STRATEGIC PLAN (Revised 2006) FOR THE CANADIAN BIOMASS INNOVATION NETWORK RESEARCH & DEVELOPMENT PROGRAM

(Combined PERD BEST POL 4.4.1 and T&I Biotechnology R&D Programs)

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on behalf of

Canadian Biomass Innovation Network (CBIN) Executive Committee

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THE CANADIAN BIOMASS INNOVATION NETWORK (CBIN)

RÉSEAU CANADIEN D'INNOVATION DANS LA BIOMASSE (RCIB)

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SUMMARY

This Strategic Plan for the Canadian Biomass Innovation Network (CBIN) has been developed to guide federal S&T investments in the areas of biomass supply for energy and industrial applications; the production of bio-energy, biofuels and bioproducts; and bioprocesses, including industrial biotechnology. The two funding programs that currently support this Applied R&D are: PERD Bio-Based Energy Systems and Technologies (BEST) program, and the Biotechnology R&D component of the Climate Change Technology and Innovation (T&I) Initiative.

This R&D is targeted to improve the availability of biomass feedstocks for energy and industrial uses, and develop technologies, processes and systems that convert biomass into energy, biofuels, materials, chemicals and other industrial bioproducts to:

- increase the amount of energy, biofuels and industrial products derived from renewable feedstocks;
- increase the energy and conversion efficiencies of Canada’s energy production, industry and transportation sectors;
- reduce the greenhouse gas (GHG) intensities of Canada's energy production, industry and transportation sectors; and
- seed the development of a more sustainable, bio-based economy in Canada.

The Strategic Plan (SP) outlines the energy-climate change challenge of meeting rising energy needs and GHG constraints. It describes the potential contributions that bio-based solutions could make to meet these opposing objectives while contributing to the economic well being of the country. After summarizing the current knowledge and technology gaps, the SP presents the CBIN Applied R&D program developed in response to these opportunities and challenges.

It is envisioned that Canada will produce at least 1,000 PJ/yr of energy from biomass in 2025 from a family of new energy conversion technologies, clean biofuels and sustainable biorefineries. It is believed that Canada, with its abundant biomass resources, can develop the necessary technologies, processes and supportive policies to attract the necessary investment and grow its bio-based economy. Biomass residue and dedicated crops will be converted into heat or power in small and large scale, as well as co-firing applications, and biofuels. Liquid biofuels and bio-based gases will be used as energy carriers in both stationary and transportation applications. Efficient biorefineries will produce a mixture of biofuels, energy and product streams from operations that are economically, environmentally, and socially sustainable. New bioprocesses, including industrial biotechnologies, will improve the efficiencies of the manufacturing sector, and provide significant energy and GHG benefits.

To do this, technical and economic barriers will need to be overcome. That is, greater conversion efficiencies are required, higher value co-products need to be identified and developed, and the costs of bioenergy (including biofuels) have to become more competitive with those of fossil fuels. The CBIN Program centres on finding technology solutions in the

applied R&D space, and advancing successful R&D along the innovation curve through dissemination and by reducing barriers to adoption.

The role of CBIN is to advance the development of cost-effective, technological solutions in the following areas:

- development of sustainable biomass supplies;
- bioenergy conversion that produces more economical energy carriers (liquid biofuels, biogas, hydrogen, etc.) and more CO_2 neutral energy (heat, power);
- valuable co-products that improve the economics of bioenergy and biofuels production;
- bioprocesses that improve the energy efficiencies of current manufacturing processes;
- new biorefinery designs that integrate biomass supply, conversion technologies, and end-use applications to maximize the economic, energy and GHG benefits; and
- environmental and socio-economic analyses that guide the development of the bio-based economy through sound analysis and efficient regulation.

Commercialization and adoption of these new solutions will involve many stakeholders from the private and public sector, and will require strong, federal leadership and coordination, an enabling policy framework and appropriate infrastructure. Practical assessment tools will be needed to evaluate the full impacts from design through implementation. Key regulatory issues, such as the approval of new GM crops, will require timely solutions. At the same time, work will need to be undertaken to develop the business cases for substantial financial investments, and to align all of the necessary partners.

The combined PERD BEST and T&I Biotechnology investment, managed by an interdepartmental Executive Committee, is serving as an essential stepping stone to continue bioenergy and biofuels R&D and initiate new R&D in the industrial bioproducts and bioprocesses areas. Historically the PERD program has supported research in the areas of biomass supply, bioenergy and biofuels. Industrial products (materials and chemicals), biorefinery development, industrial biotechnology are additional areas of R&D that are being supported by both PERD BEST and T&I Biotechnology programs.

The CBIN Program has four areas of activity: (1) Existing and New Biomass Supply; (2) Biomass Conversion and Utilization Technologies; (3) Integrated Bio Applications (e.g. biorefineries, clusters); and (4) Cross-Cutting Issues such as strategy development, assessment, policy support and program dissemination. These activities have been subdivided into 13 subject areas referred to as themes. Each theme has a federal government lead (in total, 14 experts selected from 6 departments) who reports on the R&D projects under each theme. CBIN also co-funds three ‘integrated projects’ with other T&I programs where there is a bio link. These projects involve some of Canada’s major energy users, i.e. steel industry, pulp and paper industry, and petroleum upgrading.

Shown in Table S1 is the distribution of PERD BEST and T&I Biotechnology R&D funds for the fiscal year 2005/06. These funds were leveraged by A-base, industry partners and numerous other federal and provincial programs. (The final amounts were not available at the time of posting.) In the case of PERD, project allocation is left to the discretion of the theme leaders and federal departments. For T&I Biotechnology, two RFP processes were used to select the core projects.

Table S1. Distribution of PERD and T&I Funds in 2005/06

Program Activity	PERD BEST		T&I Biotechnology	
Evaluation of Existing and New Biomass Supply	546 k	19%	276 k	5%
Biomass Conversion and Utilization Technologies	2,043 k	71%	2,055 k	37%
Integrated Bio Applications (e.g. biorefineries, clusters)	75 k	3%	2,383 k	43%
Cross-Cutting Issues (strategy, assessment, dissemination)	125 k	4%	155 k	3%
Admin & Coordination	74 k	3%	631 k[1]	11%
TOTAL	2,863 k		5,500 k	

In 05/06, the T&I Biotechnology investment grew from $1 M to 5.5 M. The biggest change was the funding of seven, large, multi-year projects that will develop 'feedstock to end-product' threads or value chains. These threads are being developed for biomass feedstocks that are strategically important for Canada, including: cereals, oilseeds, agricultural fibre and residue, and forest fibre.

With respect to GHG emission reduction, it is conservatively estimated that if the R&D is successful and the new technologies and processes are adopted, GHG emissions could be reduced by at least 30 Mt CO_2e in 2025. It is difficult to quantify the GHG reductions that are strictly attributable to R&D investment, or more specifically, T&I investment.

Shown in Table S2 are the potential GHG reductions that the combined PERD and T&I investment could make to the energy production, energy use, agriculture, and waste sectors[2]. These reductions are evaluated from the 'point of end use'. In the energy production and consumption sectors, the GHG reduction will result from the direct and indirect replacement of fossil fuel energy with CO_2 neutral bio-based energy. For the agriculture and waste sectors, most of the emission reduction claimed by T&I Biotechnology will be due to the avoided release of CH_4, generated from landfills and manure management systems, to the atmosphere. The GHG reductions attributed to the displacement of fossil fuels with biogas is attributed to T&I Decentralized Energy Production (DEP).

It is important to note that not all bio threads will yield the same GHG benefits, and some threads could show no substantial improvement over conventional product manufacture. The size of GHG reduction depends on whether biomass residues or dedicated feedstock are used, on what energy or products the biomass is converted into, what is substituted and the degree of market penetration.

[1] Includes loan repayment
[2] These are the IPCC sectors that countries are required to use in their national GHG inventory.

Table S2. GHG Emission Reduction Attributed to PERD & T&I Investments

Sector realizing the GHG reduction	**Estimated 'Point of End Use' Reduction (Mt CO_2e) in 2025**	**Type of Bio Project**
Energy Production & Use / Consumption Sectors		
- Steel industry*	10 Mt	Industrial biotechnology reducing steel consumption
- Forest product industry (reduction shared with Utilities)	11-13 Mt	Improved boiler combustion efficiency; New cycles for small scale heat and power; mostly PERD funded
- Ag Industry	5 Mt	Energy for greenhouses
- Misc. energy production & stationary consumption (residential, commercial, industrial)	5 Mt	Biomass to heat and power; Biofuels; Industrial biotechnology substitution of conv process
- Mobile consumption (transport)	15 Mt	Biofuels (ethanol, renewable diesel) Light weight materials Industrial biotechnology
Waste* & Agriculture Sectors	16 Mt	Avoided emissions: MSW – organics; manure; MSW – plastics

* Note: In the absence of guidelines, 50% of the reduction of T&I Integrated Applications projects has been claimed by T&I Biotechnology.

To establish a vibrant, more bio-based economy in Canada by 2025, additional sources of public and private funding will be needed to support strategic R&D, scale-up, demonstration and commercialization of new technologies and processes. New sources of funding are required beyond 2008. A minimum 10 year commitment should be made to the sector's development if Canada wants to seriously develop new bio-based industries, and not loose its competitive position. Canada's investments will have to be strategic. As noted in AAFC's Science & Innovation Strategy, the right investments need to be made and research will need to focus on the right priorities at the right time. For this to occur, greater clarity is needed on the most promising 'biomass to energy and product' paths.

The CBIN Strategic Plan is a 'living document' that is regularly reviewed and updated. For a copy of the latest version, go to http://www.cbin.gc.ca/KeyDocs-e.html *or e-mail:* maria.wellisch@nrcan.gc.ca.

1. INTRODUCTION

This Strategic Plan for the Canadian Biomass Innovation Network (CBIN) has been developed to guide the federal government's S&T investments in the areas of biomass supply for energy and industrial applications; the production of bio-energy, biofuels and bioproducts[3]; and bioprocesses, including industrial biotechnology. The two funding programs that currently support this R&D are:

- the PERD 'Bio-Based Energy Systems and Technologies' (BEST) program (~ $2.7 million per year), and
- the Biotechnology R&D component of the 'Technology and Innovation (T&I)' initiative of the government's Climate Change Action Plan ($20 million over 4 years).

The CBIN Strategic Plan (SP) follows the format suggested by the T&I Management Secretariat (TIMS). It begins by outlining the energy-climate change challenge, the potential role bio-based solutions can play with respect to this challenge and Canada's bio-based energy baseline. This is followed by a description of the broad vision for this sector in 2025, and the gaps that need to be addressed to realize this vision. This provides the context for the current R&D program that is intended to accelerate the development of new knowledge and technologies in the bioenergy, biofuels, industrial bioproducts and bioprocessing areas. Standardized ProGrid criteria were used to characterize the program's relevance, risk, and environmental and socio-economic impacts.

The CBIN SP is a living document that is reviewed on an ongoing basis. This revision (v 10) supersedes the "first year" plan dated Nov 1, 2004. It incorporates key input collected in 2005, including feedback from the External Advisory Panel (EAP), conclusions from strategic studies, and updates from the program's theme leaders and project reports. For the current list of CBIN's R&D themes and projects, see: http://www.cbin.gc.ca/Docs/english/CBIN-R&D-Themes.pdf

[3] Within the CBIN context bioproducts include energy and industrial products derived from biomass, not including food, feed, plant-made pharmaceuticals nor traditional forest products (pulp, paper, solid wood).

2. CONTEXT

2.1 Rising Energy Demand and GHG Emissions

Growing energy demand coupled with the need to reduce environmental pressures point to a different global energy future, one that is more efficient and relies on more renewable energy supplies. The National Energy Board (NEB) scenarios estimate that Canada's total primary energy demand will be 40-50% higher in 2025 than in 2000 and that most of the growth will be supplied by fossil fuels. Given Canada's Kyoto Protocol commitment is to reduce its emissions to 94% of 1990 levels by the end of 2012 and further reduction commitments are anticipated, meeting energy needs and GHG constraints will be a significant challenge for Canada.

As in most countries, Canada's total energy demand is expected to continue to climb. Canada faces the challenge that its energy efficiency improvements cannot meet the increases in energy demand resulting from economic growth. As shown in Table 1, the energy demands of all sectors, particularly the industrial and transportation sectors, are projected to increase. The 2005 revision[4] of this forecast shows the same upward trends and attributes most of the demand growth to higher production of synthetic crude oil and refined products. The energy intensity of the refining sector is expected to show the greatest increase as the mix of crude oil becomes heavier and requires more processing.

Table 1. Canada's Energy Demand Projections, PJ

End Use Demand	**1990**	**2000**	**2010**	**2020**
Demand by Sector				
Residential	1,358	1,452	1,439	1,569
Commercial	865	1,092	1,184	1,275
Industrial	3,015	3,561	3,959	4,382
Transportation	2,099	2,476	2,792	3,219
TOTAL	*7,337*	*8,582*	*9,374*	*10,446*
Demand by Fuel				
Refined Petroleum Products	3,081	3,393	3,690	4,163
Natural Gas	1,870	2,300	2,452	2,667
Electricity	1,487	1,742	1,953	2,204
Coal	53	61	65	75
Liquified Petroleum Gases	233	323	352	359
Coke and Coke Oven Gas	140	138	143	163
Steam	21	29	31	36
Other (incl. ind forest residue)	368	506	590	672
Residential Wood	84	95	104	113
TOTAL	*7,337*	*8,582*	*9,374*	*10,446*

Source: Canada's Emissions Outlook: Update

Canada's greenhouse gas (GHG) emissions are also projected to rise significantly. This is not surprising as 85% of the country's GHG emissions are energy related: 38% are associated with

[4] In 2005, NRCan revised its energy and emissions outlook to analyze the impact of higher oil and natural gas prices, and incorporate new developments in the energy sector.

energy production and distribution, and 47% result from the end-use consumption of fossil fuels (both combustion and non-energy use of hydrocarbons).

As shown in Table 2, transportation emissions are expected to be the largest source of GHG emissions in 2020. Canada's climate change mitigation programs are curbing emissions increase, but, as with energy demand, the reductions in GHG intensity are not expected to keep pace with emissions growth. The 2005 revision forecasts even greater increases, particularly from refining and synthetic crude oil production, new power generation and transportation.

Table 2 Canada's GHG Emission Projections, Mt CO_2e

GHG Emissions by Sector	**1990**	**2000**	**2010**	**2020**
Total	*601*	*694*	*764*	*845*
Energy Production & Use				
Power Generation	95	111	119	123
Industrial	125	125	138	152
Residential & Ag Combustion	49	50	48	51
Commercial	26	32	34	35
Fossil Fuel Industries	74	106	123	137
Transportation	147	178	197	228
Agriculture (non-combustion)	61	66	72	77
Waste	21	22	24	25
Land Use	2	2	2	2
Propellants/Anaesthetics	0	0	1	1
HFCs	0	2	7	14

Source: Canada's Emissions Outlook: Update

Clearly, both changes in demand and technological innovation are needed for development to be sustainable. The climate change issue has shone a light on Canada's energy-climate change and sustainability challenges. A less GHG-intensive energy supply and new technologies, processes and systems that provide substantial energy efficiency gains and GHG reductions need to be developed.

2.1.1 Roles of Bio-based Solutions

Biomass-derived energy in the forms of heat or power, and biofuels that can be converted into useful energy, are considered to be part of Canada's climate change solution because they can displace more GHG-intensive fossil fuel energy. The use of biomass, that is sustainably-derived and does not permanently deplete carbon sinks, is considered to be CO_2 neutral[5]. The GHG contribution that bio-based energy can make in Canada strongly depends on its cost relative to fossil fuel derived energy.

Energy is needed by all sectors of the economy for transportation, residential and commercial buildings, industrial operations and power generation. The challenge is to find the best fit, i.e. where biomass-derived energy makes most sense and has a competitive advantage over fossil

[5] Only the carbon contained in the biomass is considered to be CO_2 neutral.

fuels. As biomass is located in certain regions of the country and there are economic limitations to the transport of biomass, it makes sense to explore bio-based energy and fuels production from a regional vs. sector-specific perspective. It is therefore essential to know what type of biomass is located where, what the regional energy needs for stationary and transportation applications are, and what forms of energy and products the biomass can be converted into, etc.

Bio-based energy can be produced directly through the conversion of dry solid biomass into heat and power via the Rankine (steam) cycle. Here virtually all of the carbon is converted into CO_2 and an inorganic ash remains. On the other hand, the transformation of biomass into liquid biofuels (transportable energy carriers) yields fuels, other products and energy. Ethanol produced from the grain dry mill process, for example, also produces DDGS and CO_2. Corn gluten meal, corn gluten feed, corn oil and CO_2 are coproducts of ethanol produced from corn using a wet mill process. Biodiesel production generates glycerol as a co-product. Therefore biofuel substitution of gasoline and diesel requires the development of economically viable biorefineries that produce biofuels (e.g. ethanol, renewable diesel) and co-products for which there is sufficient market.

Biofuels can be part of the package of climate change solutions, but currently there are technological and economic limits to the size of the impact. For example, it is possible that 20% of Canada's grain production could be converted into 4 billion litres of ethanol in 2025. (O'Connor, 2006 pers comm.) Four billion litres would represent roughly 5% of the country's total gasoline demand at that time. Clearly biofuels will only be able to substitute a portion of the transportation demand. This echoes one of the principal messages of the US Role of Biomass in America's Energy Future (RBAEF) project. Ethanol could meet a significant portion of the US' gasoline demand if highly productive, low input crops such a switchgrass are established, efficient gasification and biochemical conversion technologies are commercialized, and vehicle efficiencies are greatly improved. Advances are needed on every one of these fronts.

From the efficiency perspective, all industrial activities can benefit from improvements in energy and conversion efficiency. Numerous applications of industrial biotechnology[6] have been shown to reduce energy intensity, and/or GHG emissions of industrial operations by replacing energy intensive steps. (Griffiths, 2001) To date, biotechnology R&D has focused on developing health and agricultural biotechnology applications. Industrial biotechnology is considered to be relatively unexploited with tremendous potential for energy savings. From a GHG perspective, petroleum refining and upgrading would appear to be logical target areas for new applications.

Biomass Availability

Canada's vast genetic resources form the basis of its biomass supply. This includes many different forms of living and non-living material. Within the context of the CBIN program, the living category includes microbial communities that can support a wide variety of industrial biotechnology applications, and plants (annuals and perennials) that are grown specifically for energy and/or industrial uses.

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[6] Industrial or white biotechnology is the use of biotechnology in industrial processes and production. It is a multidisciplinary area that engages classical microbiology, biology, chemistry, biochemistry, process engineering, as well as modern molecular biology techniques and advances in genomics science, etc.

At the present time, focus is on utilization of non-living biomass materials such as organic wastes, and the residues from the harvests of perennial and annual plants, i.e. forests and agricultural crops. Residue and waste are considered to be most logical near term supply in Canada as the environmental and economic impacts of their disposal require more effective uses and solutions. Current, order of magnitude, estimates of the major types of unutilized residue and waste are listed in Table 3.

While biomass material is clearly abundant, relative to petroleum feedstocks, it is highly variable with respect to form, availability and location. Both the quantities and types of biomass vary across the different regions of the country. Some materials are concentrated in and around urban areas, industrial facilities or farms, while others need to be collected from forest cut blocks and agricultural fields. Some materials (e.g. MSW, industrial wastes) are generated year-round, and others are produced on a seasonal basis and require storage. Also, as they are natural materials, periodically large amounts of biomass are made available through unplanned events such as insect-infestation or fire. Recent events such as the spread of mountain pine beetle attacks and large landscape-scale forest fires provide good examples of the large volumes of woody biomass that can unexpectedly become available. Similarly certain climatic conditions and environmental factors will reduce crop production and consequently the amount of available residue. Climate change is another variable that is expected to negatively impact biomass production in drought stressed areas.

There are widely varying opinions regarding the amounts of biomass residue and waste that are practically recoverable and could be used for bioenergy and/or industrial bioproduct production. These materials can often be fairly contaminated, have high moisture contents and only be available on a seasonal basis. Also, it is important to keep in mind that forest slash and agricultural crop residues have ecological value and are inputs to the respective forest and agricultural soil carbon sinks. Diverting these materials to other uses should be sustainable and consistent with Canada's climate change strategy vis-à-vis carbon sinks.

As a final point, it is important to keep in mind that although biomass residue and waste are grouped according to sector in Table 3, in reality, a mixture of different feedstocks will be available in a specific region. For economic viability and to deal with fluctuations in biomass supply, some conversion technologies and processes will need to handle feedstock mixtures.

The development of a bio-based economy will require more extensive resource assessments, i.e. understanding of the different types, quantities and locations of all of Canada's genetic resources. To produce substantial amounts of energy and biofuels, large quantities of biomass feedstock of known quality will be required. It is expected that residue, waste, and dedicated energy or industrial biomass feedstocks will be required. Table 4 lists the estimated additional biomass that could be available from agricultural land planted with dedicated annual crops, highly productive grasses, and agroforestry systems and short rotation (fast growing) forest plantations.

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Table 3. Current Estimates of Canada's Biomass Residue, Waste & Opportunity Feedstocks

Biomass Source/Type	Amount	Location/Availability	Description/Other Comments
Forestry			
- Mill Residues	5.4 M bdt/yr [(a)]	Near solid wood industries; BC; QC; ON; AB	softwood and hardwood species; mostly bark, mixed with whitewood
- Slash	92 M odt/yr (46 M odt/yr – if 50% left for sustainable site regeneration) [(a)]	Harvested sites in accessible timber productive forest; needs to be collected, cleaned, transported	non-stem biomass incl. large shrubs
- Opportunity Wood (infested, diseased or fire-damaged wood, salvage)	> 250 M m^3 [(b)]	Beetle-killed timber in BC interior; needs to be collected, transported	lodgepole, ponderosa and white pine softwood species
Agriculture			
- Crops available for energy and/ or industrial uses (incl. damaged crops, non-food grade quality, etc.)	Estimated at 10% of yearly average production [(c)]	Arable land in all regions of Canada	
- Crop Residues, by type	8 M odt/yr [(c)]	Agricultural land; needs to be collected, transported, pre-processed; stored	lignocellulosic material
Small cereal grains	3.0	Western Prairies	e.g. wheat straw
Grain Corn	1.3	Ontario and Québec	
Canola	1.0	Western Prairies	
Soybeans	0.2	Ontario and Québec	
Flaxseed	0.2	Western Prairies	Flax 2015 goals include tripling acreage and increasing utilization from 10 to 75%
- Livestock Manure	recoverable Mt [(a)]		high moisture organic wastes
Dairy (mature cows)	14 Mt	Ontario and Québec	split: solid & liquid manure management
Beef	20 Mt	Alberta and Ontario	solid manure management

Swine	22 Mt	QU; ON; MB; AB	liquid manure management
Poultry	2 Mt		
Municipal & Other Wastes			
- MSW	15 Mt [(a)]	concentrated around urban areas; ON; QU; BC; AB	dried combustible fraction; excluding recycled fraction
- biosolids	0.39 Mt [(a)]	" "	dry basis
- yellow grease & animal tallow		" "	
- fisheries waste		Atlantic and pacific coastal regions	

Abbreviations: M: million; bdt; bone dry tonne; odt: oven dry tonne; t: metric tonne; ha: hectare

(a) Source: BIOCAP (2003)
(b) Jeff Karau, NRCan-CFS, May 2006
(c) Mark Stumborg, AAFC, May 2006 - revised

Table 4. Biomass Estimates of Various Dedicated Energy and Industrial Crops

Biomass Source/Type	Amount	Location/Availability	Description/Other Comments
Fast growing (short rotation) forest plantations	12,000 ha (current) [(a)]; 1.3 million ha (2025) [(b)]	Areas north of the agricultural limits, abandoned ag lands (Eastern & Western Canada)	afforestation potential under study by FAACS and Forest 2020 initiatives
Agroforestry	10% of arable land converted to agroforestry by 2025 (SK target) [(c)]	Agricultural land in the Dark Brown, Brown and Grey Wooded soil zones of the Prairies; marginal agricultural areas in Eastern Canada	mixture of trees, perennial grasses, legumes
Grain Crops (non-food uses for existing crops) - feed grains (CPS wheat, poor quality HRS wheat, oats) - corn	8 million tonnes wheat; 2 million tonnes corn [(d)]	Corn: Ontario and Québec Wheat: Prairies	20% of Canada's grain production as input for 4 billion litres of ethanol (2025) [(d)]
Oilseed Crops (non-food uses for existing crops) - green seed and low grade canola	Not available	Western Prairies	input to biodiesel plants
New Starch-based Crops - triticale	4.5 million tonnes of grain; 3.0 million tonnes of straw (in 2016) [(e)]	Widely adapted to all areas of Western Canada	triticale could substitute for wheat in ethanol production
New Oilseed Crops - specialty oilseeds (see Section 2.3.1) - industrial hemp	sp oilseeds: 2.8 million ha (in 2025); 12 million ha (in 2050) [(f)]	sp oilseeds : adapted to marginal or dry areas of Western Canada	specialty industrial oilseeds (e.g. Brassica, flax, sunflower)
Herbaceous Crops/Grasses		Marginal agricultural land; high yield plants that could be grown	

		in Canada	
Miscanthus, cordgrass, switchgrass	(in future)	Ontario and Québec [(g)]	perennial, C4 warm season plants
Northern wheat grass	(in future)	Prairies [(h)]	perennial, C3 plants

Abbreviations: M: million; bdt; bone dry tonne; odt: oven dry tonne; t: metric tonne; ha: hectare

(a) Source: Yemshanov, D. et al (2004)
(b) Jeff Karau, NRCan-CFS, May 2006
(c) www.canada.com/reginaleaderpost/news/
(d) Don O'Connor, S&T Squared Consultants Inc., May 2006
(e) Triticale Biorefinery Steering Committee
(f) Dr. Wilf Keller, NRC-PBI, October 2004
(g) Source: University of Guelph, Department of Environmental Biology (2004)
(h) Mark Stumborg, AAFC, October 2004

Continuous genetic[7] improvements are expected to produce plants with higher yields and specific traits for use as industrial feedstocks. Marginal land will be used for production as well as existing agricultural land where industrial crop production yields a higher return that current commodity crops.

Right Timing for Development of Canada's Bio-based Economy

Although residues from forestry and agricultural operations have existed in abundance for many decades, energy from biomass has faced significant technical, economic and also environmental challenges. Over the last century, biomass-derived energy (almost exclusively from the combustion of forest residue) declined from 50% at the beginning of the 1900s to 6% of Canada's energy supply (~ 600 PJ) in the year 2000. This number would be even lower today if the pulp and paper industry had not made substantial investments in hogfuel and recovery boiler equipment, starting in the late 1970s. Fossil fuel derived energy, first from coal and then followed by oil and natural gas, displaced biomass energy as it was a more concentrated form of energy and considered to both economically and socially more sustainable. Biomass-derived energy conversion was less efficient than that of fossil fuels and often more expensive to produce. On the environmental side, the sustainability of biomass harvesting and air emissions from biomass combustion had to be addressed, but this in turn increased the cost of bio-based energy.

Environmental protection, high oil prices, technology advances and the need for Canada's resource industries to diversify have greatly improved the viability of bio-based energy and other bio-based climate change solutions. As shown in Figure 1, the timing of these economic and environmental drivers coincides with technological advances made in the areas of biomass to energy conversion, bioproducts development and biotechnology.

Long term R&D investments have improved direct combustion technologies and supported the development of new biomass energy conversion technologies (e.g. gasification, pyrolysis, hydrotreating) that have increased conversion efficiency, improved economics and produced new energy carriers, e.g. liquid fuels that can be used in transportation applications. Also uses are being found and developed for the co-products of biofuel production, and outputs of gasification and pyrolysis units. These are seen as critical for the economic viability of bio-based energy.

Further, the recent discoveries in genomics and biotechnology have the potential to dramatically expand the opportunities for biomass conversion. For example, agricultural biotechnology can be used to alter biomass feedstock (e.g. increase plant growth rates, produce plants with particular traits and even desired chemicals, etc.). Industrial biotechnology can convert cellulose to sugars; separate fibres from straw; facilitate the extraction of valuable biochemicals; and reduce the energy requirements of current manufacturing processes (e.g. enzymes used to reduce chemical and energy required for pulp bleaching).

[7] In scientific/genetic research literature, genetic modification is a general term that includes genetic alterations achieved through: 1) sexual crossing, 2) mutation breeding, and genetic transformation/engineering. The media equates genetic modification (genetically modified organisms or GMOs) to genetic engineering. (Dr. Wilf Keller, NRC-PBI)

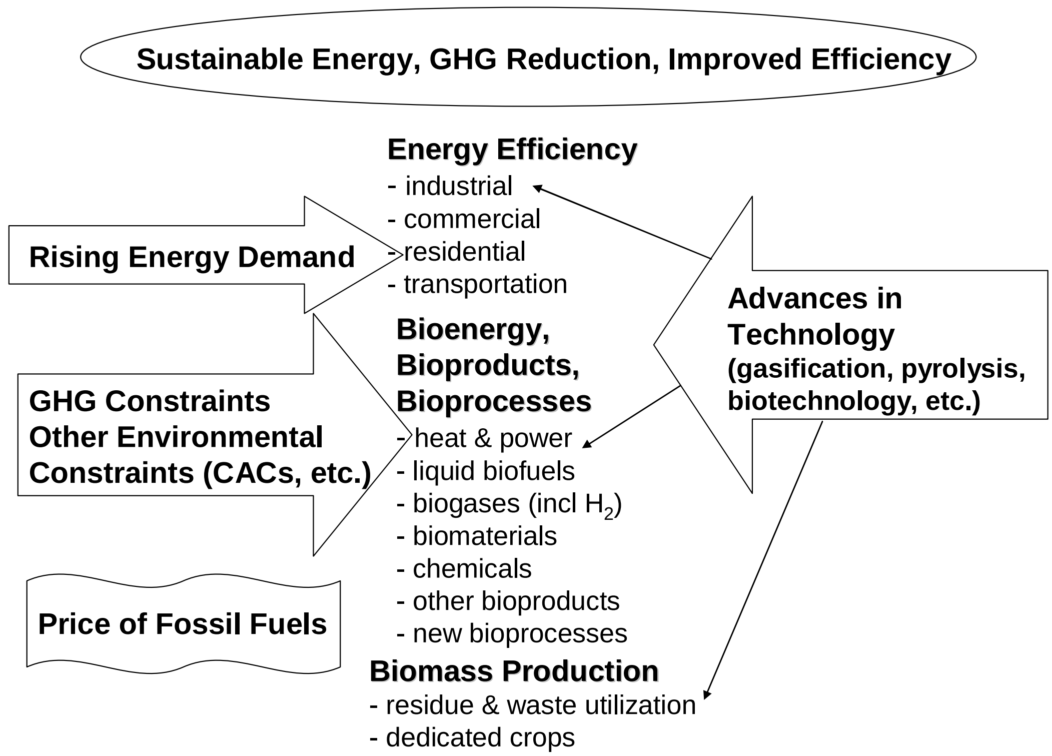

Figure 1. Driving Forces Supporting the Technological Development of Bioenergy, Bioproducts and Bioprocesses

The economic driver (i.e. price of fossil fuels) is present today, but historically it has been an inconsistent driver. Fossil fuel prices have fluctuated considerably over the last decades. When oil prices were high, as they were in the 1970s for example, they provided a strong argument for the development of bioenergy. Today's high oil prices clearly improve the economics, but current thinking is that the development of biorefineries is the key to the sustainability of bio-based energy. That is, producing the right mix of products, from volume and revenue perspectives, promises greater longevity than producing energy alone.

Figure 2 illustrates the relative price of petroleum-derived oil, soybean oil and glucose feedstocks, and how the differential has been increasing since 1998. Industrial interests, such as Cargill, Dupont, and Dow are increasing their investments in bioprocesses. Dupont recently formed a strategic alliance, known as Dupont, Tate and Lyle LLC to commercially exploit economic bioproducts technologies.

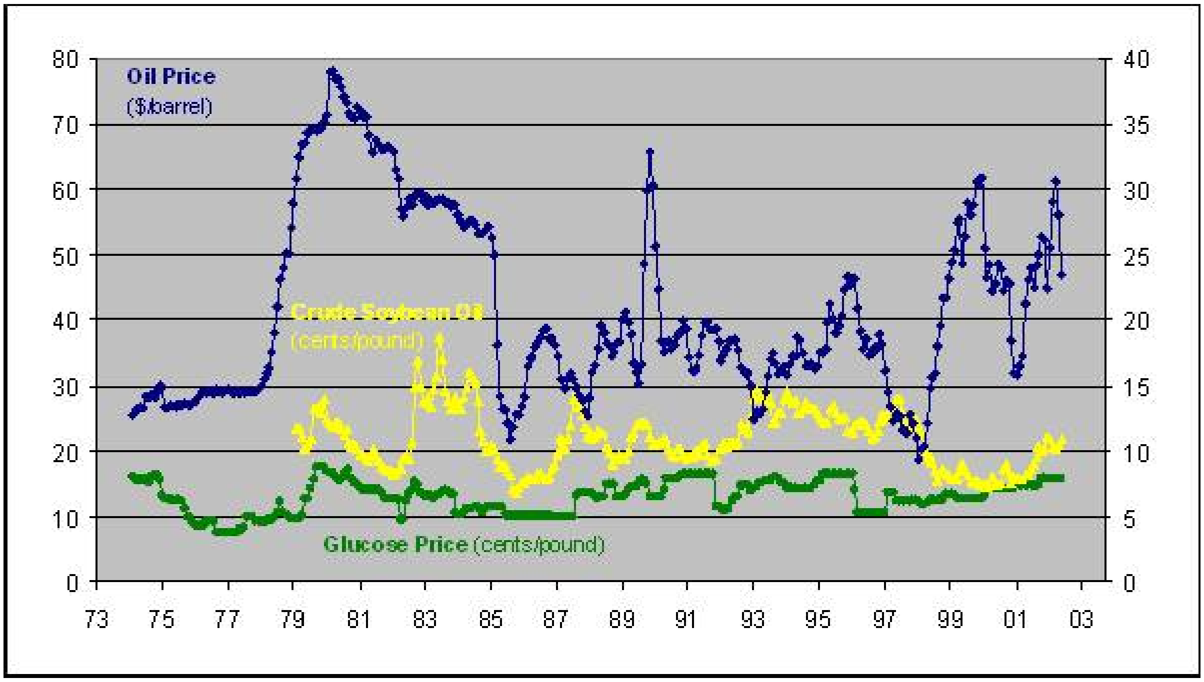

Figure 2[8]. Relationship between crude oil, vegetable oil, and sugar prices

The conversion of residues and waste into energy and fuels provides several environmental benefits. Tighter restrictions on air and water pollution require new uses to be developed for MSW, manure and sawmill residues. In the US, the need to find a substitute for MTBE (methyl tertiary-butyl ether) and a lubricity additive for ultra-low sulphur diesel, respectively, has increased the demand for ethanol and renewable diesel fuels. The ambitious GHG constraints set by the Kyoto Protocol provided an important driver for CO_2 neutral forms of energy. Further incorporation of environmental considerations into all of our energy decision-making has the potential to narrow the cost differential between fossil fuel and biomass-derived energy.

Global competitiveness, low commodity prices and the fisheries collapse are some of the reasons why Canada's resource industries need to revitalize their operations and find ways to generate new value from forests, agricultural land and oceans. Sustainably-derived bioenergy, biofuels and bioproducts appear to hold promise for these industries, providing them with more product options.

When all of these factors are considered together, there appear to be both real needs and opportunities for biomass and bioprocessing (including industrial biotechnology) to increase Canada's renewable energy supply, improve energy and material use efficiency, provide environmental solutions (including GHG reduction), and generate new economic opportunities.

As shown by the increasing number of new bio-based companies, the development of a more bio-based economy has begun. To further advance the development of bioenergy, biofuels, valuable bioproducts and bioprocesses, several technical and economic barriers need to be overcome. That is, greater conversion efficiencies are required,

[8] This figure is best viewed in colour.

higher value co-products need to be identified and developed, and the costs of biomass energy and energy carriers have to become more competitive with those of fossil fuels.

The role of the CBIN Applied R&D program is to advance the development of cost-effective, technological solutions in the following areas:

- development of sustainable biomass supplies;
- cost-effective bioenergy conversion that can produce more energy carriers (biofuels, biogas, hydrogen, etc.) and CO_2 neutral forms of energy (heat, power);
- development of bioproducts that improve the economics of bioenergy production;
- development of bioprocesses that improve the energy and conversion efficiencies of manufacturing processes; and
- integration of biomass supply, conversion technology, and end-use applications to optimize the economic, energy, GHG and other environmental and social benefits.

2.2 Bio-based Energy Baseline

Bio-based solutions will make positive contributions to Canada's energy supply and demand. On the energy supply side, the pulp and paper industry is Canada's major producer and user of bioenergy. It currently produces approximately 600 PJ of energy per year from hogfuel and spent pulping liquor. In Canada, the agriculture industry has traditionally used little bioenergy. Although substantial quantities of residue have been available, the agriculture industry is a relatively small user of stationary energy. The expansion of the greenhouse industry is starting to increase demand.

The NEB's Scenarios for Supply and Demand to 2025 are presented in Table 5. The projections are based on bio-based energy derived from forest residue that is tracked by province on an annual basis. Roughly 6% (975 PJ) of the primary energy demand in 2025 is expected to be met by biomass energy under the supply push (SP) scenario[9] and 7% (1,030 PJ) under the techno-vert (TV) scenario[10].

Table 5. NEB Scenarios for 2025: Supply Push and Techno-Vert

Source	Current	Supply Push Scenario		Techno-Vert Scenario	
		2015	2025	2015	2025
Energy from Biomass					
- hogfuel & pulping liquor	504 PJ (2000)[a]		812 PJ (5%)		884 PJ (6%)
- residential wood	95 PJ (2000)[a]		162 PJ (1%)		147 PJ (1%)
Electricity from Biomass	1,935 MW (2006)[b]	2,225 MW	2,225 MW	3,317 MW	4,481MW

a) Source: Canada's Emissions Outlook: An Update – data for year 2000
b) John Burnett, NRCan-CETC, May 2006

[9] Under the NEB's "supply push" scenario, energy demand is expected to grow an average 1.7% per year with an annual GDP growth of 2.2%.
[10] A "techno-vert" (TV) scenario leads to 7% less primary energy demand, with energy demand growing at an average 1.4% per year but a higher GDP growth rate of 3.0% per year.

Under NEB's TV scenario, electricity from biomass would triple. Pollution Probe estimates an even greater proportional increase in electricity generation. In its report "Promoting Green Power in Canada", current biomass power capacity (based on forest residues) is projected to grow to 3,000 MW by 2020, and an equivalent amount of new biomass power capacity (3,000 MW) is expected to be derived from agriculture residues. Over the next decades, heat and electricity generated from MSW and livestock manure are expected to increase.

The energy projections presented in "Canada's Emissions Outlook: An Update" were taken as a starting point in defining Canada's bio-based energy baseline. The baseline, shown in Table 6, will be improved upon as more information becomes available[11] and the technological assumptions included in the baseline are better understood.

Table 6. Bio-Based Energy Baseline

End Use Demand and Supply	Units	**1990**	**2000**	**2010**	**2020**
Industrial Demand					
Wood residue (hogfuel)	PJ	99	146	156	162
Spent pulping liquor	PJ	269	358	430	503
Other sources (e.g. landfill gas, etc.)					
Residential Demand					
Wood	PJ	84	95	104	113
Agriculture Demand					
Biogas - manure digestion	PJ	0	n/a	n/a	n/a
Transportation Demand					
Motor Gasoline	PJ	1,177	1,317	1,489	1,719
Ethanol (grain)	PJ	0	5 [a]	30 [a]	n/a
Ethanol (cellulose)	PJ	0	0	4 [a]	n/a
Diesel Fuel (road & off-road)	PJ	509	714	800	924
Biodiesel/Renewable diesel	PJ	0	4 [a]	18 [b]	n/a
Electricity Generation/Supply	PJ	2,964	3,556	3,867	4,109
- from biomass (sold to grid)	PJ	0	1.2	1	1
- from landfill gas (sold to grid) [c]	MW	0	84	n/a	n/a

(a) source: Chris Johnstone, NRCan; 200 million litres ethanol corresponds to current production from 2 corn and 3 wheat plants; 100 million litres biodiesel production is expected in 2006; ethanol conversion factor used 23.6 MJ/l
(b) Canada's national biodiesel target (500 million litres); biodiesel conversion factor used 36.9 MJ/l
(c) Source: Craig Palmer; Environment Canada; 84 MW corresponds to 166 kt CH_4 in 2001

[11] Using its model MAPLE-C, NRCan's Analysis and Modelling Division is currently updating the renewable energy projections, including energy from forest residues, landfills and biofuels. A new reference case should soon be available.

The use of biogas and liquid biofuels for energy has just begun and is therefore contributing only small amounts of energy to the mix. At present, there is no formal tracking of energy from biogas and liquid biofuels on a national basis. However, their respective energy contributions are expected to grow as a result of supportive policies and continued investment in demonstration and commercialization.

The 2010 values for ethanol and biodiesel demand, shown in Table 6, are the current national targets for ethanol and biodiesel of:

- 1.4 billion litres ethanol (> 1,000 million litres expected from corn and wheat (grain), and 150[12] million from wheat straw (cellulose)); and
- 500 million litres of biodiesel (2/3 from rendered waste and 1/3 from vegetable oil).

While they are important starts, these targets represent only 2% of the respective gasoline and diesel demand. Discussions are underway between the federal, provincial and territorial governments to consider a 5% biofuels standard for 2010. This would be a significant increase over the current target and require dedicated crop production, if the biofuels are to be produced in Canada.

At both federal and provincial levels, several programs and incentives have been put in place to increase ethanol and biodiesel production and demand. Since 2003, the federal government has provided a tax exemption of four cents per litre for biodiesel. The Commercial Transportation Energy Efficiency and Fuels Initiative (Targeted Measure) supports research, provides incentives for biodiesel pilot plants, and supports demonstrations of the effectiveness of biodiesel as a cleaner-burning alternative to conventional diesel. In 2005, biodiesel standards for B1 – B5 (1% to 5% biodiesel by volume in petroleum diesel) were approved by the Canadian General Standards Board (CGSB). The standard for B6 – B20 should be accepted by the CGSB in the near future.

Also, several provinces have provincial biofuel targets and/or tax exemptions. Ontario's Regulation 535/05 - Ethanol in Gasoline requires that by January 1, 2007, gasoline sold in Ontario will contain an average of five percent ethanol. Here, ethanol is currently exempt from the provincial gasoline tax of 14.7 cents-per-litre and from the federal excise tax of 10 cents-per-litre. Since June 2002, biodiesel has been exempt from the 14.3 cent per litre tax payable under the provincial Fuel Tax Act.

In Saskatchewan, the current ethanol (in gasoline) mandate is 2%. This will increase to 7.5% by Oct 2006. The Saskatchewan Ethanol Development Council would like to see Saskatchewan have an ethanol production capacity of 1 billion litres per year by 2015. The majority of this would be produced from feed grains (e.g. wheat, oats). The Saskatchewan Biodiesel Task Force targets are considerably more modest at 30 million litres by 2010 and 75 million litres by 2015.

On the energy demand front, increased adoption of bioprocesses, including industrial biotechnology applications, is expected to reduce energy intensity of energy production and industrial operations. This would in turn reduce the respective GHG intensities of these sectors. To track the potential energy and GHG impacts, the adopters (i.e.

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[12] There could be one 150 million litre ethanol (from wheat straw) plant constructed by 2010. (Cruickshank, NRCan, 2006 pers comm).

specific industries, communities, end-users, etc.) and the extent of adoption would have to be known.

While the energy impact, both on the supply and demand side, is only partially quantified, the potential is believed to be substantial and growing. The availability of resources, both residues and dedicated crops, combined with environmental considerations, economic development needs and high oil prices are giving rise to new opportunities for bio-based energy in Canada.

2.3 Vision 2025

CBIN supports strategic R&D investments that advance the development of bioenergy, biofuels and valuable bio co-products, and bioprocesses that directly or indirectly reduce fossil fuel energy consumption and greenhouse gas (GHG) emissions, and seed the sustainable development of Canada's bio-based economy.

The CBIN program focuses on the production of energy, fuels and industrial products from biomass, and does not cover R&D related to traditional forest products (e.g. pulp and paper, solid wood products), food and feed, or plant-made pharmaceuticals. As shown in the general schematic[11] in Figure 3, biomass residue and dedicated feedstocks can be converted directly into energy via combustion, or into energy carriers (e.g. biofuels – liquids and gases), intermediate chemicals, fibres and a variety of non-energy industrial products.

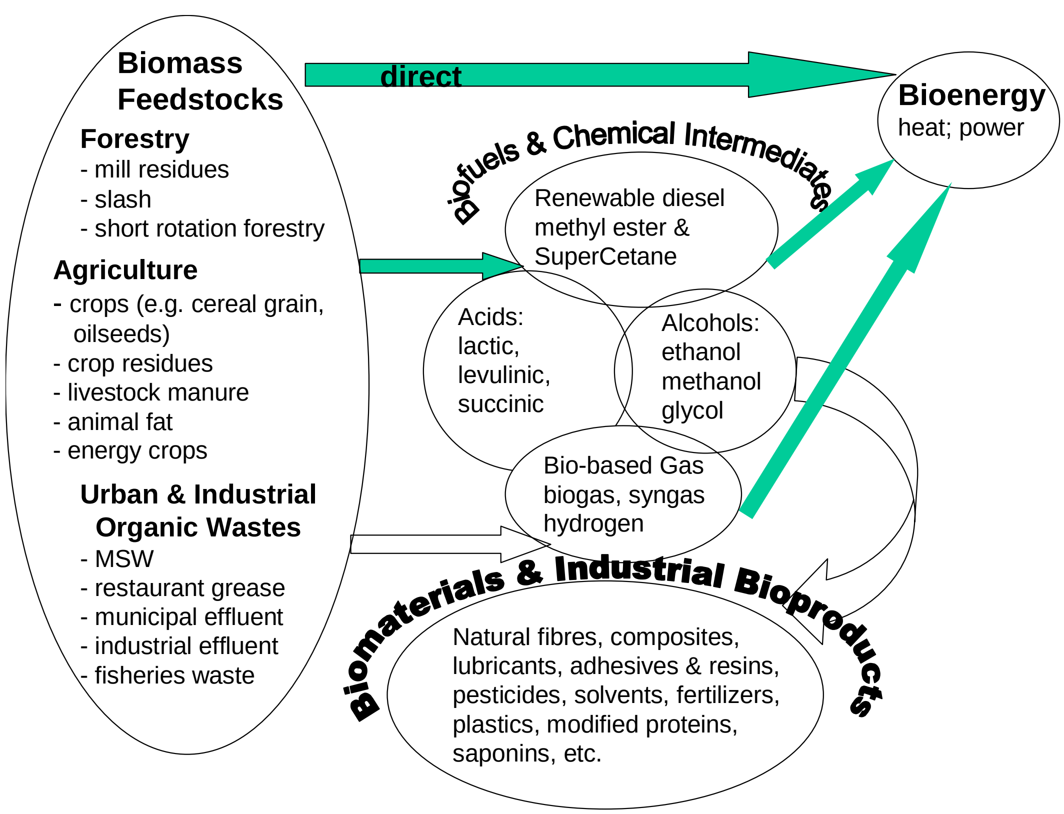

Figure 3. General Schematic of Biomass Conversion to Bioenergy and Bioproducts

CBIN's vision can be described supporting applied R&D and the development of new knowledge and technologies that will lead to:

- Increased supply of sustainable energy carriers and energy from biomass
- Minimal (near zero) quantities of unutilized and wasted biomass
- Lower non-renewable energy intensities for the energy production, industrial manufacturing and transportation sectors
- Lower GHG intensities for the energy production, industrial manufacturing and transportation sectors
- Increased production of chemicals and materials from biomass feedstocks in applications where sustainability is enhanced relative to conventional manufacturing

R&D is only one stage in the innovation curve. Realization of this vision will require the new knowledge and technologies to be demonstrated and commercialized, and the appropriate policies and regulatory systems to be in place.

The specifics of this vision, that is, the types of biomass, conversion technologies, types of products and respective quantities, are not known in detail for Canada. This is because there are literally thousands of possible pathways for converting a wide variety of biomass feedstocks (including mixtures) by thermochemical and biochemical routes into a multitude of products (including energy, chemicals and materials). One of the outputs of the CBIN program is to better understand Canada's most promising pathways for biomass to energy and industrial bioproducts. This insight would enable future programs to be more targeted and investments to be more strategic.

Over the near term, it is expected that forest residues will continue to be used by the pulp and paper industry for energy and that biomass to energy applications will be expanded to small solid wood operations. Animal fats and greases will be converted into biodiesel and some corn production will be converted into ethanol. By 2010, Canada's supplies of biodiesel and ethanol will be derived from vegetable oils and wheat, respectively. Agricultural crop residues will be converted into fibre and when costs drop for cellulosic ethanol, residues will be converted into ethanol and sugar-chemical platforms. Farms and landfills will be sources of biogas and decentralized energy production. Smaller volume branches of higher value co-products such as biochemicals will appear, and connections will be made to the production of nutraceuticals and plant-made pharmaceuticals.

Looking ahead to 2025, a different policy and regulatory context will exist from today. It is expected that there will be lower emission limits for pollutants that have the potential to negatively impact the atmosphere, stratosphere, surface and ground water resources, vegetation, soil and oceans, and all of their respective inhabitants. Tighter restrictions will exist on consumer and industrial waste disposal. A combination of policy, regulation and economic instruments will be used to conserve energy, water and natural capital, including genetic resources. Consequently, products will have to be safe and clean, i.e. reusable, recyclable or biodegradable, at the end of life. Depending upon geographic location, climate change could increase the vulnerability of some areas and their resource-dependent industries.

Technological innovation will continue. With good planning, adequate investment and enabling policy, CBIN's theme leaders[13] envision the following future for the areas of feedstock supply, biomass to energy and product conversion, and industrial biotechnology.

2.3.1 Sustainable Biomass Feedstock Supply

In 2025, there will be fuller utilization of all forms of biomass residue and waste. The amounts of forestry and agricultural crop residues that need to remain on a site for habitat, nutrient replenishment, erosion protection, etc. will be known for different areas. The quantities of residue and waste listed in Table 3 will be significantly reduced and in some cases completely eliminated (i.e. fully used). Dedicated woody crops and agricultural crops will be established as sustainable supplies of energy, fuels and industrial bioproducts. Biotechnology, in particular genetic and molecular manipulation tools, will continue to be used to increase plant productivity and to develop plants with traits needed for sustainable bioenergy and bioproducts manufacture.

Forest Residues and Dedicated Woody Crops

Forest residues and large scale short rotation plantations of dedicated woody crops will continue to provide an important supply of woody biomass. By 2025, 1.3 million hectares of new short-rotation plantation/ agroforestry systems will be established on fallow and marginal agricultural lands as well as agricultural lands under afforestation. (Karau, 2006 pers comm) These dedicated crops will produce in the order of 23 million tonnes of feedstock each year.

By 2025, biomass source options, field processing or harvesting, transporting, storage and conversion and related costs will be known. A variety of viable new energy and product uses will be identified, i.e. the technologies will have been demonstrated, costed and socio-economic and environmental (LCA) impacts assessed.

Whole Crop Utilization, Shifting Production and Dedicated Industrial Crops

Until recently, the focus of agriculture has been on the sustainable production of food and animal feed. Advances in biotechnology, extraction and separation have led to the development of nutraceuticals and functional foods, and opened the door to non-traditional agricultural products such as fuels, materials and chemicals. Both existing and new crops, including crop residues, have the potential to produce energy, biofuels and valuable non-food products that have positive energy and GHG benefits.

By 2025, commercial uses will have been found for the whole plant. Lignocellulosic residues will become an important source of biomass. Residues will be harvested and, depending upon their properties, be transformed into materials, energy, ethanol or sugars that are further converted into chemicals. Wheat straw conversion into ethanol could be the first to emerge. Oilseed flax is expected to follow. Under the Flax 2015[14]

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[13] Program theme leaders are federal government experts in specific disciplines. List is included in Appendix A.

[14] Supported by AAFC's APF Science & Innovation program, the Flax Council of Canada, the Saskatchewan Flax Development Commission and the provinces of Manitoba, Saskatchewan and Alberta.

initiative, it is expected that economic uses will be found for the whole plant and that flax straw utilization will increase from 10% (today) to 75%. Industrial hemp production and fibre utilization could be developed around the same time.

> "Flax Canada 2015 [has been] established to identify and exploit value-added opportunities for flax, with a goal to obtain a $1.5 billion farmgate value by the year 2015. Flax Canada 2015 will address how flax will become one of the main drivers of the Canadian bio-economy. It will increase the value of flax by making it an important component of the preventative approach to human and animal health. It will also support the value-added sector by developing a strategy for total utilization of the flax plant, for food, feed, fibre, health and industrial uses."
>
> Source: www.flax2015.ca/about.html

Secondly, developments in the production of energy, biofuels, industrial products and integrated biorefineries combined with supportive policies will shift some production of lower value commodity crops to higher value industrial crops. The types of crops and respective acreages will depend on the demand and markets for the end products and the return to the farmer. By 2010, it is likely that a portion of the current CPS wheat and canola production would be directed to ethanol and biodiesel production, respectively. Also, other existing crops such as triticale, a non-food crop which is currently only grown to a small extent for silage, could be expanded for ethanol production.

Thirdly, new crop varieties will be developed. Through a combination of molecular genetics, plant breeding and bioprocessing research, biorefinery-optimized plant species will be developed in conjunction with the processes technology to maximize potential value recovery. The resultant value chain will increase the profitability of crop production and crop processing. Crops will be bred specifically for energy, fibre or chemicals, for example.

Shown below are the projections for Canada's specialty oilseed crop systems in 2025 and 2050. (Keller, 2004 pers comm) In 2025:

(i) Oil content of key species including Brassicas, flax, sunflower, will exceed 50% (now in the range of 40%).

(ii) Specialty industrial oilseeds with long chain fatty acid (re: erucic acid) levels exceeding 85% (now in the order of 50%). These will serve as the source of feedstocks for polymers (including nylon 1313), lubricants, industrial chemicals. Area for this material in Canada will exceed 809,000 hectares (now in the order of 80,900 ha).

(iii) Specialty oilseeds with the polyunsaturated fatty acid, linolenic acid exceeding 90% of total fatty acid (now in the order of 65-70%) thereby offering new market for drying agents (including coatings, paint), linoleum and new building materials, safe medical products, specialty containers, etc. Targeted acreage in Canada 3.2 M ha (compared to present 607,000 – 728,000 ha).

(iv) Specialty oilseeds with elevated levels of hydroxy and epoxy fatty acids with levels in the range of 50% of total fatty acid content. Such products would have major impact on high quality lubricants and a feedstock for urethanes and related foams used in automobile (and other large) manufacturing markets. Currently such crops are not grown in Canada. Total projected area for 2025 is 1.2 M ha.

(v) Novel fatty acid (and other lipid) modifications with specialty industrial applications (this is based on the knowledge that there are more than 500 known different fatty acids and less than 20 of these are now used commercially). We could expect prototype plants under that and total area of all novel types (different from ii, iii, iv above) to be less than 405,000 ha.

A total annual bio-industrial oil production of 12 million hectares in foreseen for 2050. The above projections could increase as follows:

Type (i)	Oil content in the range of 60%
Type (ii)	2.02 M hectares
Type (iii)	4.05 M hectares
Type (iv)	4.05 M hectares
Type (v)	2.02 M hectares

Harvesting of total crops, and other separation/collection/drying and retting technologies will have been adapted to cost-effectively collect and pre-process the feedstocks so they are of consistent quality.

Biomass Supply System

The transportation infrastructure will be in place to reliably deliver the feedstocks to the conversion facilities.

Available biomass feedstock supplies will be defined at regional and local levels using GIS systems. Information will be known on the feedstock type (including forest residues, agricultural residues, manure, MSW, other solid and liquid organic wastes, dedicated agriculture and forest crops), quality, amount and cost.

More specifically, a geographic information system (GIS) tool that models biomass quantity, quality, and the associated energy, water, and transportation infrastructure will be available for efficient and sustainable use of the biomass resource. A web-based interactive map will allow the GIS to provide biomass access information that is accurate and reliable. This tool / application will be linked to remote sensing technology to provide predictive capacity for biomass availability.

2.3.2 Biomass to Energy and Product Conversion

By 2025, improved combustion technologies, Integrated Gasification Combined Cycle (IGCC) and electrical generating cycles will have been developed to convert forest residues, black liquor and other opportunity biomass feedstocks into heat and power. The forest products industry will increase its bioenergy consumption to 665 PJ in 2020, and double its electricity output. Both large and small scale heat and power applications will exist.

Anaerobic digestion (AD) systems will be available to convert different feedstocks (livestock manure and deadstock as well as municipal, industrial and pulp & paper effluents, etc.) and mixtures of feedstocks into biogas. Technologies will exist to convert biogas into energy, or value-added chemicals. OMAF estimates that 5 to 10 on-farm AD systems could be implemented in Ontario within the next 2 years, and that upwards of 10% of Ontario's livestock facilities could have systems in place over the next 15 to 20 years. Similar predictions have been made for the rest of Canada, particularly in areas with high intensity livestock production. By the year 2010, it is anticipated that anaerobic digestion will become the manure treatment of choice for 60% of all new animal facility construction, and will be retrofitted on 25% of existing facilities. By 2025, utilization of biogas from farms could be mainstream and make a substantial contribution to decentralized energy production. (Barclay, 2004 pers. comm)

GHG reduction via landfill gas recovery is expected to increase from the current level of 6.6 Mt CO_2e[15] to 8 to 11 Mt CO_2e in 2012. By 2025, all landfills (above a minimum size) should have landfill gas collection and systems in place to convert the biogas into energy or other valuable by-product, if there is no immediate energy application.

By 2025, over 750 million litres per year of inexpensive renewable diesel fuels will be produced from a wide range of feedstocks including animal fats, vegetable/plant oils, and low-quality materials such as restaurant trap greases and lipids from wastewater treatment plants. This will be achieved as a result of multiple technical advancements that improve current biodiesel technology (e.g. trans-esterification), bring to the market place novel processes (e.g. SuperCetane and, alkyl levulinates, Fischer Tropsch) and improve cold flow properties of final products. New feedstocks will include dedicated energy crops that will yield high volumes of vegetable oils. Renewable diesel fuel plants will be located across Canada in both rural areas and near large urban centres (i.e. rendering plants).

New uses will have been found for glycerol, a co-product of biodiesel production. The conversion of glycerol to fuel additives and monomeric feedstocks for polymerization applications will be demonstrated at bench scale by 2010. Commercial demonstration plants will be built by 2015. (Monnier, 2006 pers. comm)

By 2025, it is conceivable that 20% of Canada's grain production could be converted into ethanol. Over 4 billion litres of ethanol could be produced from starch (wheat, corn and other grains such as triticale) in 20 to 30 facilities across the country. (O'Connor, 2006) Uses will exist for the co-products of ethanol production, including DDGS and CO_2.

Cellulase enzymes and hydrolysis systems will convert, on a cost-effective basis, different cellulose feedstocks (forestry residues, agricultural residues, specifically grown biomass) into sugars. Very efficient fermentation systems will exist that convert sugars into ethanol, and other chemicals. Between 2010 and 2025, the cellulosic ethanol industry is expected to continue to expand in terms of the number of plants/production volume, the range of utilizable feedstocks, the number of associated co-products, and the implementation of new conversion technologies such as organosolv and thermochemical processes. By 2025, there could be 5 cellulose ethanol plants in Canada producing a total of up to 1 billion litres/yr.

Lignin, a byproduct of cellulosic ethanol production, will be used to produce heat and power. In facilities that use organosolv technologies, lignin will be used in a wide range of commercial applications such as substitutes for phenol formaldehyde resins in engineered wood products and friction materials. Lignin will also be used as a feedstock of low cost carbon fibre production for light weight automobile panels, and be one of the

[15] In 2003, 312 kt CH_4 (6.6 Mt CO_2e) was collected from Canada's landfills (C. Palmer, Environment Canada, October 2004); 171 kt CH_4 was used for 80 MW electricity generation; 12 kt CH_4 for heat energy and the remainder was flared.

components in biodegradable plastics, animal feed supplements and a variety of chemical products. (O'Connor, 2006 pers. comm)

A variety of technologies, such as membrane separation and pressurized low polarity water extraction, that can separate, extract, and purify different process streams in a biorefinery and/or products from a process stream will be commercialized. These technologies are integral to biorefinery operations and key to the recovery of valuable biochemicals. They will be cost-effective, energy efficient and environmentally-sound.

Gasification systems, suited to community scales (3 - 30 MW), will be available to convert different feedstocks (including forest residues, MSW, agricultural residues, etc.) into low energy fuel gas or medium energy syngas. Commercial gasification systems will exist for wood residues and MSW. The technologies will exist to clean the gases and convert them into heat and power, hydrogen, Fischer-Tropsch diesel, value-added chemicals, etc. (Hogan, 2004 pers. comm)

Pyrolysis systems, similar in scale to gasification technologies, will be available to convert different feedstocks (including forest residues, MSW, agricultural residues, purpose grown biomass) into bio-oil. Technologies will exist to convert pyrolysis oil into energy or into chemicals and value-added bioproducts. By 2010, there will be a viable pyrolysis industry with markets for co-products, and there will be at least 4 different ways of converting pyrolysis oils into heat and power. By 2025, it is estimated that there will be 3,000 tpd of biomass pyrolysis capacity generating roughly 50 MW of electricity. (Hogan, 2004 pers. comm) Energy and product applications will exist for highly reactive chars and valuable pyrolysis gases.

On the materials side, technologies and processes will have been developed to cost-effectively separate the components of hemp, flax straw and other agricultural residues into fibres, shives and valuable biochemicals. Natural fibres have already started to displace synthetic fibres in the production of strong and lighter weight materials in the luxury car market where they are meeting material performance standards and improving vehicle fuel efficiency. This trend is expected to continue. By 2015, 75% of flax straw production will be processed. Several processing plants will exist in Western Canada that will supply different grades of fibre to a variety of end-users including composites, insulation, filtration, and textiles manufacturers.

Markets will exist for a numerous higher value biochemicals, i.e. chemicals extracted or produced from biomass feedstocks. These could include, for example, specialized industrial fatty acids produced in high concentrations in oilseeds, alcohols produced from cellulose, ferulic acid extracted from shives, etc. They will include chemicals that are sustainable substitutes for petroleum-derived chemicals as well as entirely new products such as biopolymers that are entirely derived from plants. The chemical industry will consider biochemicals to be cost-effective, viable alternatives in specific applications.

By 2025, integrated biorefineries that make a number of products from a variety of feedstocks will be a reality. Green chemistry as an environmental priority will be flagship for increased industrial safety, economic growth and social acceptance. The biorefining industry will be recognized as a new, sustainable industry sector in Canada. Some of the existing resource-based companies in the forest products, agricultural and fisheries industries will reinvent themselves, and new industries will emerge. The sector will include many different types of companies that produce a variety of clean energy, biofuels and industrial products from biomass feedstocks (e.g. intermediate and specialty chemicals, composite materials, biopolymers, etc).

> Example: Oilseed Biodiesel Biorefinery
>
> Existing agri-food processes and industries, such as the canola crushing industry, will be organized to simultaneously produce food, feed and industrial bioproducts. Low quality materials will be diverted to industrial biomass use, as will specific lower quality streams. Solvent- extracted vegetable oils that constitute about 20% of all canola oil currently recovered in Canada will be tapped as an energy source. Export markets for high quality seed and food canola oil will be improved by the removal of the biodiesel and bioproduct streams.
>
> In 2025, several small (< 600 tpd) oilseed biorefineries will exist that convert various oilseed crops into feed protein, renewable diesel and high-value co-products (e.g. pesticides, chemicals, etc.) Well-designed biorefinery plants will be located closer to feedstock production and save considerably on transportation costs. Also, smaller plants will generate greater total revenue and economic activity. This is a shift from the current paradigm for grain collection and processing where large processing facilities have been built that off-load transport costs onto producers and rural municipalities. It is envisioned that 20-30 small oilseed refineries, using a combination of conversion and separation technologies, could exist in 2025. (Reaney, 2004 pers comm)

Numerous regional bio-clusters (eco-industrial clusters involving one or more bio-industries) will exist where traditionally unrelated facilities will exchange materials and energy with one another to maximize resource use efficiency. The integration of these enterprises will occur where there is sufficient biomass of the targeted types, sufficient land, capital, and human resources, and where there is a market advantage because of location, technology, or economics.

2.3.3 Industrial Biotechnology

The current technologies and strategic research agenda for industrial biotechnology include: genomic-based development in biocatalysts discovery and functionalization through microbial genomics and bioinformatics, gene shuffling, directed evolution and metagenomic approaches, etc; metabolic engineering and modeling; innovative fermentation science and engineering; innovative downstream processing, etc. By 2025, most of these technologies would have matured to some economic fruition. Prototype artificial microbial genomes capable of harnessing energy and biomaterials would be in place. Industrial biotechnology applications will penetrate every industrial sector, environment and health (biopharmaceutical) sectors to the same degree. Current physical-chemical-thermal unit operations in both bio and non-bio-based industries, will be increasingly replaced with cleaner, more efficient biochemical processing steps. (Lau, 2006 pers comm)

There are two main challenges that will affect the rate of adoption of industrial biotechnology. The first is the economics of replacing current technology, where capital investments are in place, with a new biotechnology. The second is the ease, or conversely, the difficulty by which biotechnologies (enzymes or organisms) can be adapted to perform the chemistry needed, in the environment needed, and on the production timescale needed.

Industries that produce relatively smaller quantities of high-value products from bio-feedstocks, such as the food industry have already started to incorporate biotechnologies. For treatment of chemical feedstocks where enzymes may need to be immobilized for stability in non-aqueous environments, the pharmaceutical and chemical industries would be next able to convert to biotechnologies due to their high-valued products.

The most challenging industry to convert to using bioprocesses, yet with the potentially greatest rewards in reducing environmental impacts, will be the petroleum industry. With billions of barrels of products per year, a wide range of chemistry needs, typically high production rates, and severe process conditions (yet with relatively low-value products) biotechnologies will need to be implemented opportunistically. The first petroleum biotechnologies are being introduced where current technologies are inadequate or do not exist. As new techniques in biotechnology, and nanotechnology, are learned from the implementation of biotechnology in the chemical and pharmaceutical industries, biotechnology uptake by the petroleum industry will increase.

By 2025, the synthetic methods required to synthesize stabilized enzyme systems for performing all of the chemistry needed to produce the desired industrial products, including in the petroleum industry, will be available. Also, the ability to synthetically convert carbon dioxide back into reusable hydrocarbons will have been developed and be included on all combustion processes. This will be a huge breakthrough for GHG mitigation! (Dettman, 2006 pers comm)

2.3.4 Specific Targets to Realize the Vision

Figure 4 summarizes the desired end-points or targets that have been identified by CBIN's theme leaders in the areas of biomass supply and conversion. The knowledge and technology gaps that impede the realization of these end-points are described in the next section. They form the basis for CBIN's Applied R&D program.

For these targets and the broad vision to come to fruition, numerous technological solutions will have to be discovered, developed, commercialized and implemented. The solutions must be sustainable from economic, environmental and social perspectives. The development of integrated solutions will involve many stakeholders from the private and public sectors, and will require federal leadership, national collaboration and effective coordination. Appropriate assessment tools, from design through implementation, will be needed to evaluate the full impacts. Key regulatory issues will require timely solutions. At the same time, work will need to be undertaken to develop supportive policies and the business cases for substantial financial investments.

2010 Outcomes

- Increasing amounts of corn, CPS wheat and canola grown for biofuels production
- Commercial equipment available to reduce residue harvest losses by 25% and improve residue quality
- (2015) 75% of flax straw production is harvested
- 10 small scale CHP systems installed (sawmills)
- 5 lime kilns at P&P mills using biomass
- 50% of pulp mill sludges dried
- Anaerobic digesters in 60% of new animal facilities constructed; retrofit in 25% of existing manure treatment facilities
- At least 4 different ways of converting pyrolysis oils into heat & power
- Viable pyrolysis industry with market for co-products
- Commercial gasification systems exist for municipal solid waste & wood residue
- 1.4 Bl/yr ethanol (> 1,000 Bl from corn and wheat; 150 Ml from cellulose) *
- 500 Ml/yr biodiesel from animal fats, greases and vegetable oil *
- (2015) flax straw converted into high quality fibre, energy & biochemicals

* Higher targets being discussed

2020 & 2025 Outcomes

- "near zero" forestry and agricultural residues, manure, organic wastes
- Increasing percentage of agricultural crops used for energy and industrial uses
- 1.3 million hectares of new short rotation plantations and agroforestry systems
- 2.8 million hectares of specialty oilseeds
- Canada's total production of bio-based energy exceeds 1,000 PJ/yr
- (2020) Forest products industry consumes 665 PJ bioenergy; electricity output of 1,630 MW
- Biogas utilization from farms is mainstream
- All medium & large landfills have gas collection in place and biogas is used for energy or converted into products
- 4 Bl/yr ethanol produced from 20% of Canada's grain production
- 1 Bl/yr ethanol produced from cellulose
- 750 Ml/yr biodiesel production from vegetable oils, animal fats & greases
- Canada's bio-refining industry established, producing bioenergy, biofuels and wide variety of industrial bioproducts – both entirely new products and substitutes for petrochemically-derived products

Figure 4. Near Term and Medium Term End-Points

Work is underway at many Canada's universities, government labs and within industry. Saskatoon's Research Innovation Park is a shining example of how a university, private industries, and federal and provincial governments are working collaboratively to develop new fuels and non-food products from agricultural crops. Each province has its own twist on the development and adoption of bioenergy, biofuels and industrial products because of the different biomass feedstock supply, institutional capacity, resources, and industry infrastructure within each province. For example, Alberta's Strategic Framework for Research and Innovation (2003) links the Province's growth strategy with the strategies of R&D providers, funders and industry. Five focus areas have been identified for its biorefinery development: oils and lipid utilization; crop utilization; fibre utilization; energy from biomass; and biomaterials, energy and chemicals derived from animal by-products. Through its Biotechnology Clusters and Innovation Program, Ontario has identified six regions that are including bioproducts as part of their economic development. NeoBio Consulting has examined the opportunities for each region with respect to chemicals, renewable fuels, functional fibres and non-timber forest products.

Private and public collaboration that builds on the individual strengths and capacities of its partners is common to all approaches. Shown in Figure 5 are the main federal programs that collectively support the development of bioenergy, biofuels and biorefineries from concept to commercialization.

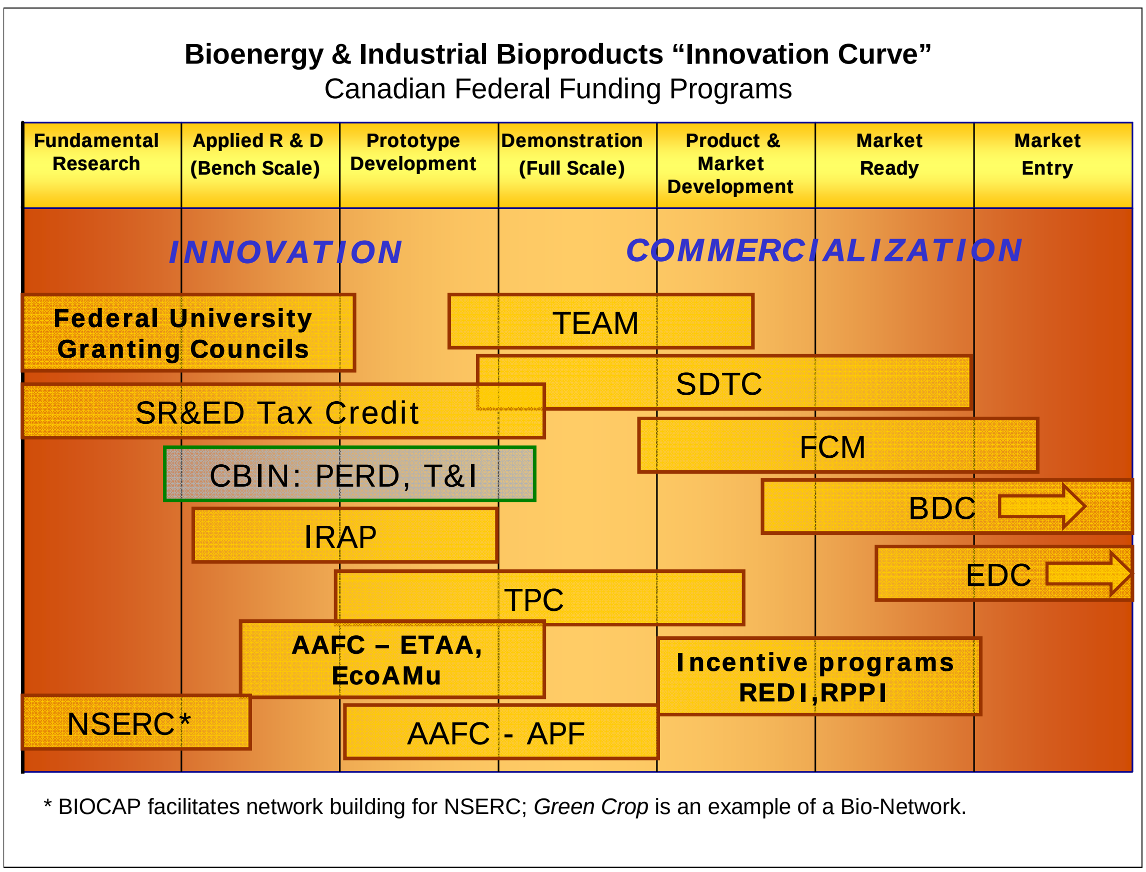

Figure 5. Bioenergy, Biofuels and Industrial Bioproducts Innovation Curve

2.4 Gaps and Rationale for R&D

CBIN's theme leaders and numerous reviewers have identified key gaps in the areas of biomass supply, biomass to energy and product conversion, 'feedstock to product' integration and adoption. These gaps have been reviewed with the External Advisory Panel, and resonate well with conclusions from numerous strategic studies. Where information was available, complementarities and linkages with other programs are indicated to show that initiatives are coordinated to minimize overlap.

Clearly, not all of the identified gaps can be addressed by the CBIN Program. Transportation infrastructure, for example, is an important issue for biomass supply. However, the design or development of this infrastructure is clearly outside the scope of this program. The CBIN Program, described in Section 3, centres on finding technology solutions in the applied R&D space, and advancing successful R&D along the innovation curve through dissemination, and by identifying and reducing barriers to adoption.

2.4.1 Gaps Related to Biomass Supply

All aspects of biomass supply - production, harvest, pre-processing, transportation, storage and inventory - must progress to advance the production of bioenergy, biofuel and industrial product conversion in Canada. As biomass resources and industrial infrastructure for biomass conversion vary by region, supply also needs to be characterized at this level.

Current resource assessments are required to assess Canada's bio-based opportunities and to develop the industry in a sustainable manner. This is not an easy, nor inexpensive task given the size of the country and diversity of genetic resources in terrestrial and aquatic environments. Canada's national forest inventory, for example, has been under development for many years. At the microbial level, in particular, it is said that only the surface has been scratched. Furthermore, unlike mineral or petroleum resources, biological resources can move and change from year to year.

As interest in the bio-based economy is increasing, more regional resource assessments are taking place. Information on biomass type, location, quality, and quantity is essential for the establishment of bio-based industries and the management of Canada's natural resources. Using the many tools of geomatics, information can be generated for integrated resource management, including the development of access and benefits sharing agreements, and the valuation of social, economic and environmental benefits and impacts associated with biomass production and conversion operations.

For good planning, realistic projections of biomass supply are required. Information is needed on the biomass demands and surplus available from current resource use, the additional biomass that could be made available in short order (i.e. less than 5 years), and what new biomass crops are in the development pipeline.

The gaps are described in terms of:

- existing supply: inventory and modeling; and harvest, transport, storage and pre-processing technologies;
- new biomass production for energy and industrial uses; and
- economic and environmental assessments related to the preceding points.

GIS-based Regional Inventory and Feedstock Supply Modeling

Industry Canada, in its Technology Road Map exercise, identified biomass inventory development as a key tool for the growth of the bioproducts sector. (Industry Canada, 2004) It is anticipated that Canada's agricultural, forestry and urban biomass inventories, when combined, will reveal key opportunities for biomass development from multiple sources.

Knowledge of the location, quality, quantity, and potential increases/decrease in the supply of biomass materials will be critical in the overall management of these biological resources as a renewable energy source. In many regions of Canada, the utilization of wood for fibre is approaching annual allowable cut limits. The amount of biomass available for energy and industrial uses need to be evaluated in relation to fibre demands of the existing resource industries. As well, the potential expansion of biomass production needs to be evaluated in marginal agriculture and other non-forest areas across Canada.

Also, there are significant biogas capture opportunities from livestock manure, municipal and industrial wastes. Existing information needs to be assembled and evaluated to identify significant biomass opportunities for exploitation from these multiple sources to determine 'hot spots' where the quantity and quality of the material available provides a low cost, low risk opportunity for conversion by any number of options considered within the context of the conversion activities.

For resource planning, the development of business plans or day-to-day management of costs and supply risks, systems that collect information and model supply are needed. Accurate and geographically-specific information requirements include: projected yields; when the material will be available; where it is located; how much can be removed sustainably (or how much needs to remain on the site); the material specifications; if it can be stored and how quality might be affected by storage.

For energy and industrial applications, the reliability of consistent supply, both with respect to quantity and quality, needs to be described. Information, such as long-term trends or availability of materials from other sources or close substitutes is required to assess and mitigate risks to industry from agricultural crop failure or tree loss to pests or fire.

Modeling of agricultural and forestry residues available from conventional production systems is an ongoing activity. Traditionally this has been funded by A-base and PERD. Work to stabilize the model of biomass productivity needs to be continued. Given the natural variability of weather and the potential effect of climate change, the models will need to identify changes in biomass production potential under a variety of climate change scenarios. As well, the model needs to be linked to remote sensing technology to improve its predictive and forecasting capability as a biomass management tool. Considerable work has been done in this area, but the activities are incomplete and untested.

Harvest, Transport, Storage and Pre-Processing

Canada has a large land base with some unique environmental challenges that must be accommodated if the harvest, transportation, storage, and pre-processing of agricultural materials is to be done at the lowest possible cost. For forest biomass, the harvesting of densely-spaced small-diameter stems, chips and other comminuted material needs to be optimized. Also, wood damaged by pests, disease, and fire offers unique challenges for harvesting, sorting, and separation of forest biomass feed stocks.

Most of the agricultural systems currently used are optimized for conventional grain and feed materials, not for whole crop utilization, nor for use as energy or industrial feedstocks. Harvest, post-harvest, and pre-processing opportunities exist to reduce the overall cost of harvest and biomass collection and to improve the quality of conventional feedstock materials. To produce high quality fibre from flax straw, for example, both the quantity and quality of the harvestable straw need to be improved. Cost-effective changes in seeding and harvesting are needed to increase straw recovery to 75%. (Ulrich, 2006 pers comm.) This work must be done in a manner sensitive to the maintenance of soil carbon and nutrients and other factors affecting overall system sustainability.

Historically, R&D on forest and agricultural 'biomass for energy' inventories received funding from PERD POL 4.2.4 "Agriculture and Forestry Biomass Supply for Energy". This POL is now part of the PERD BEST POL.

New Biomass Production for Bioenergy, Biofuels and Industrial Products

To date, the focus in forestry has been on the production of fibre that has the desired characteristics for different pulp and solid wood products. Bioenergy has been generated from mill residues. Agricultural crops have been bred for food and feed production, and insect and disease resistance. In the move towards whole crop utilization and non-food production, breeding goals will likely be adapted to support the production of nutraceuticals, plant-made pharmaceuticals, fibre, biofuels, specialty chemicals and energy.

Fast growing forest plantations and combinations of forest and agricultural crops (agroforestry) are considered to be good energy crops that can be grown on marginal land, i.e. land that is not suitable for annual crops. Gaps that need to be addressed include information on: spacing, species, densities, fertility, soil disease, pests, and foliar disease.

Managed production systems involving agroforestry plantations or shelterbelts is a novel concept in the Canadian context. The gaps include understanding the:

1) interaction of forestry species (e.g. willow, poplar clones and hybrids) by eco-zone and production system (e.g. within an agroforestry system). Effort is required to gather existing information from all sources, and then define agroforestry plantation and/or shelterbelts systems that work within the context of the landscape available. This concept needs to be evaluated in the northern prairie, the clay belt of northern Ontario, southern and eastern Ontario and southern Quebec.

2) interaction of trees (in agroforestry shelterbelts) and agricultural crops (annuals or perennials) grown between them. This concept needs to be evaluated in the northern prairie and eastern Canadian agricultural fringe landscapes employing poplar and willow forest species mixed with agricultural energy crops.

3) feasibility of utilizing agroforestry shelterbelts in the development of 'fire smart' landscapes as a potential climate change fire management adaptation strategy.

From energy and GHG perspectives, new biomass feedstocks should be high yielding and require 'low input'. 'Low input' refers to little/no fertilizer, herbicide, pesticides and irrigation. If applied in large amounts, the energy and nitrogen emissions associated these inputs have the potential to create negative energy balances and significant nitrogen pollution to the water and air. The US' 10 year bioenergy crop production program identified switchgrass as a low input, high yielding perennial feedstock for ethanol production.

Clearly crop breeding requires a long term commitment. Canada's federal and provincial agriculture and forestry departments and universities have a wealth of expertise in this area, and the seed banks and resources dedicated to the development of new crops. The Greencrop Network, funded by NSERC, is an example of a collaborative university-industry program that is developing 'greener' crops.

While the funding of energy and industrial crop breeding is outside the scope of CBIN, it is essential that the crop breeders and crop converters are closely connected. That is, researchers working on energy conversion or biorefinery development need to know what new crops are in the pipeline and when they might be available. Similarly crop breeders need to know the desirable crop qualities and quantities (e.g. yields) needed for viable conversion into fuels, materials, chemicals or energy. These linkages need to be strengthened.

It makes sense to further develop crops that grow well in Canada and have a strong, supporting knowledge base. For example, Canada is one of the largest producers of industrial rapeseed oil and flaxseed. Therefore, whole crop utilization, the addition of new traits and the development of rapeseed and flax biorefinery models would appear to be logical candidates for research and development. Dr. Wilf Keller, leader of CBIN's 'New and Improved (Fatty Acid) Feedstocks' Theme, and his colleague Dr. David Taylor (NRC, PBI) described the specialty oilseed R&D pathway as follows.

Manufacturing cost is a major hurdle to increased use of plant-derived oils, and cost is directly related to yield and purity of plant oils. Increasing the yield of the long chain fatty acid (erucic acid) in industrial rapeseed, to levels exceeding 80%, could open the door to applications such as the synthesis of nylon 1313. Similarly, increasing the yield of the polyunsaturated fatty acid (linolenic acid) in flax to levels exceeding 90% of total fatty acid could expand the range of products where the fatty acid is used to include binder adhesives in water-based paints and varnishes, linoleum and new building materials, safe medical products, specialty containers, etc.

Through conventional breeding and genetic modification, new crop varieties can be developed that consistently produce high concentrations of desired traits. The gaps, and potential funding programs, are:

1) Limited knowledge base (basic R&D) including gene discovery, regulation of novel proteins and enzymes to obtain economically-useful yields. Identification of new (long term target molecules/products, e. g., addition of fatty acids) that have never been evaluated. (This type of research could be supported via NRC and AAFC core programs, university-government-industry collaborations supported via NSERC, and Genome Canada funding.)

2) Delivery of previously-established and/or emerging knowledge/technology into commercially-relevant programs based on sustainability, renewable resources, environmental friendliness, and climate change. (This gap could be addressed CBIN, SDTC, BIOCAP, Climate Change Action Fund.)

3) Availability of new crop platform systems (outside of food crops) for production of industrial feedstocks (this also relates to gap 4 below). (This gap could be addressed through core AAFC and NRC programs, provincial funding projects (e.g. Sask Ag Development Fund), targeted industry projects, and special initiatives (e.g. future Molecular Farming initiatives supported via Industry Canada).)

4) Seamless regulatory system to facilitate industrial product commercialization. (This gap requires public research in collaboration with CFIA, Environment Canada, and possibly Health Canada. This currently represents a significant gap that requires comprehensive program funding.)

Economic and Environmental Aspects of Biomass Supply

Feedstock cost and environmental sustainability are two potential 'show stoppers' for a bio-based industry. That is, feedstock cost (including transportation), not energy cost, has generally been the biggest hurdle in the use of biomass residues for energy or other industrial uses. Feedstock cost curves are essential to explore the economic feasibility of potential operations.

In addition to knowing what can be grown, where, at what yield and cost, economic modeling is required to define which crops and what acreages make economic sense within the broader agricultural production system. System modeling is needed to answer questions such as: "what crops ?"; "how much could be grown?"; " what crops would be displaced?"; "what land and rotation constraints are there?"; "what incentives would be needed for farmers to grow them?"; and "where would you locate processing plants and how big would they be ?" (Freeze, 2006, pers comm.)

AAFC uses the Canadian Regional Agricultural Model (CRAM) as a policy tool to determine impacts on: farm income, land-use and production patterns, other commodity prices, and regional and national economic benefits. The model is currently being used to evaluate the economic feasibility of adopting a 5% biofuels target in Canada. Increased global demand for biofuels is believed to have the potential to improve farm income as the higher demand for bulk grain and oilseed crops are expected to increase commodity prices. (Flick, 2006, pers comm.) Also, when cellulose ethanol technology becomes economical, new demands will be created for residues and grasses. However, there are many factors that need to be reviewed including the role of co-products, land competition, impacts on stabilization payments, etc. to determine the net benefits and best path forward.

Finally, for bio-based operations to be sustainable for the long term and justify large capital expenditures, biomass production and harvesting must be carried out in an environmentally sound manner, e.g. to conserve genetic diversity, and be able to adapt to change. Long term environmental sustainability of biomass production systems is presently not well understood. Key gaps that need to be addressed include determining the long term impacts of existing and new management practices with respect to their impacts on soil moisture, fertility and nutrient supply.

As well, there are major gaps in understanding crop response to potential climate change and other global change elements including atmospheric pollution, changes in atmospheric chemistry (CO_2, NOx, O_3) and increased exposure to UV-b radiation. These aspects need to be evaluated in the context of developing mitigation and adaptive responses to potential changes in order to maintain sustainable biomass feedstocks.

2.4.2 Gaps Related to Biomass Conversion & Utilization Technologies

This section describes the key research needs related to the conversion and utilization technologies that transform biomass into energy, biofuels and industrial bioproducts. As illustrated by the overview in Figure 6, there are many possible biomass to energy conversion pathways. The non-energy co-products, that are integral to bio-based fuel and energy production, are not shown here but also need to be further developed.

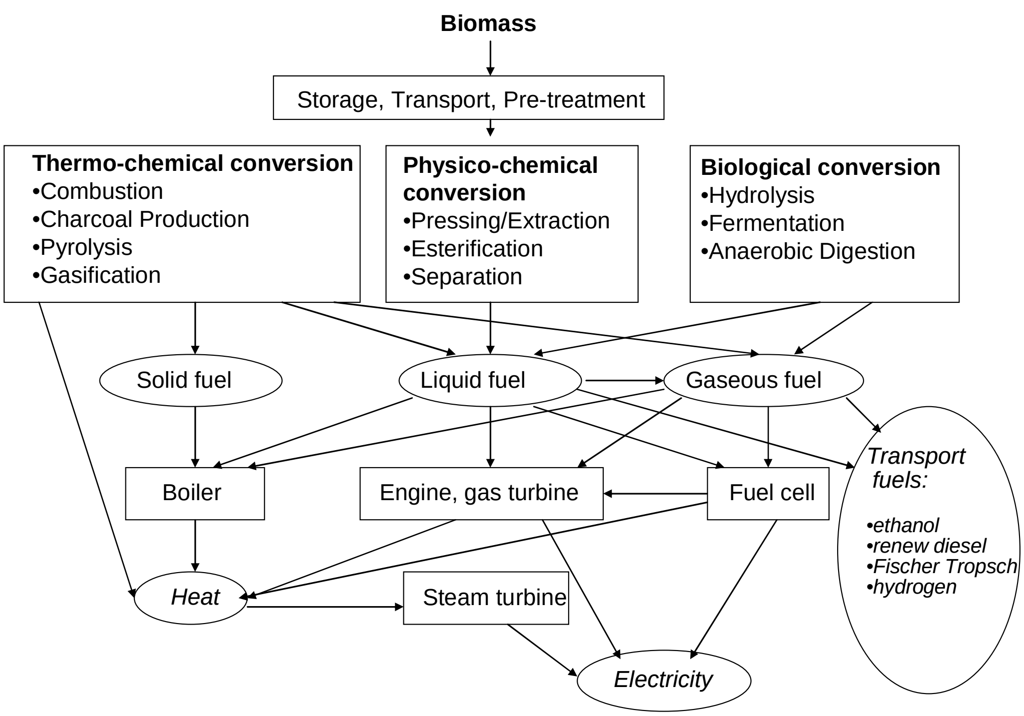

Figure 6. Biomass Fuel Chains (adapted from ICPET, 2004)

One of the primary objectives of biomass to energy or biofuels technology R&D is to close the economic gap or improve the cost competitiveness of bio-based energy and biofuels. This can be done in a variety of ways including: using less expensive feedstocks, e.g. residues and wastes; increasing conversion efficiencies; reducing production costs; and producing valuable co-products to offset costs.

The gaps are organized by feedstock (e.g. forest residues – combustion, gasification, pyrolysis, fermentation; agricultural crops and crop residues - etc.). The conversion of mixtures of biomass feedstock mixtures is not discussed at great length, however, conversion issues related to mixtures and feedstock variability will also require some R&D work.

Conversion of Forest Residues into Energy and Biofuels

Canada's forest products industry has direct access to large amounts of wood residue and has strong reasons (e.g. residue disposal issue, large purchaser of electrical energy, etc.) to find ways to cleanly and cost-effectively increase the conversion of wood residue to energy. The pulp and paper industry has high capital cost hogfuel and recovery boiler – steam turbine systems in place that convert biomass to heat and power. R&D is needed to improve the conversion efficiency and reduce the resulting air emissions to meet approved limits. Black liquor gasification, which would increase conversion efficiency and produce more electrical energy (vs. steam) is a technical option that needs exploration in the Canadian context. Also new ways to increase mill biomass use and decrease fossil fuel consumption such as in the lime kilns of Canada's 60 kraft pulp mills need to be found.

The solid wood industry encompasses approximately 900 operations that are comparatively much smaller energy users than the pulp and paper industry. With the requirement to shut down its beehive burners, this industry has been searching for ways to convert its residues into energy or other valuable uses. The demonstration of small, economical combined heat and power (CHP) units is key to addressing the use of excess wood residue. If successful, these units will offset GHG emissions from natural gas consumption and purchased power.

In addition, recent, unexpected events such as large scale fire and insect infestation, have generated large amounts of wood available. In BC, it is estimated that there is approximately 250 Mm^3 beetle-killed wood that needs to be harvested. The pressing need to find a uses for this material could spur testing and demonstration of close-to-commercial technologies.

Presented in Table 7 is a listing of the forest industry's technology gaps, the measures and the potential GHG reductions in 2010 and 2020-2025. The 2010 estimates were taken from the Forest Sector Issue Table work, while the 2020-2025 estimates were provided by John Burnett (NRCan, CETC).

Table 7. Forest Products Industry Technology Gaps and Reduction Potential

Measure	Potential GHG Reduction by 2010 (Mt CO_2e)	Potential GHG Reduction by 2020-2025 (Mt CO_2e)	Technology GAP to be overcome to reach potential
Optimize recovery boilers - 35 pulp and paper mills	0.39	0.60	Mills need tools (modeling, optimization strategies, test methods) to allow industry to get the highest efficiency out of existing equipment.
Modernize of hog fuel boilers - 35 pulp and paper (p&p) mills	0.48	0.60	To improve bioenergy utilization, mills need tools and methods for modifying operation and/or auxiliary equipment (modeling, optimization strategies, heat exchanger modifications, biomass drying and material handling systems) to get greatest efficiency out of existing equipment. Many mills are limited in their use of existing capacity by air emissions limits. Technologies to reduce air emissions (both add on technologies as well as changes to operation) will be tested and evaluated.
Increase wood waste cogeneration – 12 p&p mills (mills sell excess electricity)	2.46	3-5.0	To decrease the cost of biomass cogeneration it will be necessary to continue to develop the technologies mentioned above in order to maximize the conversion rate of biomass to useful energy (heat and power). As an option to increasing the amount of feedstock, bioenergy capacity can be increased by efficiently drying the biomass prior to combustion or gasification. Drying technologies will be tested and evaluated by p&p partners and technology providers. This increased cogeneration is expected to require additional quantities of biomass (i.e. residues currently left on the forest floor).
Black liquor integrated gasification and combined cycle cogeneration - 3 pulp emerging p&p mills (mills sell excess electricity)	0 (1.09 in Forest Table Report)	1.09	Canada cannot solve all of the gaps in this area on its own. In collaboration with the IEA, Canada is addressing areas where we have particular strengths or have specific needs. R&D will focus on gasifier modeling, fuel distribution, material testing and process verification.
Fuel-switching - lumber and panelboard mills	1.51	2.0	There is a need for a small economical combined Heat and Power (CHP) unit in the under 5 MWe size. It is planned to assist Canadian technology providers to demonstrate their technologies. These mills will also benefit from the improved material handling and drying technologies.
Increase number of hog fuel boilers - 12 p&p mills	1.33	2.5	Biomass will need to be transported from greater distances and improved methods will be required to recover biomass that is currently be left in the forest. Tools, methods and recovery technologies will be developed (or Canadianized) to allow investors to examine the impacts of biomass recovery for increased bioenergy plant capacity. (Bioenergy thermal plants need to be a minimum size to be economical.)
Biomass gasification to feed lime kilns - 10 p&p mills	0.8	1.2	Testing and demonstration is required to reduce the risk to a mill and to prove that pulp quality and mill operation will not be negatively impacted.
TOTAL	7	11-13	

Currently, the forest products industry is Canada's largest converter of biomass to energy, generating approximately 500 PJ per year. Interest has been expressed by utilities and other large industrial energy users, such as the steel industry, in testing the use of biomass for energy in co-firing and other types of applications.

Forest residues can also been converted into syngas and bio-oil, respectively, using smaller scale gasification and pyrolysis units. These promising technologies can convert both bark and whitewood into biogases and liquid biofuels that can be used for energy or be further converted into chemicals and other products. While these units are considered to be close to commercialization, several technology gaps still exist that prevent the gasification and pyrolysis systems from being adopted. Gasification systems need to be scaled up, and gas clean-up technologies need to be developed to enable the syngas to be used for energy or converted into chemicals. Pyrolysis oils are difficult to use ‘as is’ and require quality improvements to make them easier to burn.

Secondary conversion technologies that convert the products of biomass gasification and pyrolysis into biofuels, chemicals and energy need to be further developed. The global demand for biofuels could provide the ‘pull’ for this technology development. This R&D falls more within the domain of chemical and industrial engineering, and is less influenced by feedstock type than primary conversion technology development. Examples of this R&D are the development of methanol, Fischer Tropsch fuels, and hydrogen from syngas and pyrolysis bio-oil.

Whitewood (i.e. the non-bark portion of forest residues) can also be fermented into ethanol or converted into chemicals and other co-products. Most of Canada’s forest residues are from softwood species. In order to ferment these residues, efficient and cost-effective chemical pretreatment technologies are needed to separate the primary constituents with minimal degradation. Fermentation R&D is also required to increase efficiency and lower costs. This gap is somewhat smaller for softwoods, when compared with agricultural residues and hardwoods, as they produce fewer pentose sugars.

Hardwood residues can also be chemically pretreated and converted to ethanol via fermentation. However, the cost of the ethanol is high because the yields are still low. Fermentation systems need to be developed that can efficiently use pentose sugars. As almost one-third of the total sugars that can be obtained from agricultural and hardwood feedstocks are pentose sugars, overcoming this hurdle could potentially increase the overall ethanol yield by 30%.

Finally, Canada’s forest products industry has extensive knowledge of wood chemistry as it has been converting stemwood into pulp, paper, chemicals and a variety of solid wood products for over a century. Canadian industry is facing significant competition and financial challenges, and needs to move beyond the production of traditional commodities (e.g. pulp, paper, solid wood products). New bioenergy and biorefinery models could revitalize this important industry.

NRCan’s energy and forestry sectors, CETC and CFS, have been the federal leads in this area for many years, managing the R&D and representing Canada on several bio-related IEA task forces. Historically, R&D on forest biomass combustion, gasification, pyrolysis and fermentation to ethanol has received federal funding from PERD through POL 2.1.3 “Transportation Fuels from Renewable Energy Sources” and POL 4.2.3 “Forest and Forest Products Industry”. Both of these POLs are now part of PERD BEST POL 4.4.1.

Conversion of Agricultural Crops and Crop Residues into Energy, Biofuels and Industrial Bioproducts (Materials and Chemicals)

In a climate of growing international competition and declining commodity prices, Canada’s agriculture sector is looking to move beyond food and feed production to non-food products and energy that provide new sources of revenue for the sector. Agricultural crops, including crop residues, can be converted into energy, biofuels, materials and chemicals that have the potential to contribute positive energy and GHG benefits.

Energy: Heat and Power

Relative to wood residues, the conversion of agricultural crop residues into energy is only practiced to a very small extent in Canada. This is attributed to a number of factors including the low energy demand of the sector, (until recently) a climate of low energy prices, an abundance of wood residue that could more easily be converted to energy, the absence of an agricultural residue disposal issue (unlike wood residue or manure), and the high capital and maintenance costs of energy conversion systems.

On the technical side, the silica content of residues is problematic for combustion and gasification systems. Feedstock pretreatment (e.g. densification) needs to be improved for gasifier feeding. In terms of the R&D timeline, gasification of agricultural residues is expected to occur after progress has been made in the gasification of MSW and wood residue.

Recently, the combustion of agricultural residues as mixed feedstocks appears to be gaining interest in Canada. Applications such as utility co-firing or co-combustion with other biomass feedstocks to meet greenhouse energy needs are being examined.

Biofuel: Ethanol

There is a large market for fuel ethanol. Several countries including the US, EU (in particular, Germany, France and Spain), and Brazil have set renewable fuel targets. Over the last decade, the US demand for ethanol has grown dramatically as an MTBE substitute and fuel extender. The US renewable fuel content of gasoline is targeted to be 4.5% in 2012.

Both agricultural crops and residues can be converted into ethanol via a number of different routes. It is important to note that each process has its own energy balance, economics, and impacts, including GHG reductions. In Canada, ethanol is currently being produced from corn and wheat using both dry and wet mill processes. Ethanol production from grain is considered to be relatively mature technology, although further optimization would reduce the cost of ethanol. Over the next five years, new supply is expected to mainly be derived from cereal grains - wheat, triticale (possibly), barley, rye, and corn.

To a large extent, the cost of ethanol depends on feedstock cost. Relative to grain, cellulose is an abundant residue and lower cost feedstock. It could also be purpose grown in the form of high yielding, low input grasses, which would not compete with food needs. Considerable PERD investment has been made over a number of years to develop cost-effective processes for cellulose conversion. A breakthrough is needed to increase the yield and reduce the cost of cellulose conversion.

For both grain and cellulose, further research is needed to optimize the biorefinery processes and improve the efficiencies of the key technologies (e.g. pretreatment, fermentation, separation). The R&D gaps include:

- improved sugar to alcohol fermentation efficiencies;
- development of valuable co-products in the production of ethanol from small grain cereals: wheat, rye, barley;
- in the conversion of cellulose to ethanol, improved fermentation of pentose sugars to increase ethanol yield and reduce the cost of ethanol produced from cereal grain straw, grasses and short rotation forestry crops; and
- development of valuable uses for lignin generated during the production of ethanol from cellulose.

Biofuel: Renewable Diesel

Biodiesel[16] and other renewable diesel fuels can be produced from waste greases, animal fats and vegetable oils. As with ethanol, the cost of biodiesel is strongly influenced by the feedstock cost. Yellow grease and animal fat are lower cost feedstocks than vegetable oils but are limited in supply. It is estimated that approximately 300 to 400 million litres can be produced from this source, with the additional supply coming from vegetable oils. In the near term, oilseeds (e.g. low grade canola, mustard, soybean, etc.) are seen as the most likely feedstock for renewable diesel fuels. Here, feedstock supply does not appear to be a limitation unless the demand greatly increases (e.g. EU demand increases, higher targets are set in Canada).

As with ethanol, the R&D gaps relate to reducing the cost of biofuel production. Targeted areas include: increasing the amount of oil produced in the plant; improving extraction efficiency; developing more valuable co-products, and optimizing the oilseed biorefinery process.

Conversion of Byproducts of Biofuels Production

The economic viability of biofuels depends on their production costs, the values of the biofuels and their co-products, and the relative price of fossil fuels. The co-products generated during production, e.g. DDGS (from ethanol dry mills) and glycerol (from biodiesel production), currently have uses and markets. As biofuel production increases in North America, the supply of these co-products will also increase and flood the market if the demand for these materials remains the same. Therefore, alternate, high-value uses need to be found for the co-products of biofuel production, e.g. DDGS, glycerol, lignin, etc.

Biofuels R&D is funded through the PERD and Biodiesel Targeted Measures programs, and the GreenCrop Network.

Separation Technologies

Liquid-liquid and liquid-solid separations are inherent to most, if not all, all biorefinery operations. In the biotechnology industry, separations can constitute up to 90% of the processing costs and up to 70% of capital and operating costs in high-volume chemical applications. Also, they can be very energy intensive and involve the use of aggressive chemicals. (Mazza, 2004 pers comm.) Separation technologies that can efficiently

[16] Biodiesel is one type of renewable diesel fuel; biodiesel fuel is produced from the trans-esterification of triglycerides.

separate different streams in a biorefinery and extract valuable components from biorefinery streams are required. The critical streams requiring new or improved separation technologies need to be identified and developed. Clarification and focus on the most promising pathways will help this work.

Scientists with AAFC and NRC have considerable experience developing separation technologies for food and nutraceutical applications. This experience is naturally being extended into non-food applications. A-base and PERD funding have traditionally supported this work.

Fibre and Materials

Agricultural crops and residues can also be converted into non-energy industrial products that have positive energy and GHG benefits, and could potentially provide Canadian farmers with greater income. Relative to direct energy and biofuels applications, it is considerably more complex to assess the GHG benefits of bio-derived materials and chemicals.

In a review of ten bio threads for ADEME, it was found that agrimaterials (materials partly composed of agricultural fibres) had the highest non-renewable energy and GHG benefits. The benefits were mostly attributed to the high strength and low weight properties of natural fibres. Also, in some applications, the superior properties of natural fibres can translate into a lower fibre requirement for the same functionality. (ADEME, 2004)

The values in Table 3 show that there are currently at least 8 million tonnes of agricultural residue available in Canada. Flax and industrial hemp, both grown in this country, are well known for their strong fibres that can substitute cotton fibres in textiles, glass fibre reinforced plastics in automobile panelling elements, or chemical fibers in carpets, for example. The development of valuable uses for the flax straw (both fibre and shives) is an integral part of Canada's Flax 2015 strategy. This will require the development of a number of new technologies for straw retting, to separate the straw into different grades of fibre and shives, and to transform the fibre and shives into higher value end-products.

Similarly for industrial hemp, Canada lacks the expertise and technology for processing the non-seed portion of hemp. While Canada has the climate and supporting regulations to grow industrial hemp, the full value of industrial hemp will not be realized until the sector has the processing tools to convert its major components (fibre bark and hurd) into higher-value commercial products (e.g. high-quality fibres). The development of a viable, enzyme-based process for extracting clean fibres from the hemp plant is seen as the critical first step. As hemp has a complex structure, such enzyme R&D work could also benefit the retting of other fibres, such as flax. Hemp hurd, with its cellulose/ hemicellulose fibre and little lignin, can potentially converted into fermentable sugars, or non-wood pulp. Additional R&D is needed on hurd hydrolysis.

Intermediate Chemicals

Chemicals is the area where the CBIN Program interfaces with nutraceuticals (or functional foods) and plant-made pharmaceuticals. Hydraulic fluids, lubricants, solvents, surfactants, polylactic acid (PLA) are examples of the more well known industrial chemicals being produced from plants today.

Intermediate chemicals are defined as biomolecules that are involved in the production of a number of different chemical products that have a clearly defined end use and market. Intermediate chemicals can be produced directly inside the plant, where the plant itself serves as the biorefinery, and extracted. Alternatively plant constituents can be broken down into simpler molecules, e.g. sugars, that can then be further transformed into a variety of different chemicals.

There is almost no limit as to what chemicals biomass can be converted into. The challenge is to find the opportunities where biomass-derived chemicals have a comparative advantage, and for T&I funding, where they yield a GHG benefit.
In general, the gaps include increasing the yield of the chemical (or the precursor) in the feedstock, developing cost effective extraction or primary conversion processes, and optimizing secondary manufacturing where the chemical is transformed together with other products into the final end products.

Dr. Greg Penner, in his recommendations to the Province of Ontario, suggested that there are specific entry points in the chemical industry value chain where a bio-based alternative might be accepted. In particular, the production of acids from biomass (which already contains oxygen) would appear to make good economic sense. Penner recommended that research focus on the development of bio-based intermediate chemicals that are either available in the biomass or structurally similar to existing biological chemicals. (NeoBio, 2004)

Due to the vast number of different chemicals and manufacturing routes, it is not possible to automatically claim that a chemical produced from a biological feedstock has a better energy balance or greater GHG benefit than the same product derived from a petroleum feedstock. There are considerably fewer lifecycle studies to draw on for validation. However, the body of literature is growing and continuing to reveal cases where bio-derived materials have equal or better functionalities and good environmental performance.

Assuming that one has freedom to operate, the challenge here is to show that a bio-based chemical can be reliably produced at lower cost than a petroleum-based alternative with equal or better performance.

Conversion of Livestock Manure into Biogas

The treatment and conversion of livestock manure into valuable products is considered to be of great importance in Canada due to the large number of animals raised in confinement within relatively small geographic areas, and the odour, nuisance and groundwater impacts associated with manure management. Over 132 Mt of manure are produced in Canada each year, with the major livestock sources being: beef, dairy cattle and swine. Canada's GHG emissions from manure handling and storage (excluding paddock) were estimated to be 8.4 Mt CO_2e in 2004[17]. Currently very little of the biogas generated from manure handling and treatment is collected.

[17] Chang Liang, Environment Canada, Greenhouse Gas Division, May 2006.

Technologies such as farm scale and combined agricultural/municipal anaerobic digestion (AD), while proven in other parts of the world, have failed in Canada due to many hurdles unique to our climatic, environmental and economic conditions. Being cost-driven, the farming community cannot afford to take on this technical risk on its own.

Manure to energy R&D involves agriculture and energy departments, the agriculture community and technology developers. Work underway at NRCan, AAFC, and other departments has identified the following R&D gaps and issues that need to be addressed: GHG analyses; environmental lifecycle assessments; market analyses; social, financial and market barriers; resource assessment and management; bio security; and digestion of mixed feedstocks (e.g. animal manure and dead stock). This R&D should be well coordinated with the R&D supported by AAFC and the T&I Decentralized Energy Production program to avoid duplication.

Conversion of Municipal Solid Waste (MSW) into Biogas

Concern regarding the disposal of urban organic wastes such as MSW and effluent treatment sludges continues to grow. With the introduction of viable technologies, these wastes can be transformed from environmental liabilities into economic opportunities.

Most large landfills have or will soon have gas collection systems in place. Recent data show that gas capture and flaring have been increasing since 1997, however electricity production appears to have remained constant at approximately 80 to 85 MW. (Palmer, 2004 pers comm.) One of the next challenges is to capture and use gas collected from medium-sized landfills. This requires identification of the technical barriers for medium-sized operations, and development of new technologies or validation of existing technologies that can convert MSW into energy.

Municipal solid waste can also be gasified and converted into syngas. The current technology gaps include MSW pretreatment (i.e. sorting, preparation, drying, pelletizing); producing a syngas of stable quality; syngas cleaning, which is needed for heat and power generation or reforming; and resolving the unknowns that might arise with scale up. To sell MSW gasification to the public, a solid case needs to be made that this option is superior to landfilling. Information such as engineering calculations, environmental impacts and total costs are required.

Conversion of Other Waste Materials (Greases, Animal Fats) into Renewable Diesel

While the technologies exist to convert yellow grease and animal tallow into renewable diesel fuels (e.g. biodiesel, SuperCetane[18]), these technologies can still be improved to reduce the production cost and better product quality.

The potential for other low cost, lipid sources to serve as feedstocks for renewable diesel production needs to be explored. Trap greases and oils separated during wastewater treatment, for example, are significantly less expensive than those currently used for biodiesel production, but are usually very contaminated. Technologies need to be

[18] SuperCetane is a low sulphur, high cetane diesel blending stock obtained from catalytic hydrotreating of biomass-derived feedstocks containing triglycerides and fatty acids, such as yellow grease, animal tallow, vegetable oils, tall oil, etc.

developed that can cost-effectively convert various highly acidic, contaminated triglyceride feedstocks into renewable diesel fuels.

As stated earlier, higher value uses need to be found for glycerol, a byproduct of renewable diesel production.

Also, the cold flow properties of renewable diesel fuels need to be improved to increase their use in transportation applications. Improving cold flow properties will facilitate the adoption of these fuels by consumers during the coldest months of the year and in the coldest regions of Canada.

Much of this R&D is being funded by the Biodiesel Targeted Measure program. Ed Hogan (NRCan/CETC), leader of CBIN's 'Advanced Biomass Conversion and Utilization Technologies' theme, also manages the Biodiesel TM Program.

Demonstration and Product Testing

In addition to R&D related to primary conversion technologies, R&D is needed:

- to support demonstration, e.g. R&D to resolve the 'bugs' encountered during scale up; and
- for product utilization, e.g. to ensure safety and performance standards can be met; to determine net energy balances and life cycle impacts.

Demonstration of a new technology or process is a critical part of technological innovation. It characterizes the risks, usually at a larger scale of production, and thereby provides the confidence needed for further investment. Traditionally PERD funding has been used to leverage TEAM or SDTC projects, with the PERD funds supporting the R&D aspects of a demonstration projects.

Similarly, testing of new bioproducts is an important step in bringing them to market. In addition to being cost competitive, their performance, safety, unique attributes, energy balance, environmental footprint, etc. need to be validated.

For example, R&D is needed to test the use of biodiesel in stationary (heat and power) applications to ensure that it can be used safely and without technical problems. Specific needs include:

- air emissions testing of various biodiesel/petroleum diesel blends in different combustion systems (e.g. home furnaces, boilers, diesel engines), under both laboratory and field conditions;
- biodiesel fuel specification to address issues such as cold flow, blending, stability and storage; and
- protocols for the use of biodiesel.

Industrial biotechnology

While certain enzymes, such as cellulose, have received considerable attention in industrial applications, overall, industrial biotechnology is considered to be relatively unexploited. Case studies have shown that some applications can provide substantial energy savings. The report "Bioprocesses for Enhanced Industrial Efficiency" proposes applications for various Canadian industries, both biobased and non-biobased. From a

GHG impact perspective, petroleum refining and upgrading would appear to be logical areas to target for further investigation. As biotechnology is developing at a very rapid pace, the opportunities for industrial applications should be reviewed using the most up-to-date state of knowledge.

Industrial (white) biotechnology research has a strong base in Canadian universities, private firms as well as the various NRC Institutes and NRCan-CETC's laboratory in Devon, AB.

2.4.3 Gaps Related to Integration (Bio Threads and Clusters)

The development of a sustainable, more bio-based economy will result from the establishment of more bio-based operations. For this to occur, the 'biomass to energy and/or industrial bioproducts' value chains or threads[19] need to be developed for the feedstocks that are relevant to Canada, such as cereal grains, oilseeds, agricultural residues, wood fibre, manure and MSW. As with other manufacturing processes, different technologies or unit operations need to be combined and engineered to develop a biorefinery operation that is technically sound, economically viable and meets accepted environmental and social standards. The facility needs to be well integrated with its feedstock suppliers, the users of its products and the other participants in the value chain, as well as the community and local environment within which it resides.

Integration is key to optimizing economic returns and efficiencies, and enabling sustainability. Typically, industrial design and engineering activity tends to fall further along the innovation curve and is supported by other programs such as SDTC. As the industry is in a relatively early stage of development, R&D is needed to start designing the 'biomass to energy and/or industrial bioproduct' threads and biorefinery concepts. This is needed to reduce the unknowns and uncertainties regarding the establishment of a new industry, and to show how and where this industry will be woven into the current petroleum based economy. Also, current thinking in sustainable design proposes that a systems or life cycle approach should be adopted as early as possible in the design process.

The next generation biorefinery concepts will build on the experiences of the forest products and agriculture industries with respect to biomass production, harvesting, pre-processing and possibly even some of the conversion steps. These biorefinery concepts could be adaptations of existing operations or entirely new concepts. As whole crop utilization is desired, biomass processing should be designed to derive value from all parts of the harvested material. As such, the economics of the operation will be based on the entire suite of generated products and energy.

Within these different biorefineries, the intermediate steps may have many common elements. That is, although forestry, agriculture or MSW feedstocks and have differing chemical compositions and can be quite distinct in their unprocessed forms, they can be broken down into common constituent groups such as proteins, oils, starches, lignin, cellulose, hemicellulose, chemical extractives, etc. Some valuable components can be directly extracted, while others can be converted into different length sugars and fermented into a variety of intermediate chemicals of higher value. Alternatively biomass

[19] CBIN uses the term 'thread' to describe a biomass 'feedstock to end product' system. It has a similar meaning to value chain.

can undergo thermochemical conversion (e.g. gasification or pyrolysis) and be converted into gas or pyrolysis oil mixtures that can be used as intermediate feedstocks. It is at this stage of fuel and chemical production that biorefining starts to more closely resemble petroleum refining, and the two industries and their respective technologies start to merge.

It is important in biorefinery engineering not to neglect developments in agricultural and forestry biotechnology. Precision feedstock design for energy and industrial applications lies within the foreseeable future. Advances in these types of (green) biotechnologies are expected to shift more of the processing, especially initial feedstock decomposition, to the plant. For example, it is speculated that over the next decade, enzymes that can break down cellulose will be bred directly into the plant. Some type of trigger mechanism will start the decomposition activity after harvest. By the time the harvested material arrives at the processing facility, first stage processing will already have been completed. Such technologies could be truly transformative and substantially reduce energy consumption, GHG emissions and life cycle processing costs.

At the community level, clusters of industrial operations, commercial establishments, schools and hospitals can act together like a biorefinery. That is, the byproduct of one facility can be used by another unrelated facility that is usually in close proximity. Eco–industrial clusters offer the promise of more sustainable industrial development. The following data, information and tools are needed to design and assess cluster configurations:

- Practical tools for modeling the flow of biomass among a group of companies in a particular region and understanding of how such tools and model can be used to assess quantitatively the energy and GHG implications of different patterns of biomass conversion/utilization;
- Data on the relationship between reduced energy use and improved economic performance within a group of companies (e.g. data from case studies); and
- Information on what types of biomass conversion processes are compatible and can work in support of each other, e.g. is there a way to characterize and model thermal, biological and chemical processes into various types/groups so that e.g. the waste heat from one can be used to drive another or the byproducts of one readily provide the starting material for another?

2.4.4 Other (Non Technological) Gaps to Adoption

There are many policy, regulatory, economic, public acceptability, environmental and other non-technological barriers that could impede further development of successful R&D. Bringing new technologies, biofuels, industrial bioproducts and bioprocesses to market involves research, demonstration and testing, product/process development and commercialization, regulatory approval, supportive policy, financing, education and outreach.

The support of public policy makers is critical for the development of any new industry. It provides a signal to the private sector that the public sector is willing to take risks with this industry. This signal is slowly appearing in Canada, first emerging in the form of biofuel targets and now growing with support for the diversification of agriculture into non-food products.

Renewable energy policy, in particular, has been critical to the expansion of renewable fuels and biorefineries in many countries. As an interim measure, many countries 'kick start' the adoption of bioenergy and bioproducts by mandating biomass quotas, setting renewable portfolio standards or establishing procurement policies to help level the playing field. (Sims, 2002) Duffield and Collins (2006) provide a concise overview of US policy and legislation that has promoted the demand and production of renewable fuels in the US. This includes: federal energy legislation, environmental policies, state energy programs and farm policies. The Biomass Research and Development Act of 2000, the 2002 Farm Bill, and the Energy Policy Act of 2005 are three critical pieces of legislation that are supporting technology development, mandating a phase-in of renewable fuels, and providing loan guarantees and tax credits in the U.S.

As with any initiative, a solid case needs to be made to policy makers that development of the bio-based economy is in alignment with national priorities. The potential benefits (positive impacts) and risks need to be well articulated. The innovation needs to be driven by science, evidence, and a strong knowledge base, including competitive intelligence and comparative advantage. The proposed pathways, decision points and selection criteria need to be transparent. This is particularly important in such a complex area where many different biomass feedstocks could follow a variety of different routes to produce a myriad of products. Policy makers need to be convinced that there is a workable plan with achievable goals that is adequately resourced. The key challenges and possible approaches to these challenges must be well explained. If Canada wants to be a successful converter of biomass into energy, biofuels and bioproducts, i.e. more than a producer of biomass or primary products, then new technologies will have be commercialized. Measures need to be put in place so viable technologies are not lost in the infamous 'valley of death'. Finally, as new industries do not develop overnight, policy makers will have be to convinced to make a long term commitment.

The T&I R&D program allows a small percentage of the program funds to be allocated to work that facilitates or pulls successful R&D to the next stage of development. This type of work is also supported under the 'stewardship pillar' of the Canadian Biotechnology Strategy (CBS). Three important areas where effort and additional work are required are:

1) Communication and dissemination of R&D results;
2) Strategic work to identify Canada's most promising 'biomass to energy and/or industrial bioproducts' pathways in order to focus future investments; and
3) Sustainable development (SD) framework and assessment tools to demonstrate that these new bio-based technologies and industries are being designed within the context of sustainability.

Communication and Dissemination of R&D Results

To a large extent, CBIN's success depends on the ability of different disciplines and organizations (private and public) to collaborate, share resources and information in a timely manner. This is particularly important for the integration of biomass supply and conversion R&D which involves people of different disciplines, some of which do not have a history of working together. Effective internal communication between R&D projects and themes needs to be a priority for the program.

CBIN's ability to move successful technologies to the next stage of development requires awareness and good working relationships with the numerous government and non-government programs that support this area, and potential industry adopters. CBIN's R&D receptors include demonstration programs, provincial and municipal governments, industry (e.g. technology developers, adopters – industries, farms, municipalities), and policy makers. Networking to build and strengthen linkages between all levels of government, different industries and academia is considered to be one of CBIN's key roles. Also, potential receptors of the new knowledge and technologies, who are not already involved in specific CBIN R&D projects, need to be identified.

Strategic Work

Strategic work is needed to build the case for policy makers to support the bio-based economy. In particular, a clearer vision and depiction of the viable 'biomass to energy and product' pathways and actions that will enable the realization of this vision are required. At present, it is known that a wide diversity of feedstocks can be transformed using a range of different technologies into energy, biofuels, and a broad range of materials and chemicals. An expression that is often heard is: "Anything you can make out of hydrocarbons can be made out of carbohydrates." While this may be true theoretically, policy makers and investors need to be presented with a more focused picture of the bio-based sectors, its potential contributions and risks.

Some of the needs and information gaps that fall under strategic studies include:

- Coordination with other partners in the bio area, within and outside fed community;
- Description of promising bio pathways, including 'what technology is ready when'; pathway selection criteria; and prioritization;
- Indicators and targets to describe impacts and measure progress;
- Sound process modeling (e.g. US RBAEF model); and
- Economic modeling (e.g. AAFC CRAM model).

Also, the results of the technology R&D should feed into and support the future strategic direction of the program. For example, promising R&D should be supplemented by techno-economic and market assessments, IP studies, environmental impact assessments and analyses of the regulatory framework they are likely will encounter. Together, this information will help to identify the 'biomass to energy and product' pathways that should be further supported.

Sustainable Development (SD) Framework and Tools

To a large extent, the development of the bio-based economy is based on the premise that the use of renewable resources to derive society's products and services is more sustainable over the long term than the use of non-renewable resources. Sustainability is a concept that is difficult to define, not to mention measure. Frameworks are needed to evaluate sustainability, performance, utility and efficacy of bio-based products and processes, and compare these to conventional products and processes. Tools need to be developed and applied to verify that the pathways and technology choices are more sustainable and realize the expected energy and/or GHG reductions. Impact data are needed to evaluate the environmental, economic and social aspects of the different bio threads.

2.5 Greenhouse Gas Reduction Potential in 2025 (New Section, June 2006)

As the goal of the T&I Program is to develop long term GHG solutions, it follows that investment should target R&D that has the greatest potential for GHG reduction. Energy production and use – Canada's biggest GHG contributors - are important target areas that can be addressed by further development of bio-based energy systems, biofuels and industrial biotechnology. Bioenergy and biofuels can replace fossil fuel energy with CO_2 neutral energy, while industrial biotechnology has been shown to significantly reduce the energy consumption (and consequently GHG emissions) of certain industrial operations. The reuse of MSW and livestock manure for energy and other applications will reduce the country's GHG emission by avoiding the release of CH_4 from landfills and manure management systems to the atmosphere.

Obtaining a clearer picture of the 'GHG opportunity' landscape has been an important but challenging project for this program. This is because bio is an emerging area and there are fewer studies to drawn on. Secondly, the CBIN program supports a very broad range of bio projects, with both energy and non-energy end-uses. It is considerably more difficult to assess the GHG benefits of non-energy bioproducts.

At the program level, the two main sources of GHG impact information are:

1) A large, European review of non-renewable energy and environmental performance of 10 bio threads (agro-forest products/materials; ethanol; renewable diesel; bioenergy from forest biomass; bioenergy from agricultural biomass; biopolymers; surfactants; lubricants; solvents and chemical intermediates) carried out for ADEME (Agence de l'Environnement et de la Maitrise de l'Énergie); and

2) An independent review of the GHG reduction claims made by the T&I Biotechnology project proponents. (See Appendix C.)

The ADEME (2004) report found three threads to have medium to high benefits with respect to energy and GHG emissions - agro-forest products/materials, bioenergy from forest biomass, and bioenergy from agricultural biomass. This report identified the areas in the lifecycles of ten bio threads where further technology development could provide the greatest environmental benefits. http://www.cbin.gc.ca/Docs/english/ADEME-04-Info-Sheets.pdf

In 2005, Lynn Ross Energy Consulting and then Envirochem Services Inc. were hired to review the GHG reduction claims made by the T&I project proponents. Envirochem reviewed 12 of the approved T&I projects and proposed ways to maximize their GHG reduction potential. The study results led to the following conclusions:

- Not all bio-based projects will have a significant GHG benefit or positive energy balance.

- Greater GHG reductions and environmental benefits will be accrued if biomass residue and waste are used as feedstocks, versus dedicated crops. Residue and waste should be targeted first.

- High yield, low input crops will generate the most GHG benefits. Grasses and fast-growing plantations should be considered as priority dedicated feedstocks for bioenergy and biofuels production.

- The size of GHG reduction will depend on what biomass is converted into, and what form of energy or type of product it displaces, and the degree of market penetration.

- Liquid biofuels have a significant, but not a large GHG reduction potential from a national perspective. This is because Canada's current biofuel targets represent ~ 2% of the country's gasoline and diesel fuel demand. However biofuels are seen as an important interim GHG solution given that there are no other alternative fuels currently available to meet the growing transportation energy demand. Also, biofuel production is expected to lay the groundwork for the development of the biorefineries and bio-based chemicals.

- Industrial biotechnology applied to big energy consumers (or high volume producers), such as fossil fuel energy production, has the potential for large GHG reduction.

- Although it is more difficult to assess the GHG benefits of non-energy bioproducts, bio-based materials and chemicals should not be overlooked as they can have substantial indirect GHG benefits. For example, the superior strength to weight ratio of natural fibres, reduces the weight and, consequently the transport-related emissions, of products in which they are used.

It is conservatively estimated that if the R&D is successful and the new technologies and processes are adopted, GHG emissions could be reduced by at least 30 Mt CO_2e in 2025. How much GHG reduction is attributable to R&D, or more specifically T&I investment, is difficult to answer.

Shown in Table 8 are the potential contributions that the PERD and T&I investments could make to the energy production, energy use, agriculture and waste sectors[20]. These reductions are evaluated from the 'point of end use' perspective. To determine the total net impact, the GHG emissions should be assessed over the entire lifecycle.

[20] These are the IPCC sectors that all countries are required to use in their national GHG inventory.

Table 8. GHG Emission Reduction Attributed to the PERD and T&I Investments

Sector Realizing the GHG Reduction	Estimated 'Point of End Use' Reduction in 2025 ($Mt\ CO_2e$)	Type of Bio Project
Energy Production & Use/ Consumption Sectors		
- Steel industry	10 Mt *	Industrial biotechnology reducing steel consumption
- Pulp and Paper industry (reduction shared with Utilities)	11 - 13 Mt	Improved boiler combustion efficiency; New cycles for small scale heat and power; mostly PERD funded
- Agriculture Industry	5 Mt	Energy for greenhouses
- Misc. energy production & stationary consumption (residential, commercial, industrial)	5 Mt	Biomass to heat and power; Biofuels; Industrial biotechnology substitution of conv process
- Mobile consumption (transport)	15 Mt	Biofuels (ethanol, renewable diesel) Light weight materials Industrial biotechnology
Waste & Agriculture Sectors	16 Mt *	Avoided emissions MSW – organics; manure; MSW – plastics

* In the absence of guidelines, 50% of the reduction of the T&I Integrated Applications projects are claimed by T&I Biotechnology.

3. RECOMMENDED ACTIONS: CBIN R&D PROGRAM

An interdepartmental federal Executive Committee[21], known as the CBIN ExCo, has developed and manages the CBIN Applied R&D Program. CBIN's mission is to harness the potential for bio-resources, bio-based energy, bioprocesses and bioproducts to help Canadian industry meet efficiency, sustainability and climate change challenges.

The CBIN ExCo allocates and manages the funds of two separate R&D programs PERD BEST POL 4.4.1[22] and T&I Biotechnology R&D. The combined program responds directly to the Strategic Directions and Objectives articulated in the S&T Companion Document, and the T&I Criteria.

The PERD BEST component of CBIN is guided by:

> Strategic Intent 4: Reduce the overall energy intensity of Canada's industrial sectors through efficient processes and systems, and bioenergy systems, consequently reducing GHG emissions and improving productivity and providing Canadian companies with potential economic opportunities.
>
> Strategic Direction 4: Provide the S&T for the strategic and coherent development and transformation of biological resources into energy supply, efficient bioprocesses and energy related biomaterials.

The Climate Change Technology & Innovation Initiative (T&I) is part of the Climate Change Plan for Canada (2003). Its objective is "to accelerate R&D in longer-term technologies to achieve GHG reductions. Activities will be based on a strategic analysis of current state and needs of climate change file in order to better design and deliver the S&T". All T&I projects are required to have partnerships, leveraged funds, quantified GHG impacts (for 2025), and dissemination strategies.

Shown in Table 9 are the funds that were allocated to the PERD BEST POL and T&I Biotechnology R&D initiatives in 2003. This funding is leveraged by A-base funding, industry partners, and from other federal and provincial programs.

Table 9. CBIN R&D Program Funds (million $)

Fiscal Year	PERD BEST (POL 4.4.1)	T&I Biotechnology[23]
04/05	2.7	1
05/06	2.7	5
06/07	2.7	6
07/08	2.7	8

[21] See Appendix A for list of CBIN ExCo members.
[22] See Appendix B for description of PERD BEST POL.
[23] The total funds assigned to T&I Biotechnology R&D were $20 million over 4 years; CBIN has requested that the funds be reprofiled in years 3 to 5 to support key multi-year projects.

The CBIN Program was started in 2003 by Mark Douglas, A/S&T Director, NRCan, CETC Ottawa. Representatives from 6 federal departments/sectors: Agriculture and Agri-Food Canada, Environment Canada, Industry Canada, National Research Council, Natural Resources Canada – CETC, CFS and OERD, set out the following goals:

- To build a national network for collaborative research and development in the areas of biomass supply, bioenergy, bioproducts and bioprocessing
- To help Canadian industry meet efficiency, sustainability and climate change challenges
- To deliver new concepts, new technologies and novel integrated approaches to feed downstream components of the innovation chain such as TEAM, IRAP, APF Science & Innovation and SDTC
- To maintain a balanced risk/reward portfolio of R&D activities
- To influence development of effective policies, incentives, standards and codes
- To build public acceptance for bio-based industries, energy and products

The CBIN R&D Program that was developed is quite broad in scope, covering the conversion of forest, agriculture, and urban biomass feedstocks into energy, biofuels and industrial bioproducts using numerous different technologies. Applications of bioprocessing and industrial biotechnology are also supported by CBIN. The Program's objectives are to support collaborative Applied R&D involving industry, government, and university partners that will:

- characterize (physically, chemically, biologically) existing and future biomass feedstocks;
- develop modelling and GIS capability that will result in a geographically-specific, evergreen inventory of biomass supply from agriculture and forestry;
- improve biomass feedstock availability through the development of cost-effective production, harvesting, transport, storage and pre-processing technologies;
- develop technologies and processes that can cost-effectively convert biomass into energy and energy carriers (liquid biofuels and biogases);
- develop the technologies and processes that can produce value-added co-products from biofuels production and non-energy products that have energy and GHG benefits;
- develop biocatalysts and bioprocesses that can reduce the energy requirements and environmental footprint of manufacturing processes;
- start the design of new biorefineries, from the point of feedstock supply through conversion technologies, to produce a suite of bio-based energy and products;
- understand how to develop and assess regionally clustered enterprises that could achieve major energy, materials and cost savings (beyond what the enterprises could achieve individually);
- identify the most promising biomass to 'energy and industrial bioproducts' pathways for Canada;
- develop the tools and carry out assessments to verify that the pathways and technology choices are sustainable and realize the claimed energy and GHG consumption patterns;
- provide technical support for the development of sound government policies; and
- communicate the results of the program to downstream receptors (e.g. other government programs and policy departments, technology developers, industry), universities and the broader scientific community.

Beyond 2008: Next Ten Years

To establish a vibrant, more bio-based economy in Canada by 2025, additional sources of public and private funding will be needed to support strategic R&D, and demonstration and commercialization of new technologies and processes. The combined PERD BEST and T&I Biotechnology investments have served as an essential stepping stone to continue the development of biomass supply, bioenergy and biofuels production, and initiate new R&D in the industrial bioproducts and bioprocesses areas.

New sources of funding are required beyond 2008. A minimum 10 year commitment should be made to the sector's development if Canada wants to seriously develop new bio-based industries, and not loose its competitive position. As indicated in the report "Towards a Canadian R&D Strategy for Bioproducts and Bioprocesses", the required investments could be substantially greater than current levels. The report authors, Science-Metrix, proposed three financial scenarios for the period 2005 to 2009: 1) catching up with the US: $425 million; 2) developing Canada's leadership: $650 million; and 3) defining bioproducts as a top national priority: $850 million.

Canada's investments will have to be strategic. As noted in the excerpt from AAFC's Science & Innovation Strategy below, the right investments need to be made and research will need to focus on the right priorities at the right time. For this to occur, greater clarity is needed on the most promising 'biomass to energy and product' paths.

Agriculture and Agri-Food Canada Science & Innovation Strategy (May 2006)

"New knowledge needs to fuel Canadian innovation that, in turn, affects every aspect of food and non-food production, changing the way Canadians grow, process, preserve, transport, distribute, and use the products derived from agriculture. In other words, new discoveries and their application are crucial to ensuring Canadian farmers and the Canadian public benefit from Canada's natural advantage, i.e. its ability to produce food and an ever-increasing range of non-food products from the land. Examples of these new applications include new bio-materials, bio-medical and bio-health products, bio-fuels, bio-energy, bio-chemicals, and bio-pharmaceuticals.

While there is a good foundation and capacity for innovation in Canada, our ability to capture the benefits of our science investments will require renewed thinking about how we work together, how we optimize the use of our scientific resources and how we manage our investments in science and technology to ensure returns across the innovation value chain.

To continue on this path, we need to focus on new priorities, new challenges and new opportunities, and to build new critical mass and to develop new partnerships among Canada's university, government and industrial sectors to enhance returns on investments in science and innovation. Innovation efforts must also be supported by the development of a coordinated and enabling public policy and regulatory framework that keeps pace with the advances in science and technology.

As one of the most significant contributors to agricultural science and technology research in Canada, Agriculture and Agri-Food Canada (AAFC) is committed to ensuring that the right investments are made in science and innovation, and that research focuses on the right priorities at the right time, for the benefit of Canada's agriculture and agri-food sector and all Canadians."

3.1 Description of the CBIN Program

The CBIN program has been divided into four areas of R&D activity, shown in Figure 7, and program administration. Each activity has been subdivided into themes, and each theme has been appointed a federal government lead who oversees and reports on the projects within a theme. As all projects require partnerships, the project teams include representatives from industry, university and other organizations. Projects are led by a federal government expert in the specific area of study.

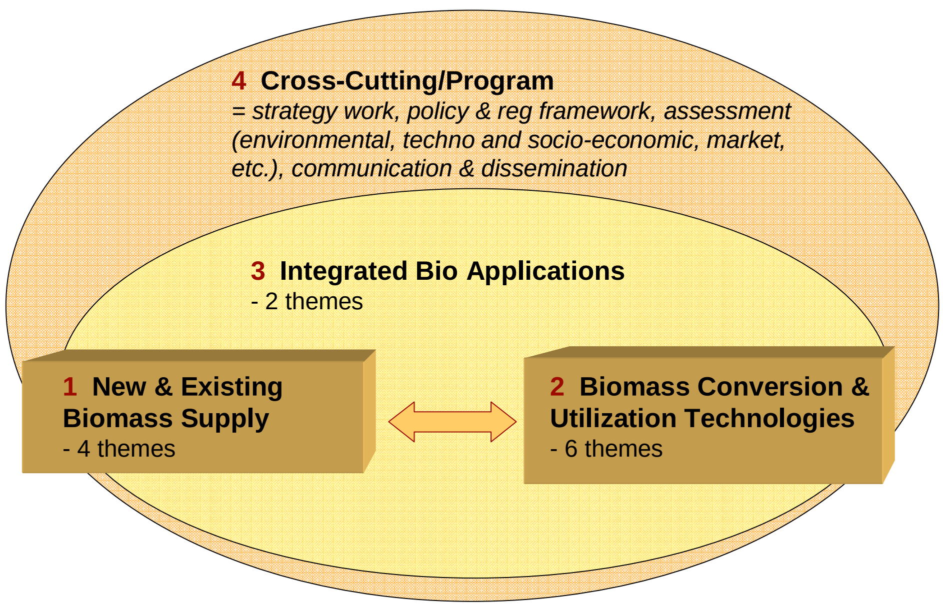

Figure 7. Relationship between CBIN's Four Activities

A general description of each area of activity follows. Further details are contained in the CBIN Action Plan.

Activity (1) Existing and New Biomass Supply

This activity aims to improve the availability of Canada's two largest sources of biomass supply from forestry and agriculture operations. R&D in this area will generate information that is vital for planning, costing and siting of bioenergy, bioproduct or biorefinery operations. This will include detailed inventory information, improved understanding of purpose-grown woody biomass production systems (e.g. fast-growing plantations, agroforestry) and the development of technologies and processes that will generate cost-effective and sustainable supplies of agriculture and forest biomass. It also includes the development of new oilseeds that can produce high concentrations of specialized fatty acids for industrial applications.

This activity supports projects in the following theme areas:

- Detailed Agriculture and Forestry Biomass Inventory
- Purpose-Grown Woody Biomass Production (forestry and agroforestry)
- Technologies for Harvesting, Preparation, Storage and Transportation
- New and Improved Biomass (Fatty Acid) Feedstocks

Activity (2) Biomass Conversion and Utilization Technologies

This activity supports R&D that advances the development of different thermochemical, biochemical and physico-chemical unit operations that are involved in the efficient conversion of different biomass feedstocks into energy (heat and electricity), liquid biofuels, biogases and chemical and material products. It supports projects in the following theme areas:

- Biomass Conversion to Heat and Power (bioenergy)
- Conversion of Waste to Bio-based Gases
- Key Separation and Conversion Technologies for Bio-based Products
- Biocatalysis for Industrial Applications
- Advanced Biomass Conversion & Utilization Technologies
- Renewable diesel fuels for Transportation Applications[24]

The R&D investment is intended to lead to the generation of new knowledge, technologies and partnerships that will increase the production of bioenergy and biofuels from forestry, agricultural and municipal waste feedstocks. Improving the efficiency and economic sustainability of production is one of the key objectives of this R&D as it has been a main barrier to greater adoption of renewable energy in Canada. This can be done directly through improvements in conversion efficiency or new conversion processes, and/or indirectly, through the development of valuable co-products and biorefinery systems.

[24] This theme is supported by funds from the Biodiesel Targeted Measure program.

This R&D will include such work as:

- improvement of combustion efficiency and reduction in criteria air emissions of existing wood residue fired boilers (pulp and paper mills);
- development and demonstration of new cycles for small scale biomass heat and power (for solid wood industry);
- development of know-how and tools to convert MSW into energy;
- improvement of anaerobic waste to energy technologies for on-farm, municipal and industrial applications;
- development of pretreatment processes to overcome the recalcitrance of softwood residues in ethanol production;
- improvement of cellulase enzyme and fermentation efficiencies for ethanol production;
- development of extraction; fractionation and separation processes to recover value-added products from biomass feedstocks (crops, residues and waste streams);
- improvement of pectinase enzyme efficiency to reduce the cost of hemp and flax fibre separation;
- improvement of gasification and pyrolysis technologies applied to forest residues and MSW (to advance these technologies to commercialization stage);
- testing of pyrolysis bio-oil and renewable diesel fuel in stationary applications,
- improvement of existing biodiesel production systems and development of new processes that convert low quality feedstocks to renewable diesel fuels;
- development of ways to produce alkyl levulinates, SuperCetane and valuable co-products from glycerol
- enhancement of product characteristics of renewable diesels so they can be used in Canadian winter conditions.

Activity (3) Integrated Bio Applications

Activity 3 takes a broader, integrated view of the entire 'feedstock to product' system. It supports R&D the development of new biorefinery concepts for Canada from the point of feedstock supply harvest through energy, biofuel and bioproduct manufacturing. This activity supports projects in two themes:

- Integrated Biorefining
- Regional Clusters

The current CBIN program is funding the development of biorefinery concepts for the following feedstocks:

Oilseeds

- production of biodiesel and valuable co-products
- production of erucic and linolenic fatty acids (industrial applications)

Cereals/Starch

- production of ethanol and co-products from wheat
- production of thermoplastic starch and biopolymers

Forest Fibre

- development of short rotation plantations and agroforestry systems for bioenergy production
- conceptual development of the new pulp and paper biorefinery

Agricultural Fibres and Residues

- harvest and conversion of agricultural residues into bioenergy and bioproducts
- conversion of flax straw into biomaterials, biochemicals and bioenergy

Mixed Biomass Feedstock

- conversion of mixed biomass residues into bioenergy for greenhouse industry applications

Note: The conversion of livestock manure and MSW feedstocks is covered under Activity 2.

Activity 3 also supports the study of eco-industrial clusters to determine how bio-based operations can be best integrated with other facilities in a community.

Activity (4) Cross-Cutting Issues

The primary aim of Activity 4 is to assist the most promising technologies and processes to advance along the innovation curve.

This activity deals with overarching or cross-cutting subjects such as strategy development, analysis and assessment, policy support, and communication and dissemination. Its objectives include:

1) alignment with the strategies and policies of other federal bioenergy, bioproduct and industrial biotechnology initiatives;
2) identification of the most promising 'biomass to energy and industrial product' pathways for Canadian circumstances;
3) development and use of environmental, economic and sustainable development (SD) assessment tools to verify that the pathways and technology choices are sustainable and realize the expected energy and GHG reduction;
4) identification of non-technological barriers and provision of technical support for the development of sound government policies;
5) facilitate internal communication between projects and themes; and
6) dissemination of the program's project results to industry, other government programs, and appropriate receptors to move the technologies to the next stage of development.

3.2 Program Design 2004/05

The Program's structure, of 4 areas of activity and 13 themes, was set up prior to the start of the first fiscal year of the CBIN program. In April 2004, the CBIN ExCo selected the projects for the each theme for funding in fiscal 2004/05.

Shown in Table 10 is the distribution of PERD BEST and T&I Biotechnology funds. In 2004//05, the PERD funds were almost three times those of T&I, so the program design was heavily influenced by PERD. As a general rule, projects that were continuing or had resulted from previous PERD R&D, were allocated PERD funds. New projects were allocated T&I funds. A few small exceptions were made for the total funds to balance.

Table 10. Distribution of 04/05 R&D Funds by Program and Activity (as of Sept 3, 2004)

Program Activity	PERD BEST		T&I Biotechnology	
Evaluation of Existing and New Biomass Supply	575 k	21%		
Biomass Conversion and Utilization Technologies	1,933 k	71%	828 k	83%
Integrated Bio Applications (e.g. biorefineries, clusters)	75 k	3%		
Cross-Cutting Issues (strategy, assessment, dissemination)	125 k	5%		
Admin & Coordination			172 k	17%
TOTAL	2,708 k		1,000 k	

Seventy-five percent of the R&D funds were allocated to projects in 'Activity 2: Biomass Conversion and Utilization Technologies'. This was due to the historical attribution of PERD, and the decision to focus T&I Biotechnology funds in this area for the first year. The T&I funding decision responded to the guidance received from the T&I DG Steering Committee in May 2004. In summary, Activity 2 was selected for three reasons:

1) It best met the core T&I objective of GHG impact. The ProGrid analyses carried out on the individual Program themes, showed that the the R&D in this area had the largest potential for quantifiable GHG reductions (> 5 Mt CO_2e) in 2025. (See Appendix E.)

2) When compared with the other R&D activities, Activity 2 appeared to be more relevant to near term government and industry objectives, such as developing waste management solutions for MSW and manure and achieving national biofuel targets set for 2010.

3) It had the potential for the most leverage, one of the mandatory T&I criteria. Historically, federal R&D in this area has been leveraged by at least 50% with industry funds.

3.3 Program Design 2005/06

The 2005/06 allocation of R&D funds, by activity, is presented in Table 11. The total PERD BEST funds increased by a small amount as several projects were transferred from another POL. The departmental distribution of PERD funds was kept the same as the previous year. In 05/06, the T&I Biotechnology funds rose substantially this year to 5.5 million, a five fold increase over the previous year.

Table 11. Distribution of 05/06 R&D Funds by Program and Activity (updated Nov 7, 2005)

Program Activity	PERD BEST		T&I Biotechnology	
Evaluation of Existing and New Biomass Supply	546 k	19%	276 k	5%
Biomass Conversion and Utilization Technologies	2,043 k	71%	2,055 k	37%
Integrated Bio Applications (e.g. biorefineries, clusters)	75 k	3%	2,383 k	43%
Cross-Cutting Issues (strategy, assessment, dissemination)	125 k	4%	155 k	3%
Admin & Coordination	74 k	3%	631 k[25]	11%
TOTAL	2,863 k		5,500 k	

Note: For leverage information, see 2005/06 Annual Report.

Forty-nine percent of the funds were allocated to Activity 2, and twenty-nine percent were allocated to integrated biorefinery projects in Activity 3. This decision was based on TIMS' recommendation that T&I investments take the form of fewer, larger investments. Also, TIMS suggested that investments could take the form of feedstock to energy and product threads that would contribute to realizing the program's vision to 2025.

Using an RFP process, requests were made for smaller, stand alone R&D projects and thread projects. Supporting thread work allowed for the inclusion of biomass supply R&D and other non-energy R&D where the GHG impacts are more difficult to demonstrate. The T&I funds were reprofiled, and seven large, three-year thread projects were approved.

3.4 Integration with Other T&I Programs

Some of the R&D projects carried out under Activity 2: 'Biomass Conversion and Utilization Technologies' are linked to work being carried out in other T&I programs.

CBIN Theme: Conversion of Waste to Biobased Gases (J. Barclay, NRCan)

Anaerobic digestion R&D projects in this theme link to T&I Decentralized Energy Production (users of biogas) projects. R&D under the T&I Biotechnology program focuses on biogas generation (i.e. digester/landfill design, microbial activity, etc.) and complements the R&D being done under T&I DEP, which focuses on biogas utilization (biogas cleanup, combustion, etc.).

Both programs partner with anaerobic digestion demonstration work underway by AAFC. An interdepartmental working group monitors and directs the work to avoid duplication.

[25] Includes loan repayment

Also, three projects are being co-funded as T&I Integrated Applications with other T&I programs and TIMS. (Note: In all three cases, the other programs, not T&I Biotechnology, are responsible for project reporting.)

CBIN Theme: Advanced Biomass Conversion & Utilization Technologies

> The "Canadian Steel Breakthrough Programme – Biofuels for Canadian Steelmakers" project is co-funded with T&I Industry (HEIST) and TIMS.

CBIN Theme: Biocatalysis for Industrial Applications

> The "Petroleum Bio-upgrading for Refinery Corrosion" project is co-funded with T&I Bitumen and Heavy Oil and TIMS.

CBIN Theme: Integrated Biorefining

> The "Optimizing the Carbon Value Chain in the Pulp and Paper Process Biorefinery" project is co-funded with T&I Industry (HEIST) and TIMS.

3.5 Innovation Curve

The projects that are supported by PERD BEST and T&I Biotechnology funds fall under the category of applied research. As illustrated in a general way in Figure 8, some of the themes are positioned earlier on the innovation curve and support projects making the transition from more fundamental to applied research. Other themes, in particular those that had been previously funded by PERD, include demonstration projects. As PERD funds can be leveraged[26] with TEAM funds, PERD BEST projects include first-of-a-kind pilot or prototype testing.

The following text provides examples of where some of the CBIN-supported R&D lies on the innovation curve, and how far away the technology might be from commercialization or implementation.

Production of new industrial crops and conversion into biochemicals

The development and full scale production of new industrial crops can take 10 to 20 years. The R&D supported by CBIN is here will help identify and develop end-uses and the respective conversion technologies that could be applied to these new biomass feedstocks. Full scale production will depend on an effective regulatory system being in place.

Status of agricultural residue harvesting

Harvest systems for agricultural residues exist and are utilized by existing straw-based industries. Improvements that enhance quality and reduce losses within the harvest system are expected to require 4 years of development. They should be adopted rapidly by the industry once proven. It is estimated that by 2010 there will be commercial equipment available to reduce losses by 25% and improve harvest residue quality.

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[26] T&I funds can only be leveraged with TEAM funds with the approval of the T&I DG Committee. This is done on a case by case basis.

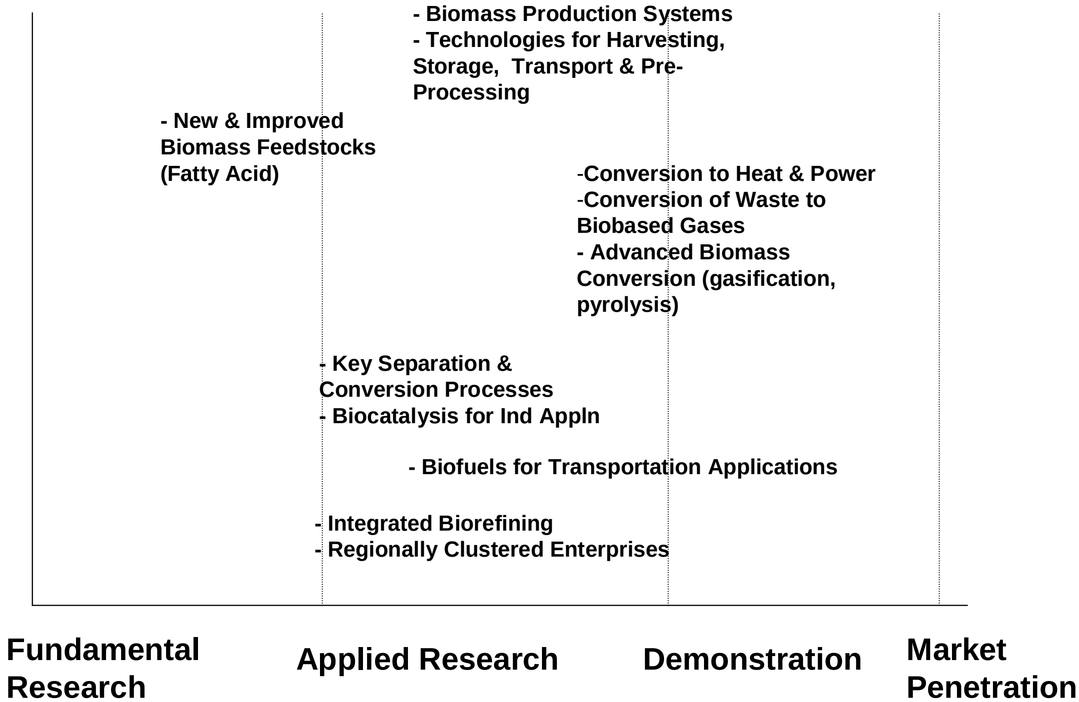

Figure 8. Positioning of CBIN Program Themes Along the Innovation Curve

Status of conversion of flax straw into biomaterials, biochemicals and bioenergy

The interim results of the flax straw R&D, funded by T&I, will be used to design a regional processing plant sometime between 2006 and 2008. By the end of 2007/08, it is expected that the proof of concept will have been completed and the first generation of technologies will have been developed. Successful R&D could be ready for pilot testing and larger scale demonstration.

Status of increased conversion of forest biomass into heat and power

The R&D work for large scale biomass to heat and power systems tends to focus on incremental increases in system efficiency and air emission reduction for existing systems at Canadian pulp and paper mills. For small scale biomass power there is a need for a completely new system or cycle to meet the needs of the smaller regionalized biomass resources - as in the case for the over 900 sawmills in Canada. It is expected that Canadian developers will commercialize at least 2 technologies by 2008 and 10 small scale systems could be installed by 2010.

Status of anaerobic digestion of livestock manure

It is envisioned that some of the more applied R&D, such as the enhancement of European AD technology to become viable under the domestic environment, will be adopted by industry in the short term. It is anticipated that Canada's growing environmental industry will have the capacity to implement these technologies once they are market ready. By the year 2010, it is anticipated that anaerobic digestion will become the manure treatment of choice for 60% of all new animal facility construction, and will be retrofitted on 25% of existing facilities.

Status of gasification and pyrolysis technologies

The gasification and pyrolysis R&D work is considered to be close to commercialization. It is possible that, by 2010, there will be a viable pyrolysis industry with markets for co-products, and there will be at least 4 different ways of converting pyrolysis oils into heat and power. By this time, commercial gasification systems could exist for MSW and wood residues.

Status of biodiesel development

Biodiesel standards for B1 – B5 were approved by the Canadian General Standards Board (CGSB) in 2005, and the standard for B6 – B20 should soon be accepted. The technologies for manufacturing biodiesel will include other coproduct developments such that by the year 2010 the biodiesel industry will derive less than 60% of the economic value from the biodiesel component and Canada will have met its target of 500 million litres/yr of biodiesel production from vegetable and plant oils and animal fats.

Status of cellulosic ethanol

Development of new technologies for the conversion of cellulosic biomass has been supported under the PERD program for many years. It is anticipated that the first commercial plant, capable of producing 150 million litres/year of ethanol from wheat straw, will be operational in Western Canada or the US before 2010.

Status of Canada's biorefining industry

The status of today's biorefining industry is analogous to the beginning of the fossil fuel refining and petro-chemical industry in the early 20th century. The demand for alternative fuel has been an important driver in the development of biorefineries. Biorefineries exist for corn-derived ethanol and are being developed for biodiesel. Concepts exist for numerous other biorefineries. Over time, emphasis is expected to shift from the production of biofuels to higher value non-energy bioproducts.

4. CRITERIA: RELEVANCE, RISK AND IMPACTS

All of the activities carried out in the combined CBIN R&D Program are relevant to the T&I's strategic goals and Canadian circumstances. The program was designed to have low and manageable delivery and adoption risks, and provide significant GHG emission reductions, as well as other environmental and socio-economic benefits.

The following section is a summary for the CBIN R&D Program as a whole that was prepared in May 2004. It is based on the ProGrid analyses completed by the Program's theme leaders. Two sections have been updated in the 2006 revision of the Strategic Plan, namely Delivery Risk and GHG Emission Reduction.

4.1 Relevance of Proposed R&D

Relevance to T&I Strategic Goals

The proposed R&D program is expected to substantially contribute to T&I's overall objective of reducing GHG emissions over the long term because it will lead to new technologies that produce cleaner, CO_2-neutral forms of energy (heat, power, biofuels, bio-based gases); and modify existing and produce new manufacturing processes to consume less energy and use more bio-based feedstocks (substituting petroleum-based feedstocks and fossil fuels).

This program will contribute to T&I's strategic goals in the following ways:

"goal (1) to accelerate development of cost-effective mitigation and transformative technologies for reducing GHG emissions" by conducting R&D on existing and new technologies that efficiently and cost-effectively convert different forms of biomass (incl. forest residues, MSW, manure, agricultural residues) into CO_2-neutral energy (heat and power), biofuels (e.g. ethanol, biodiesel), gas (e.g. biogas, syngas, hydrogen) and other valuable co-products. Technologies include: thermal, thermochemical (e.g. fast pyrolysis, gasification) and biochemical (e.g. anaerobic digestion, fermentation, biocatalysis using enzymes) and physical-chemical (e.g. separation technologies).

"goal (2) to develop technical knowledge to aid the development of policies, codes, standards and regulations to facilitate the uptake and deployment of the technologies" by working on sector strategy development and regulatory assessment framework that should identify gaps in policies, regulations, standards and codes.

"goal (3) to establish new and strengthened alliances and partnerships to foster the implementation and acceptance of the technologies". Through the program's interdepartmental ExCo, multi-stakeholder External Advisory Panel and outreach activities, close ties with the downstream programs and industry developers will be established to promote further development, financing and adoption of new feedstocks, technologies, processes and products.

"goal (4) to expand the knowledge base upon which to build the intellectual foundation for long-term technological advances" by providing information on: (1) the location, form, quality and availability of Canada's biomass supply on a regional basis; (2) the technical feasibility of technologies and biorefinery processes that will convert different types of biomass into energy, biofuels and non-energy products; (3) new applications of industrial biotechnology; and (4) the 'biomass feedstock to energy and industrial product' pathways that make the most sense for Canada to develop.

"goal (5) to increase awareness of the technologies among current and potential receptors, and increase market opportunities"; As much as possible, project teams will be encouraged to include potential end-users (receptors). Through its dissemination strategies at the program and project levels, CBIN will work to increase the awareness and more deeply engage key receptors who are not already involved, including: government procurement departments; municipalities; the agricultural community; the chemical industry, and the engineering and industrial design community.

Relevance to Canadian Circumstances

Given Canada's abundance of natural resources, commitment to sustainable development, a clean environment and healthy communities, and a desire for clean, affordable energy and green technologies, R&D investment in the area of bioenergy, bioproducts and bioprocesses is very relevant to Canadian circumstances. This investment should accelerate the development of knowledge and technologies that will:

- increase Canada's supply of renewable, CO_2-neutral energy
- help Canada to meet its international obligations and national goals with respect to climate change, environmental protection and sustainable development
- provide more sustainable re-use options for organic municipal and industrial wastes (i.e. alternatives to landfilling and incineration without energy recovery)
- help Canada's resource-based industries (forestry, agriculture and fisheries) to become more energy self-sufficient and efficient, and diversify their product offering
- support the development of bio-based economy and new industries (e.g. biorefineries, green technologies, etc.) that produce energy, biofuels, materials, chemicals from renewable feedstocks
- greater availability of cleaner fuels and products from renewable resources in the Canadian marketplace
- provide new opportunities for rural development, including aboriginal and northern communities

More specifically, the particular Canadian needs that will be addressed by this R&D investment are:

- understanding of the regional availability, cost and quality of Canada's biomass supply (incl. information on the type of biomass, production potential, quantity, quality, geographic location, transportation infrastructure, etc in GIS format)
- modified harvesting technologies for industrial biomass collection, and efficient transportation, storage and pre-processing to minimize costs and maintain feedstock quality (i.e. these systems have been optimized for conventional grain and other feed materials)
- identification of promising biomass pathways (i.e. feedstock-conversion-energy-products) for Canada
- increased production of energy (heat and power) from biomass for stationary applications
- increased production of liquid biofuels (ethanol, renewable diesel, etc.) and bio-based gases that can be used for stationary and/or transportation applications

- greater, sustainable utilization of biomass residues and less wasted biomass (e.g. sawmill residues, crop residues, manure, municipal solid waste, etc.)
- improved energy self-sufficiency and competitiveness of Canada's forest product industries by improving existing technologies and developing new technologies that convert forest residues into energy (i.e. energy costs are a substantial portion of the pulp & paper industry's operating costs)
- improved energy self-sufficiency and competitiveness of Canada's agriculture industry by generating more value from crops and developing new technologies that convert agriculture residues into biofuels, materials and chemicals
- new processes that produce valuable co-products from biomass conversion technologies, thereby improving the economics of bioenergy and biofuel production
- 'energy from waste' technologies, suitable for Canadian conditions, that can convert low cost, waste materials such as livestock manure, MSW, municipal and industrial effluents, and low quality waste greases into biogas, syngas or hydrogen, pyrolysis oil, renewable diesel fuel
- improved technical specifications of renewable diesel fuels so these fuels can be used reliably under Canadian conditions
- increased export opportunities (related to above)

4.2 Risks Associated with Proposed R&D

ProGrid defines risk in terms of delivery capacity, receptor capacity and international context (i.e. whether the R&D will be bought or "made in Canada".)

Delivery Capacity

Collectively, the Government of Canada and its domestic partners, have the human resources and intellectual capacity, facilities and financial resources to carry out the proposed R&D in bioenergy, biofuels, bioproducts and bioprocesses, and to communicate the resulting new knowledge and technologies. The delivery capacity is spread out among numerous government departments, universities, technology developers and other industries. This capacity is expected to become more effective (through increased coordination) and grow over the 4 year funding period.

This Applied R&D investment extends and compliments existing research activities at NRCan (CETC and CFS), AAFC, NRC, EC, and universities and industrial research facilities. It is leveraged by A-base funds and other sources such as Biodiesel Targeted Measures, SDTC, Canadian Biotechnology Strategy, Genome Canada, Agricultural Policy Framework, etc. It is important to note that several of the PERD-funded projects have been under development for several years. As such, these projects have established teams.

The funded R&D projects will be carried out by teams that include experts in different disciplines from industry, federal and provincial government laboratories and universities. Partnerships are a mandatory requirement for funding. They enable the sharing of expertise and facilities, the leveraging of Applied R&D funds, and will help move successful R&D to the next stage of development.

April 2006 Update: The late transfer of R&D funds to departments each year, and the restrictions related to carry-over have provided significant challenges to for the researchers. Furthermore, the year to year uncertainty regarding how much will be received and this year's program budget cuts are impacting the delivery of R&D. These conditions are preventing research teams from hiring and retaining the best people. Also, they provide no leeway to accommodate delays in start-up, equipment delivery, etc. Some researchers have remarked that it is becoming harder to maintain credibility with non-government partners and leverage could potentially drop.

- Receptor Capacity

Potential receptors of the new knowledge and technologies generated from this R&D have been identified for each activity and theme. Many of these receptor organizations are well aware of this work and/or are included in the project teams. However, some work will be required to more fully engage: government policy makers; chemical and manufacturing industries; municipalities; parts of the agricultural community; and the engineering and industrial design community. Increased awareness of these receptors is one of the objectives of the Program's dissemination strategy.

- International Context

Almost all of the new knowledge and technologies will be developed within Canada. International contacts with organizations such as the IEA, US DOE, US National Biodiesel Board, European Biodiesel Board, NREL and state NYSERDA government facilities and OECD will be maintained to keep abreast of new R&D developments and avoid potential duplication. In some projects, these organizations will be approached to provide external input or advice.

In some cases, technology developed in other countries may be adapted to come up with a 'made in Canada' solution. For example, the adaptation of forest harvest technologies is expected to draw on technologies developed in Canada, Europe and the US.

4.3 Environmental and Socio-Economic Impacts

- GHG Emission Reduction

By 2020-2025, it is expected that the implementation of this R&D will result in significant, incremental, quantifiable annual GHG reductions that exceed 30 Mt CO_2e/yr. Note: It is difficult, without allocation rules, to specify the amount of reduction that can be strictly attributed to R&D investment.

GHG reductions (> 30 Mt CO_2e) would be achieved through:

1) the substitution of CO_2 neutral biomass energy (using stationary combustion, IGCC, gasification, pyrolysis) for fossil fuels (coal, oil, natural gas) to generate heat and power

Using the projections contained in the Forest Sector Issue Table report, 11-13 Mt reduction could be achieved by 2025 from increased electrical production through higher efficiency of both energy conversion (combustion and gasification) and the generating cycle utilized (IGCC for both black liquor and wood residues); economical, small biomass cogeneration units for the solid wood industry; and new technology that allows biomass to replace fossil fuels in the lime kilns.

2) the avoided release of CH_4 from wastes, and substitution of CH_4-derived energy for fossil fuels to generate heat and power

Optimization of biogas generation from manure and MSW, and conversion of the gas into energy is estimated to have the potential to reduce GHG emissions by 30 Mt by 2025. According to EC, GHG reductions from landfill gas recovery are expected to increase from 6 Mt CO_2e today to 8 -11Mt CO_2e in 2012. Further reductions are anticipated as gas collection is extended to medium and smaller landfills.

(Note: As this R&D is shared with T&I DEP, only 50% of the potential reduction has been claimed for T&I Biotechnology.)

3) the substitution of biofuels (ethanol, renewable diesel) for fossil fuels (gasoline, diesel) in transportation applications

- 20 to 30 grain ethanol plants could produce 4 billion litres of ethanol in 2025 and reduce CO_2e emissions by 6 Mt (O'Connor, 2006);
- 1 lignocellulosic ethanol plant (150 million litres) is estimated to provide 0.5 Mt CO_2 reduction by 2010; over 5 plants producing 1 billion litres and contributing 2 Mt CO_2e reduction could exist by 2025 (O'Connor, 2006)
- 500 million litres of renewable diesel are estimated to provide 1-2 Mt CO_2 of reduction by 2010); potential replacement of 5% of petroleum diesel pool could result 8 Mt CO_2 reduction

4) the application of industrial biotechnology in the fossil fuel industry, i.e. petroleum upgrading, is expected to reduce GHG emissions by 21 Mt CO_2.

(Note: As this R&D is shared with T&I Bitumen and Heavy Oil, only 50% of the potential reduction has been claimed for T&I Biotechnology.)

5) the direct and indirect reduction in energy demand of numerous stationary and mobile applications is expected to reduce GHG emissions by 5-10 Mt CO_2.

Additional GHG reductions are expected from the substitution of biomass for petroleum feedstocks, e.g. materials and chemicals. (See Section 2.5.)

- *Other Environmental Benefits*

By 2020-2025, the adoption of new knowledge and technologies developed in this area are expected to result in significant, quantifiable incremental environmental improvements. The largest environmental benefits will be incurred from implementation of technologies that convert wastes with environmental liabilities into energy or other valuable products.

The main environmental improvements are expected to be:
- improved local air quality resulting from the closure of wood residue incinerators (less PM, VOC and unburned HCs) and current manure management systems (less CH_4, NH_3, odour, etc); gasification and pyrolysis offer further improvements over most combustion systems
- Less groundwater pollution due to the reduction in residue landfilling, diversion of MSW to energy applications, and closure of current manure management systems; and

- Less air pollution contributed per litre of diesel fuel combusted, as renewable diesel releases less particulate matter, hydrocarbons and carbon monoxide

Certain bioproducts, such as biolubricants, would also provide the environmental benefit of biodegradability over their petroleum-based counterparts. (Note: Not all bioproducts are biodegradable.) Also, any technologies that lower energy consumption will provide indirect environmental benefits.

It is important to note that bioprocesses and the production of biomass, bioenergy and bioproducts are not inherently environmentally benign because they are based on natural systems. They can offer the advantage of using fewer non-renewable resources for feedstock and energy. With proper design, controls and operation, they could be developed to be more environmentally friendly than conventional processes and products. As with all other production, the full environmental impacts (both positive and negative) need to be evaluated from a life cycle perspective and validated through monitoring.

- *Socio-Economic Benefits*

By 2020-2025, the adoption of knowledge and technologies in this area is expected to generate significant and enduring quantifiable socio-economic benefits to Canadians. As with environmental benefits, there is great potential but the actual benefits realized will depend on the degree of market penetration.

The development of a more bio-based economy is expected to provide the following socio-economic benefits (in no particular order):

- additional energy supply security afforded by diversity in supply
- more sustainable rural development
- new employment opportunities related to feedstock collection, transport and processing; plant operation; and product distribution
- new business and employment opportunities for resource-based industries (agriculture, forest products, fisheries) and aboriginal communities
- development of (value-added) secondary bio-industries (and new employment opportunities)
- higher prices for agricultural crops
- new markets for agricultural crops and crop residues
- new export opportunities for non-energy products
- increased need for industrial biotech research and technology development
- increased energy self-sufficiency (e.g. forest products industry, food processing industry, farm operations)
- linkage of farm operations to distributed energy systems, providing an additional source of revenue and back up during utility disruptions
- improved workplace conditions (e.g. farm operations, manure management)
- improved community relations (i.e. new economic development, farmers with adjacent landowners, etc.)
- opportunity to expand livestock production (i.e. given a solution to manure disposal)
- healthier communities and improved quality of life (resulting from less pollution, availability of cleaner forms of energy and ‘greener’ products)

ACRONYMS AND ABBREVIATIONS

AAFC	Agriculture and Agri-Food Canada
AD	Anaerobic digestion
APF	Agricultural Policy Framework
bdt	Bone dry metric tonne
BRI	Biotechnology Research Institute (NRC Institute)
CBIN	Canadian Biomass Innovation Network
CBS	Canadian Biotechnology Strategy
CETC	CANMET Energy Technology Centre
CFS	Canadian Forest Service (NRCan)
CO	Carbon monoxide
CO_2	Carbon dioxide (a greenhouse gas)
CO_2e	Carbon dioxide equivalent; greenhouse gases are expressed in CO_2e units using the appropriate global warming potential of the gas
CPS	Canada Prairie Spring (wheat class)
DDGS	Dried Distillers Grains with Solubles
DEP	Decentralized Energy Production
EC	Environment Canada
EcoAMu	Energy CoEnergy Co-generation from Agricultural and generation from Agricultural and Municipal Wastes
ETAA	Environmental Technology Assessment for Agriculture
EU	European Union
FCM	Federation of Canadian Municipalities
FERIC	Forest Engineering Research Institute of Canada
GHG	Greenhouse gas
GIS	Geographic information system
HC	Health Canada
IBS	Institute for Biological Sciences (NRC Institute)
IC	Industry Canada
IEA	International Energy Agency
IRAP	Industrial Research Assistance Program (NRC)
LCA	Lifecycle Assessment
MSW	Municipal solid waste
Mt	Mega tonnes (million metric tonnes)
NEB	National Energy Board
NRC	National Research Council
NRCan	Natural Resources Canada
odt	Oven dry metric tonne
OEE	Office of Energy Efficiency (NRCan)
OERD	Office of Energy Research & Development (NRCan)
OMAF	Ontario Ministry of Agriculture and Food
PBI	Plant Biotechnology Institute (NRC Institute)
PERD	Program of Energy Research & Development (NRCan)
SD	Sustainable development
SDTC	Sustainable Development Technologies Canada
T&I	Technology & Innovation (federal climate change program)
TEAM	Technology Early Action Measures
TIMS	T&I Management Secretariat

US DOE	US Department of Energy

BIBLIOGRAPHY

ADEME (Agence de l'Environnement et de la Maitrise de l'Énergie) (2004) "Environmental Impacts of Plants Used for Chemical, Material and Energy Purposes Status of Current Knowledge: Life-cycle Analysis (LCA)", Final Report, October 2004.

Agriculture and Agri-Food Canada (2006) "Science and Innovation Strategy", AAFC Science Policy and Planning, Science Bureau, May 2006.

Alberta Agriculture, Food and Rural Development, (2003) "Alberta's Agriculture Research and Innovation Strategic Framework", March 2003.

Alic, J.A.; Mowery, D.C. and E.S. Rubin (2003) "US Technology and Innovation Policies – Lessons for Climate Change", Report prepared for the Pew Center on Global Climate Change, November 2003.

Analysis and Modelling Group, National Climate Change Process (1999) "Canada's Emissions Outlook: An Update", December 1999.

Batelle Memorial Institute (2004) "Near-Term US Biomass Potential: Economics, Land-Use and Research Opportunities", March 2004.

Biotechnology Assistant Deputy Ministers' Coordinating Committee (2004) "Building the 21st Century Economy – A Government of Canada Blueprint for Biotechnology", Draft, Feb 14, 2004.

Campbell, S.J. (2003) "Bioprocesses for Enhanced Industrial Efficiency", Report prepared for Environment Canada, March 3, 2003.

Canadian Agricultural New Uses Council (2004) "An Assessment of the Opportunities and Challenges of a Bio-based Economy for Agriculture and Food Research in Canada", Final Report, March 3, 2003.

Conway, R.K. and M.R. Duncan (2006) "Bioproducts: Developing a Federal Strategy for Success", Choices, pp. 33-36, first quarter, 2006

Duffield, J.A. (2006) "Overview: Developing New Energy Sources from Agriculture", Choices, pp. 5-7, first quarter, 2006.

Duffield, J.A. and K. Collins (2006) "Evolution of Renewable Energy Policy", Choices, pp. 9-14, first quarter, 2006.

Eidman, V.R. (2006) "Renewable Liquid Fuels: Current Situation and Prospects", Choices, pp. 15-20, first quarter, 2006.

Energetics Inc. (2003) "Industrial Bioproducts: Today and Tomorrow" Report for US DOE, Office of Biomass Program, July 2003.

Envirochem Services Inc. (2005) "GHG Examination of Selected CBIN Bio Projects", Final Report, November 18, 2005.

Greene, N. (2004) “Growing Energy – How Biofuels Can Help End America’s Oil Dependence”, Natural Resources Defense Council, December 2004.

Griffiths, M. (2001) “The Application of Biotechnology to Industrial Sustainability” OECD Study, 2001.

ICPET and E4tech (2004) “Bioelectricity Vision: Achieving 15% of Electricity from Biomass in OECD Countries by 2020” Report prepared for WWF International and Aebiom, April 2004.

Industry Canada and BioProducts Canada (2004) “Innovation Roadmap on Bio-based Feedstocks, Fuels and Industrial Products”, 2004.

Jaworski, J. (2004) “Industrial Bioproducts and Sustainable Growth” Draft Strategy and Action Plan of the Federal Working Group on Bioproducts, March 29, 2004.

Minns, D. (2005) “Review of the findings of the October 2004 ADEME study of LCAs of bioproduct supply chains and their implications for CBIN programming” Report prepared for CBIN, March 2005.

National Energy Board (2003) “Canada’s Energy Future – Scenarios of Supply and Demand to 2025”.

NeoBio Consulting (2004) “Recommendations for an Ontario Bioproducts Strategy”, Report prepared for Ontario Ministry of Economic Development and Trade, Draft, Oct 29, 2004.

Olsen, K.; Wellisch, M.; Boileau, P.; Blain, D.; Ha, C.; Henderson, L.; Liang, C.; McCarthy, J. and McKibbon, S. (2003) “Canada’s Greenhouse Gas Inventory”, August 2003.

Pneumaticos, S. (2002) “Renewable Energy in Canada – Status Report 2002”, National Report prepared for the Renewable Energy Working Party of the IEA, March 2002.

Reeve, D. (2004) “Biomass Innovation Strategic Research and Development Plan”, Source document prepared for NRCan, CANMET Energy Technology Centre, February 9, 2004.

Science-Metrix (2004) “Towards a Canadian R&D Strategy for Bioproducts and Bioprocesses” Report prepared for National Research Council of Canada, April 2004.

Sims, R. (2002) “The Brilliance of Bioenergy - In Business and In Practice”, James & James (Science Publishers) Ltd, February 2002.

Statistics Canada (1996) “A Geographical Profile of Manure Production in Canada” Statistics Canada – Catalogue No. 16F0025XIB

Stumborg, M.; Cao, R.; Mazza, G.; Champagne, C.P. (2004) “AAFC Theme 310 Strategic Recommendations”, Working Document, Ver 7, Jan 13, 2004.

Tampier, M. (2002) “Promoting Green Power in Canada” Report prepared for Pollution Probe, November 2002.

University of Guelph, Department of Environmental Biology (2004) “Potential Sources of Non-Traditional Biomass for Bioenergy Candidate Species, Available Land and Carbon Sequestration Potential: A Case Study for Ontario”, March 2004.

US Bioenergy Program (2002a) “Vision for Bioenergy & Biobased Products in the United States”, October 2002.

US Bioenergy Program (2002b) “Roadmap for Biomass Technologies in the United States”, December 2002.

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Biomass Program. (2003) “Roadmap for Agricultural Biomass Supply in the United States”, November 2003.

Wood, S.M. and D.B. Layzell (2003) “A Canadian Biomass Inventory: Feedstocks for a Bio-based Economy”, Final Report prepared for Industry Canada, June 27, 2003.

Appendix A. CBIN Executive Committee and Theme Leaders (March 2006)

CBIN Executive Committee (ExCo)

Hamid Mohamed, NRCan-OERD (Chair)
Nicole Richer, NRCan-OERD (S&T Science Advisor)
Nathalie Beaupré, NRCan-CETC (CBIN Communications Officer)

Members :

AAFC: Dr. Christiane Deslauriers ; alternate - Mark Stumborg
EC: Dr. Terry McIntyre ; alternate – Matthew Schacker
IC: Dr. John Jaworski ; alternate – Joe Cunningham
NRCan – CFS: Jeff Karau ; alternate – Dr. Robert Stewart
NRCan – CETC: Dr. Andrew McFarlan ; alternate – Jody Barclay
NRCan – CETC: John Burnett ; alternate – Ed Hogan
NRC: Kevin Jonasson ; alternate - Jane Dyment-Saaltink

CBIN Theme Leaders

Theme Title	Theme Leader	Dept Affiliation
Activity 1: Existing and New Biomass Supply		
Detailed Agriculture and Forestry Biomass Inventory	M. Stumborg	AAFC
Purpose-Grown Woody Biomass Production (forestry & agro-forestry)	J. Karau M. Stumborg	NRCan-CFS AAFC
Technologies for Harvesting, Preparation, Storage and Transportation		
- Ag Residues	M. Stumborg	AAFC
- Salvage Wood (forestry)	J. Karau	NRCan-CFS
New and Improved Biomass Feedstocks		
- Annual Plants (Fatty Acid Feedstocks)	Dr. W. Keller	NRC-PBI
Activity 2 : Biomass Conversion and Utilization Technologies		
Biomass Conversion to Heat and Power (forest products ind)	J. Burnett	NRCan-CETC
Conversion of Waste to Bio-based Gases (biogas, syngas, hydrogen)	J. Barclay	NRCan-CETC
Key Separation and Conversion Processes for Bio-based Products	Dr. G. Mazza Dr. A. Kumar	AAFC NRC
Biocatalysis for Industrial Applications	Dr. P. Lau	NRC-BRI
Advanced Biomass Conversion & Utilization Technologies	E. Hogan	NRCan-CETC
Renewable diesel fuels for Transportation Applications	Dr. J. Monnier	NRCan-CETC
Activity 3: Integrated Bio Applications		
Integrated Biorefining	tbd	
Regional Bioclusters	Dr. J. Jaworski	IC
Activity 4: Cross-Cutting		
Strategic Work, Communication & Dissemination	M. Wellisch	NRCan-CETC
Policy Support & Assessment Frameworks	Dr. T. McIntyre	EC-ETAD

Appendix B. PERD BEST POL 4.4.1

Bio-Based Energy Systems and Technologies (BEST) Program

The BEST program was established by the Office of Energy Research and Development (OERD), Natural Resources Canada. The aim of the program is to provide a coherent strategic approach to the R&D of using bio-resources instead of fossil fuels, and the underlying theme of the new "POL" is the conversion of renewable biomass resources to fuels, heat and electricity, and chemicals. It was constituted from the relevant parts of the following previous closely linked POLs:

2.1.3. Transportation Fuels from Renewable Energy Sources

- "A coordinated research initiative to develop and demonstrate the feasibility of producing transportation fuels from sources that are renewable and economically and environmentally advantageous."

4.2.3 Forest and Forest Products Industry

- "To reduce fossil fuel intensity in the forest and forest products industry, including the pulp and paper industry, the sawmill sector, the panel board industry and the secondary wood industry."

4.2.4 Agriculture and Forestry Biomass Supply for Energy

- "To increase the supply and production of sustainable biomass feedstock as an energy source at a competitive cost with minimal environmental impacts."

Ongoing activities under the previous POLs are summarized in Table B:

Table B. Activities under the BEST Program

Transportation Fuels from Renewable Energy Sources	Forest and Forest Products Industry	Agriculture and Forestry Biomass Supply for Energy
R&D on process, or processes, involved in the production of bio-ethanol. This involves bench-scale and up to pilot-scale development and testing of the unit processes necessary for the production of bio-ethanol.	Bio-fuel quality and supply. This activity involves projects pertaining to improved processes for the utilization of waste materials, as well as Kraft black liquor conversion and utilization technologies, for example, delignification.	Agricultural Resource Assessment. This activity involves assessing the quality and availability of biomass feedstock from agricultural residues such as straw and low-grade oilseed.
Unit process integration. This activity involves R&D identified from and associated with the start-up and initial operation of a pre-commercial demonstration plant to identify technical problems and solutions and evaluate the feasibility of commercial production of lignocellulosic ethanol.	Energy conversion. This activity involves projects pertaining to field trials for the advancement of combustion processes, fuel switching, and waste wood and black liquor thermal conversion technologies.	Agricultural production and harvesting systems. This activity focuses on reducing cost and increasing efficiency of harvest and collection technologies, transport systems and storage systems.

R&D on future opportunities. This activity involves early research on the production of ethanol from synthesis gas and the production of bio-hydrogen.	Energy utilization. This activity involves projects pertaining to technologies to improve the utilization of electrical and thermal energy.	Forest Residues. This activity involves improving technologies to assess the availability of biomass from forestry harvest residues and associated long-term environmental impacts. The second focus of the activity is on developing and improving technologies for collection and transportation,
		Forest Energy plantations. This activity focuses on improving plantation technologies and the selection, testing and genetic improvements of sustainable tree species for high biomass productivity with minimal inputs.

Appendix C. Estimated GHG Reductions of Selected Bioenergy and Industrial Bio Projects

Envirochem Services Inc. reviewed 12 R&D proposals that were approved in the 2005/06 RFP for T&I Biotechnology Funds. The selected proposals represent approximately 37% of the CBIN's total R&D investment for 2005/06. For the complete 'GHG story', the reductions from the PERD and remaining T&I projects should also be included.

Shown in Table C1 are the estimated 'point of end use' GHG reductions, i.e. the reductions that could result if the assumed market potentials were realized for the respective end use applications. They are organized according to the end use sector where the reductions will occur. For example, the production of biofuels and lighter weight materials would be expected to reduce GHG emissions in the "Fuel Combustion – Transport" sector.

Table C1. Potenial GHG Reductions of Selected T&I Projects*

GHG Inventory Sector	T&I Project	Reduction in 2025 (Mt CO_2e)
CRF SECTOR 1 – ENERGY		
Energy - Fugitive Emissions; Fuel Combustion - Iron and Steel	TIIA.06 - Petroleum Bioupgrading	(21 Mt)
Fuel Combustion - Other Sectors (Agriculture)	TID8 30 - Renewable Energy for Greenhouses	5.37 Mt
Fuel Combustion - Transport; Fuel Combustion - Energy Industries	TID8 31 - Short-Rotation/Agroforestry	4.55 Mt
Fuel Combustion - Transport	TID8 33 - Oilseed Integrated Refinery	2.86 Mt
Fuel Combustion - Transport; Fuel Combustion - Manufacturing Industries	TID8 23 - Natural Fibres Initiative	1.6 Mt
Fuel Combustion - Transport; Fuel Combustion - Energy Industries	TID8 26 - Agricultural Residues for Bioenergy and Bioproducts	1.3 Mt
Fuel Combustion - Other Sectors (Residential)	TID8 28 - Biodiesel for Heat and Power	0.97 Mt
Fuel Combustion - Industry: Pulp, Paper; Fuel Combustion - Other: Manufacturing Industries and Construction (Cement)	TID8 29 - Biomass in Lime Kilns	0.72 Mt
Fuel Combustion - Transport	TID8 34 - Wheat Ethanol R&D	0.57 Mt

Fuel Combustion - Other Sectors (Agriculture); Agriculture Sector - Emissions from Manure Management	TID8 27 - Conversion of Chicken Litter	0.0004 Mt
CRF SECTOR 6 - WASTE and CRF SECTOR 4 - AGRICULTURE		
Solid Waste Disposal on Land; Fuel Combustion - Other Sectors (Agriculture); Fuel Combustion - Energy Industries; Agriculture Sector - Emissions from Manure Management	TID8 21 – Residual Organic Wastes	(30 Mt)
Waste Incineration	TID8 24 - Starch-Based Polymers	1.8 Mt

* The project was classified according to the primary sector that it targets.

Appendix D. Distribution of 05/06 PERD and T&I Funds by Theme

Activity	Theme/Theme leader	PERD BEST 4.4.1 05/06	T&I BIO 05/06	TOTAL 05/06
Existing and New Biomass Supply				
1.1	Biomass Inventory - Stumborg	143	276	419
1.2	Biomass Production Systems - Karau/Stumborg	222		222
1.3	Technologies for Harvesting, Preparation, Storage and Transportation - Stumborg / Karau	131		131
1.4	New and Improved biomass Feedstocks – Keller	50		50
Biomass Conversion and Utilization Technologies				
2.1	Direct Conversion to Heat and Power – Burnett	774	150	924
2.2	Conversion - Waste to Biobased Gases – Barclay	180	874	1,054
2.3	Key Separation & Conversion Processes - Cruickshank/ Mazza / Kumar	576	212	788
2.4	Industrial Biocatalysis - Cruickshank / Lau	295	514	809
2.5	Biofuels for Stationary Applications – Hogan	218	305	523
2.6	Biofuels (Renewable diesel fuels) for Transportation Applications - Monnier	funded by Biodiesel Targeted Measures		
Integrated Bio Applications/Systems				
3.1	Integrated Biorefining (oilseeds)	50	368	418
	Integrated Biorefining (cereals, starch)		495	495
	Integrated Biorefining (forest fibre)		698	698
	Integrated Biorefining (agricultural fibre)		422	422
	Integrated Biorefining (mixed fibre feedstock)		400	400
3.2	Regional Bioclusters - Jaworski	25		25
Cross-Cutting				
4.1	Strategy, Communication & Dissemination - Wellisch		155	155
4.2	Assessments & Networks - McIntyre	125		125
Program Delivery, Taxes, Loans - Wellisch		74	631	705
TOTAL		**2,863**	**5,500**	**8,363**

Appendix E. Summary of ProGrid Analysis of Program Themes

This chart, completed in May 2004, summarizes the results of ProGrid "self-assessments" that were carried out by the CBIN theme leaders.

Activity	Theme	T&I Strat Goals	Canadian Circumstances	Delivery Capacity	Receptor Capacity	Internatl Context	Impacts in 2020-2025		
							GHG Red'n	Env Impacts	Socio-Economic Impacts
Cross-Cutting (Strategy, Assessments, Disseminatior		D	D	C	C	D	not directly	not directly	not directly
Existing & New Biomass Supply									
	Biomass Characterization, Evaluation and Quantification	C	D	C	D	D	indirect, difficult t	indirect, difficult	indirect, difficult to quantify
	Technologies for Harvesting, Preparation, Storage & Transportation	C	C	B	D	C	indirect, difficult t	indirect, difficult	indirect, difficult to quantify
	New and Improved Biomass Feedstocks	D	C	D	C	D	indirect, difficult t	C	C
Biomass Conversion and Utilization Technologies									
	Conversion to Heat and Power	C	C	C	D	C	B	D	C
	Conversion of Waste to Gases	D	C	C	C	C	B (need to verify)	D (if implemente	C (if implemented)
	Key Separation & Conversion Processes	C	D	D	C	B	B (expected to gı	D (if implemente	C (if implemented)
	Biocatalysis for Industrial Applns	D	D	C	C	D	B (2010)	C (if implemente	C (if implemented)
	Advanced Biomass Conv & Utilizatn	D	C	C	C	C	C	D	C
	Biofuels for Transportation Applns	D	D	C	C	C	B (C after 2010)	D (air)	C
Integrated Bio Applications									
	Integrated Biorefining	D	C	C	C	C	B (after 2008)	C	D
	Regional Bioclusters	D	C	C	C	C	not directly, diffic	not directly, diffic	not directly, difficult to quanti

The A-D scoring is described in the ProGrid documentation. In general, A refers to the lowest impact and D to the highest.