplify innovation in the province. One sector of focus is cleantech. MaRS Cleantech assists entrepreneurs and startups in the cleantech, advanced materials and advanced manufacturing sector with the following:

- Business planning
- Sales and marketing
- Financing and funding strategy
- Human resources
- Financial management, accounting, tax
- Legal and intellectual property
- Product development and marketing
- Operations and manufacturing
- Customer relationship management
- Strategic partnerships

MaRS Market Intelligence provides support and market research services to the cleantech sector at MaRS, as well as all of Ontario's regional innovation centres. Clients include companies in the bioproducts space.

10. The way forward

Together, from the north to the south, the east to the west, Ontario has a talented and robust network of people and organizations dedicated to bringing the innovations coming out of Ontario's academic and scientific research centres to market. While there are sustainability, technical and business challenges, these challenges can be overcome.

Ontario is rich in forest, agricultural and waste feedstock resources. Pprovincial innovations in feedstock supply and end-use applications are positioning Ontario to realize numerous benefits from job creation, economic growth, trade, education and social innovation.

Discussions around sustainability standards have already begun. The success of these efforts can go far in ensuring sustainable harvests and reducing the environmental footprint of bioproducts. Technical challenges include scaling up from a demonstration phase to a full-scale commercial manufacturing facility, consistent biomass quality and supply chain logistics. Business challenges include policy and trade policy, codes and standards, financing and incorporation into the existing value chain.

The innovators profiled in this report indicate that there is a significant market opportunity for Ontario companies to harness the power of the feedstocks and bioproducts, and bring real economic and social change to our bioenergy future.

Appendix A

The key players in Ontario

Innovation centres
Agri-technology Innovation Centre
Bioenterprise Corporation
Bioindustrial Innovation Centre
BioLinc
Biomass Innovation Centre
BIOpole (proposal, under development)
Bioproducts Discovery and Development Centre
GreenCentre Canada
Thunderbay Biotechnology Centre

Academic
Nipissing University
University of Guelph
University of Western Ontario
University of Toronto
Western's Sarnia-Lambton Research Park – Western University, Sarnia

Associations and groups
Biogas Association
Canadian Gas Association
Canadian Renewable Fuels Association
Canadian Bioenergy Association
Dairy Farmers of Ontario
First Nations Energy Alliance
Ontario Agri-Food Technologies
Ontario Federation of Agriculture
Ontario Food Industry Environmental Coalition
Ontario Soil and Crop Improvement Association
Ontario Sustainable Energy Association
Wood Pellet Association of Canada

External players
Alberta:
Alberta Innovates
Alberta Biomaterials Development Centre
Biorefining Conversions Network (University of Alberta)

Quebec:
Institut Polytechnique LaSalle Beauvais

Manitoba:
Winnipeg Composites Innovation Centre

Canada:
FP Innovations

Funders
Government:
Sustainable Development Technology Canada; Government of Canada; Investment Accelerator Fund; Ontario Centres of Excellence; Ontario Emerging Technologies Fund; Ontario Ministry of Economic Development and Innovation; Ontario Ministry of Research and Innovation; Natural Sciences and Engingeering Research Council of Canada; Sustainable Chemistry Alliance; Technology Partnerships Canada; US Department of Energy

Private:
MaRS Cleantech Fund; CIBC; RBC; Volkswagen; Petro-Canada; Royal Dutch Shell; Investeco; VentureLink Funds; Rosetta Capital; Fibria; Birch Hill Equity Partners Management Inc.; Goldman Sachs Private Equity Group; Wellington Financial Fund; Business Development Bank of Canada; Rosetta Capital; Wellington West Capital Markets

Government bodies
Federal:
Agricorp; Department of Foreign Affairs, Trade and Development; Natural Resources Canada; CanmetENERGY; National Research Counci; Natural Sciences and Engingeering Research Council of Canada; Agriculture and Agri-Food Canada

Provincial:
Ministry of Natural Resources; Ontario Government; Ontario Power Authority; Hydro One, Ministry of the Environment; Sarnia-Lampton Economic Partnership; Ontario Ministry of Farming and Agriculture

Companies active in Ontario

Agri-Neo Inc.
Agrisoma
Altranex Corporation
Anaergia
Archer Daniel Midlands
Azule Fuel
Bio-Organic Catalyst Canada
BioDiesel Reactor Technologies
Bioethanol Enzyme 3R
BioExx
Biopower Canada
BIOREM Technologies Inc
Bioversal Inc
Biox Corporation
Canadian Carbon Solutions Group
Capstone Infrastructure Corporation
CastorSol
Centurian Biofuels Inc
CHAR technologies
Commercial Alcohols
Converted Carbon Technologies
CORE Biofuel Inc
Domestic Diesel Ltd
Dow
Drystill Holdings
Eco Waste Solutions
Ecoflame International Inc
Elementa Group
Energentium
Enerkem
EnerSysNet
Ensyn Technologies
ExxonMobile
GFL Waste and Recycling Solutions
Great Lakes Biodiesel
Green Planet Biofuels
GreenCore Composites Inc
Greenfield Ethanol
GreenScience Technologies
Harold Doan and Associates Ltd
Husky
IGPC Ethanol Inc
Iogen Corporation
Jessop Group
Kawartha Ethanol
KMX Corporation
Lanxess
Lougheed Biodiesel Reactors Inc
Methes Energies Canada
Mitsui & Co
Natural Energy Systems
NorCon Energy
Northland Power
Noroxel Energy Ltd
Performance Plants
Plasco Energy Group
Pond Biofuels
Prodal-G
QuantaGREEN Corporation
Responsible Energy Inc
Rothsay Biodiesel
Sodanol
Solutions4CO2 Inc
Stonehedge Bio-Resources
Suncor
SunOpta BioProcess
Switchable Solutions Inc
Switchblade energy
Thesis Chemistry Inc
Trade Brilliance Inc
Trivium Industries
Unisphere Waste Conversion
UTAG Green Energy Technologies Inc
Vertichem
Woodland Biofuels
World Bio-Fibre Technology Inc
Zero Waste Energy Systems Inc
ZooShare Biogas Cooperative

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