

Ontario's Bioeconomy: Role of Research and Innovation and Agricultural Biomass

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**13th International Symposium on Bioplastics, Biocomposites and Biorefining,
Delta Guelph Hotel and Conference Centre, May 19-24, 2014**

Outline of Rajib's presentation

- Brief history of agricultural bioeconomy research in Ontario
- A snapshot of agricultural bioeconomy research under
 - OMAF and MRA Partnership with UofGuelph
 - OMAF and MRA Partnership with other institution (ARF, ND)
- Ontario Research and Innovation capacity for agricultural bioeconomy beyond OMAF/MRA and UofG
- Conclusion

OMAF and MRA Mandate



MINISTRY OF AGRICULTURE AND FOOD



MINISTRY OF RURAL AFFAIRS

Ontario.ca | Français

Promote a more competitive and productive agri-food and agri-product sector, and economic growth and opportunities for rural Ontario



Ontario's Bioeconomy



Bioeconomy refers to the exchange of products manufactured in whole or in part from renewable biomass resources.

- Ontario government funds bioeconomy research and innovation through various ministries programs (Research chair, project operating grants, infrastructure etc...)
- OMAF and MRA focus on **agricultural bioeconomy** through use of agriculturally-derived biomass to produce bioenergy, biomaterials and biochemicals.
- OMAF and MRA has been promoting partnerships and collaboration in research and innovation

History of Agricultural Research in Ontario

1874-88

- College of Agriculture (1874)
- Department of Agriculture under Minister of Agriculture (1888)

Ministry of **Agriculture and Food**
Ministry of **Rural Affairs**



1962

- Agricultural Research Institute of Ontario (ARIO) was established by an Act of Legislature
- To stimulate interest in research on agriculture, veterinary, household science, production and marketing efficiency

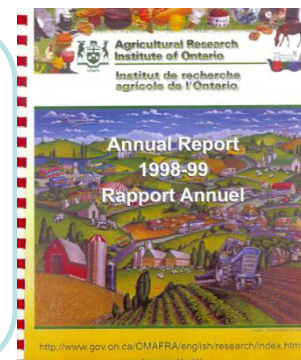
1968-69

- ARIO provided strategic directions to research and service programs
- Research projects: livestock and poultry, field crops, horticulture, soil, engineering, virus, bacteria, veterinary medicine, food and nutrition, textiles, economics & marketing



1998-99

- ARIO provided priorities and directions for agriculture, food and rural research activities
- Research and service programs
- Review of long term strategic plan indicated that "ARIO considered *novel non-food, non-feed applications*, human health, environmental benefits offered by these renewable hydrocarbon sources."



Agricultural Bioeconomy Research in Ontario

1999

- In 1999, OMAF/MRA introduced **Special Research Fund** promoting research partnership with industry, govt and universities to develop i) new value-added food products and ii) new **non-food products**. This program is now known as New Directions Research Program.

2004-06

- Alternative Renewable Fuels Plus R&D Fund (2004-05): Take advantage of renewable fuels
- **OMAF/MRA-UofG Partnership establishes New Bioproducts Research Program (2005-06)**

2007-08

- ARIO provided advice on strategic directions for agriculture, food and rural research activities
- Long-term strategy for R&D infrastructure
- Recommended seven “Strategic Agri-Food and Rural Research Themes” for Ontario

2007-08

- Ministry adopted seven Research Themes
 - 1. Agriculture and Rural Policy
 - **2. Bioeconomy Industrial Uses**
 - 3. Emergency Management
 - 4. Food for Health
 - 5. Environmental Sustainability
 - 6. Production Systems
 - 7. Product Development & Enhancement

Agricultural Research
Institute of Ontario (ARIO)



Annual Report 2007-2008

OMAF and MRA-UofG Partnership

OMAF and MRA - UofGuelph Partnership

Research

Laboratory Services

Education

- **1874:** Provincial School of Agri (now OAC) as a branch of the Department of Agriculture
- **1964:** UofG became an independent University and a series of agreements with OMAF & MRA for research, education, tech transfer.

Over 100 years old Partnership



- Unique capacity (expertise, infrastructure, linkages..) at U of G supports provincial agri-food priorities
- **1997:** Landmark "Enhanced Partnership Agreement"
- **2002:** Agreement Renewal
- **2008-2018** - Current Agreement

Build on UofG's globally recognized excellence

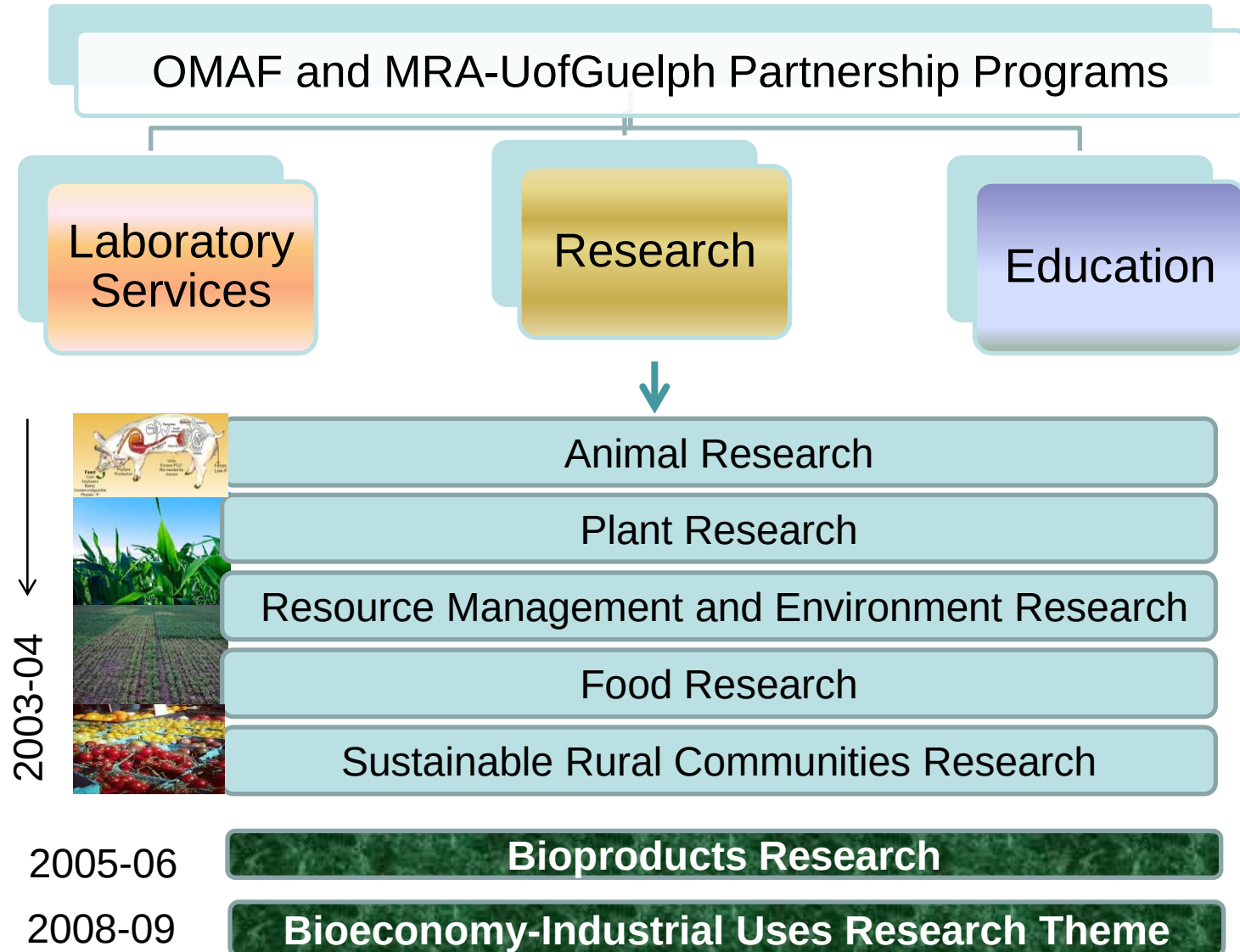


- Agri-food industry competitiveness and innovation
- Food safety & quality
- Environmental protection and human health

Current Agreement 2008-18



OMAF and MRA-UofG Partnership- Past



OMAF and MRA-UofG Partnership Bioeconomy Milestones: 2005-08

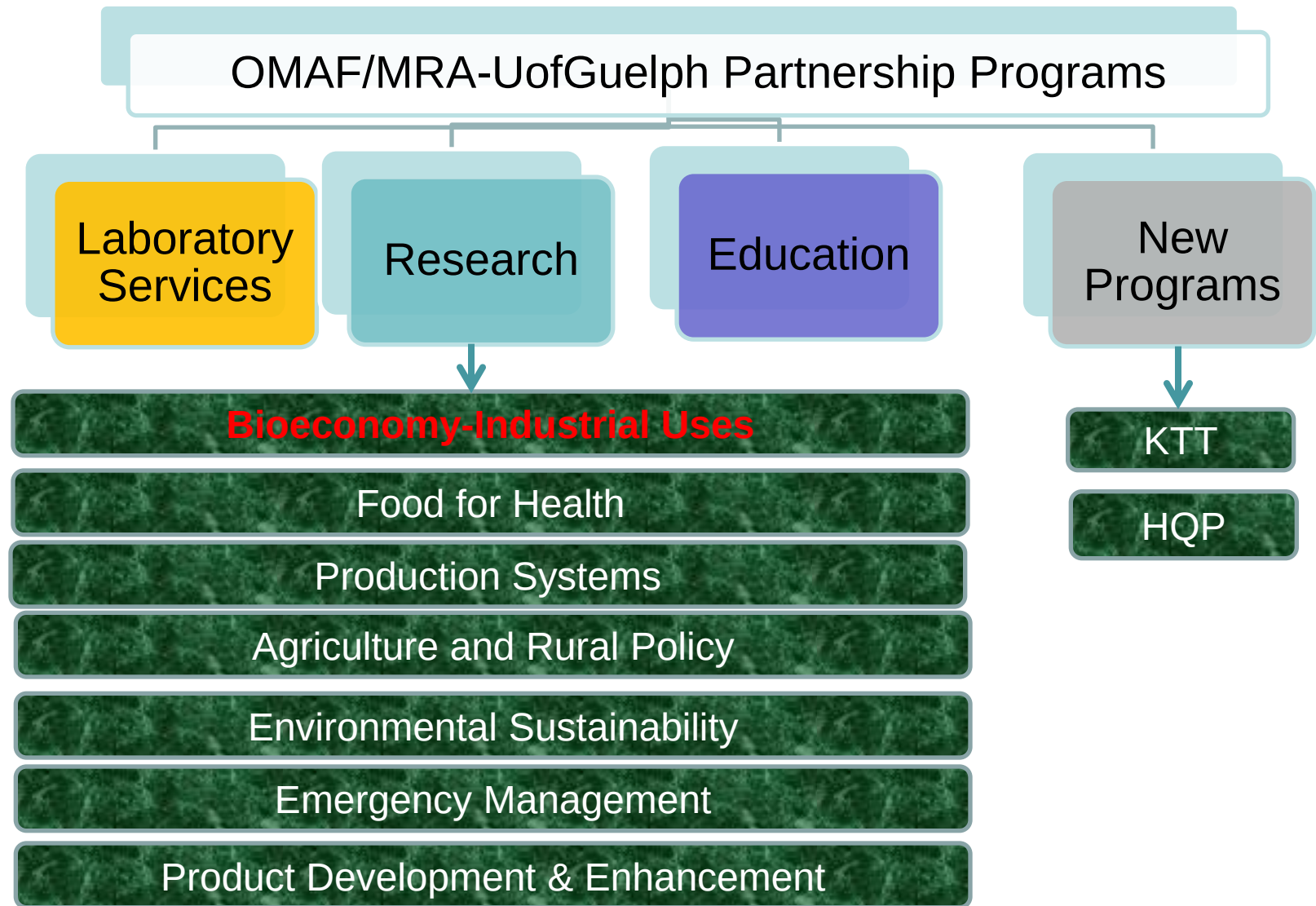
New Bioproducts Research Program established: Focus on bioproducts (chemicals, fibres and other compounds but NOT biofuels) derived from agricultural-based renewable resources

- Government funded Premier's Research Chair in Biomaterials and Transportation
- UofG announced Prof. Amar Mohanty as the Premier's Research Chair
- Ontario BioCar Project- 4 universities, industry and public sector

UofGuelph's Bioproducts research program focused on the utilization of agricultural biomass primarily for chemicals and materials: e.g.

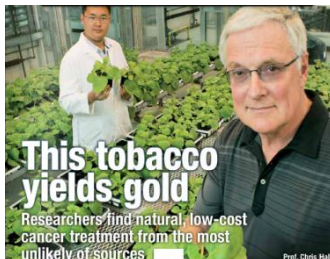
- Novel industrial starches, starch synthases and branching enzymes
- Recombinant antibody in tobacco
- Proteins for manufacturing industrial films
- Nano micro-fibers from soya hull
- First biocomposite bridge installed at Guelph Arboretum
- First wheat-polypropylene composite material incorporated into chairs

New OMAF and MRA-UofG Partnership: 2008-18

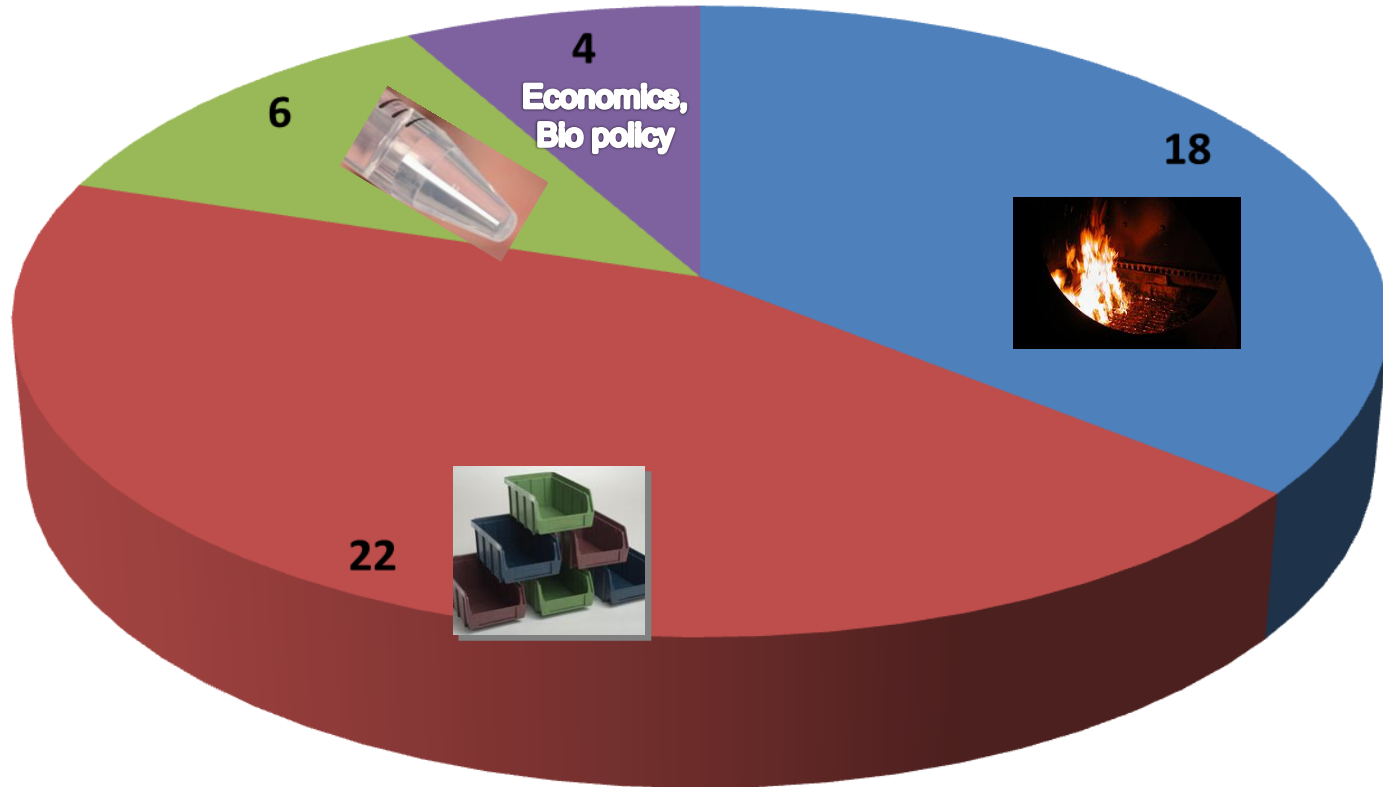


Bioeconomy Research Projects- Highlights

- Bioeconomy research projects funded since 2008
 - New Directions Research Program : 10
 - Alternative Renewable Fuels R&D Fund: 07
 - OMAF and MRA-UofG Partnership : 33
- Examples of the research projects
 - Genetically engineered tobacco plants for biosimilar breast cancer drug
 - Breeding for high oil content of soybean
 - Biocomposite bins commercialized
 - Biomaterials for automotive, housing panel...
 - Evaluation of biomass crops
 - Assessment of ag biomass availability for energy
 - Phytosperix- starch nanoparticles
 - Plant protein for industrial fibres and films
 - Nanocomposites
 - Land Use and Policy Impacts



Distribution of Bioeconomy Projects



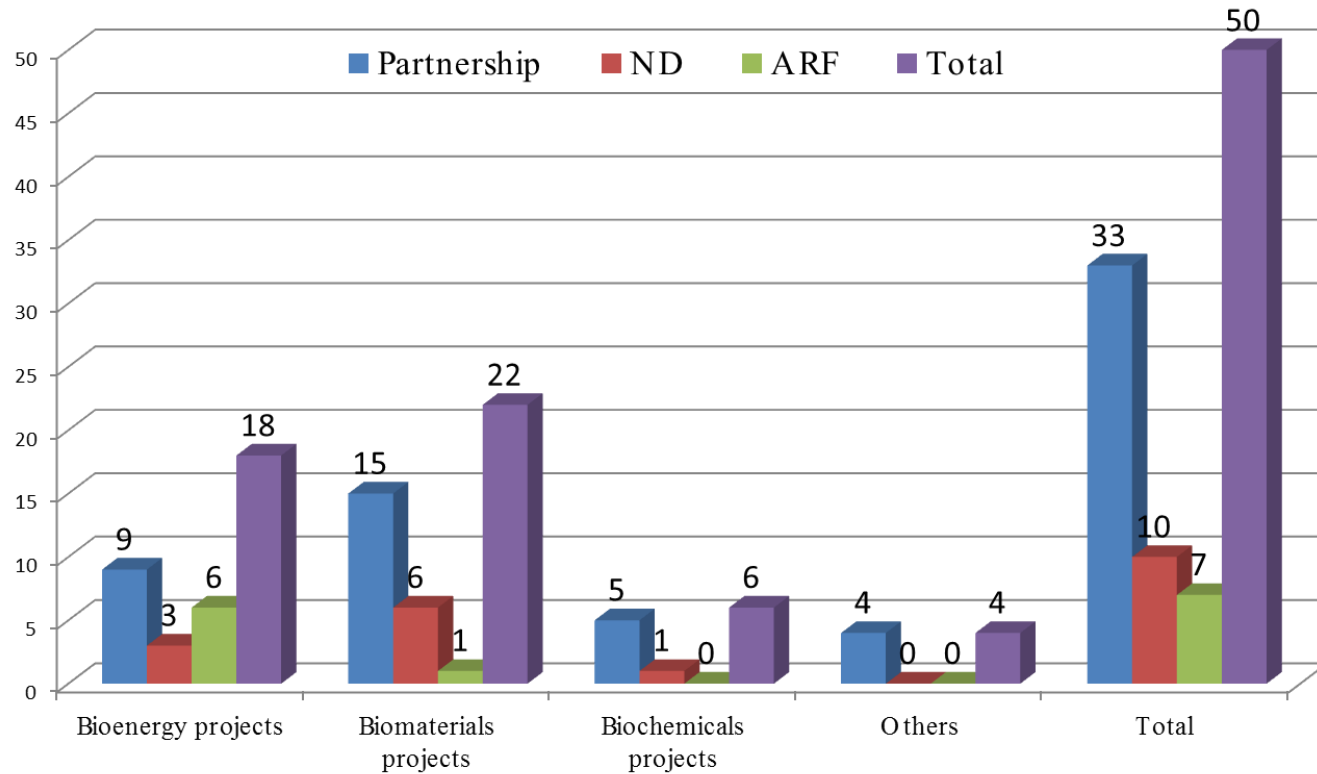
■ Bioenergy projects

■ Biomaterials projects

■ Biochemicals projects

■ Others

Research Projects (2008-12)



OMAF/MRA-UofG Partnership Bioeconomy projects (2008-2013)

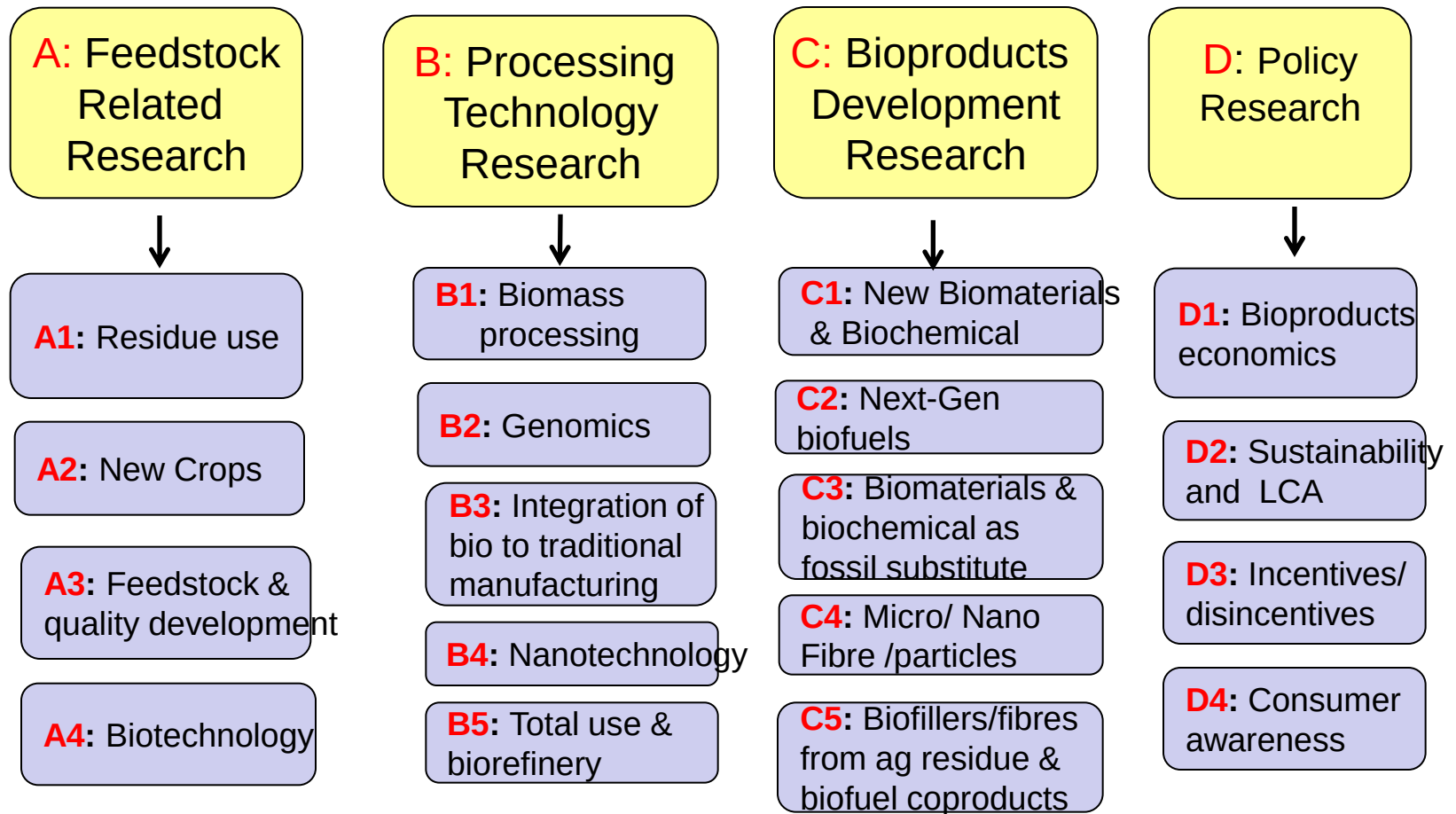
Year	[Number of projects] funded by Bioeconomy and other themes : Focus areas
2013	No Bioeconomy in 2012 Partnership interim call
2012	[4]: R. Dandelion (breeding), xylitol, phytosperix, bioadhesive
2011	[9]: Greenhouse plant pots, biochar, CO2-based biomaterials, torrefaction, branching enzymes, castor, dry fermentation, nanocomposite for energy storage, biodiversity risk of bioenergy crops
2010	[11]: Ag biomass availability, Ag fibre quality genes for Auto applicn, catalyst for C4-C6 sugars to alcohol, BioABS, composites for housing panel, policy-(land use, CC, green economy), novel starch biopolymer, superstarch + ethanol, identification of successful business models, aquaculture feed.
2009	[9]: biomass crop for Ontario, Biogas and ag. feedstock LCA, nano-enhanced biopolyurethane, biomass crop evaluation, lightweight green composites from lignin +Miscanthus+SG+bioplastics
2008	[4]: Miscanthus production-nutrition and economics, biogas-ES, Biocomposites, Premiers Research Chair equipment funding (previous agreement)
2005-07	[7]: Novel industrial starches, novel biomaterials (Ford flex), bioactive cellulose filters, Tobacco r-Ab, economic effects of bioproducts, protein based industrial fibres and films

New Directions and ARF Research Program (2008-2013)

Year	[# project s in New Directions and ARF program]: Focus areas
2013	[3 ND]: Genomics for bioplastics; Biorefining ag biomass for CA/PF; Agronomy of euphorbia and vernonia for epoxidise esters)
2012	No call for bioeconomy issued
2011	
2010	[4 ND]: Russian Dandelion-agronomy, biodegradable cell phone case, nano-biocomposite for wind turbine blades, energy crops for dry fermentation.
2009	[4 ND/ARF]: Metaproteomic analysis for engineering cellulose degrading enzymes, biomaterials from glycerol+PLA, biofuel crops in marginal land, C-nanostructures from lignin
2008	[1 ND+7ARF]: Automotive interior parts from bio-fibers and renewable resource based bioplastic, biofuel residue for biogas, catalyst for hydrogenation of biooil, breeding high oil soybean, ag feedstock for biogas production, economic feasibility of biogas, biocomposites from DDGS+ bioplastics, biomass for fuel pellets.

Bioeconomy-Industrial Uses theme priorities

The **Bioeconomy-Industrial Uses** theme supports the development of the bioproducts sectors (biomaterials, biochemical and bioenergy includes biofuels) through the use of agriculturally-derived biomass.



Other Organizational Capacities for Bioeconomy Research

- Federal Government:
 - GF2 AgriInnovation Program (\$698M for 5 yrs.- includes \$468 M for Industry-led research and rest AAFC-led research)
 - NSERC biomaterials programs (e.g. NSERC/GFO/ERS Industrial Research Chair in Lipid Derived Biomaterials- Dr. S. Narine, 2010 at Trent Univ.)
 - Others
- Industry and NGO examples: GFE, Woodbridge Group, NEF, FAO/OSCIA, Ecosynthetix, NeoVentures Biotech, OGI, AMP.....
- Academic: UofGuelph, Toronto, Trent, McMaster, Waterloo, Windsor, Trent, Western, Queen's, Lakehead,.....
- Innovation capacities offered by various organizations (ATCC, SCA, Green Centre Canada, business development offices at Universities....)
- Other support:
 - MRI was created to act as catalyst for innovation in Ontario
 - Ontario Innovation Agenda: “Opportunities to combine existing strengths in forestry and agriculture with new technologies to create bio-based industries and boost regional development, especially in rural and northern Ontario.”

Conclusion

- Agricultural bioeconomy is still emerging
- Potential benefits are recognized and diverse
- Research and Innovation is crucial
 - New information, process, technologies/products
 - HQP training
 - Industry
 - Collaboration and capacity building to lead innovation
- Significant momentum in research capacity, outcomes, collaborative discussion and work

Outline of Mahendra's Presentation

- **Overview of Ontario Agriculture**
- **Land Base for Agricultural Biomass**
- **Bioeconomy system**
- **Biomass from agricultural sources in Ontario**
 - Crop biomass and carbon potential
 - Dedicated perennial biomass species
 - Industrial crops
- **Agricultural Bioeconomy Supply Chains**

A Snapshot of Ontario's Agriculture

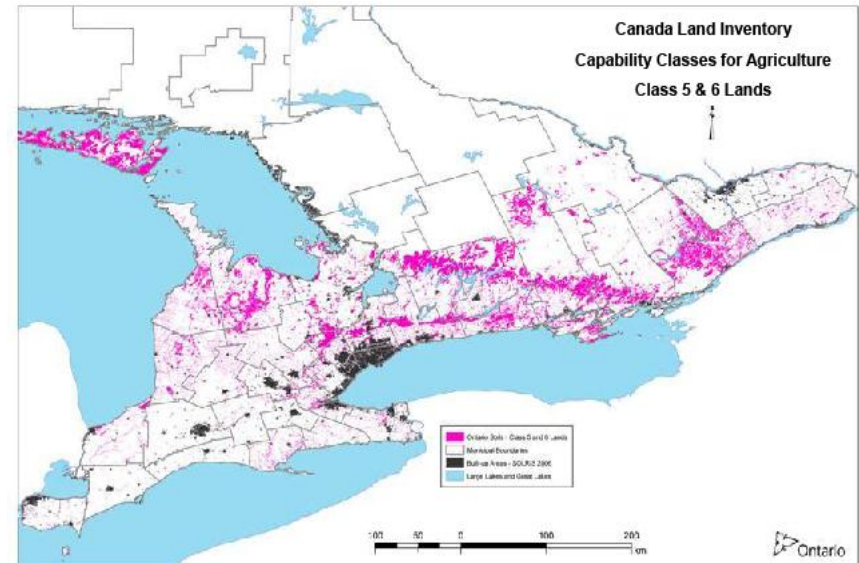
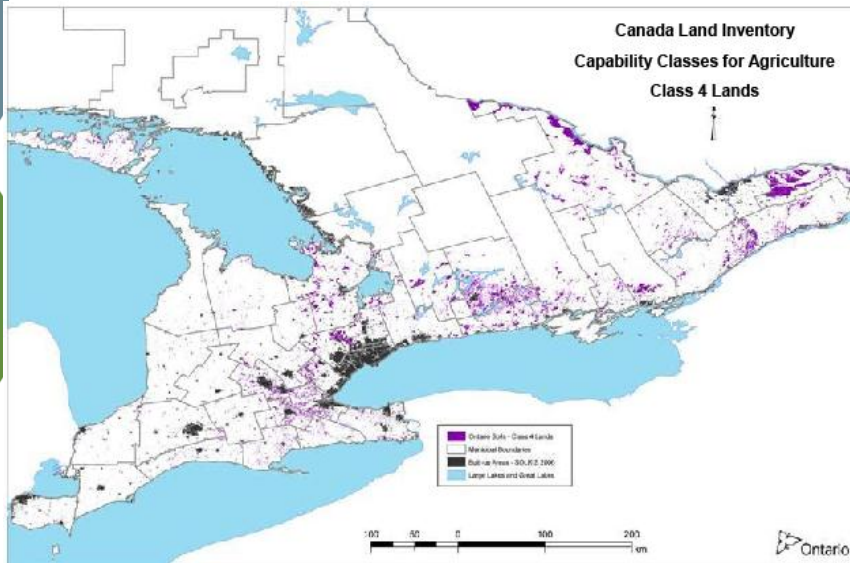
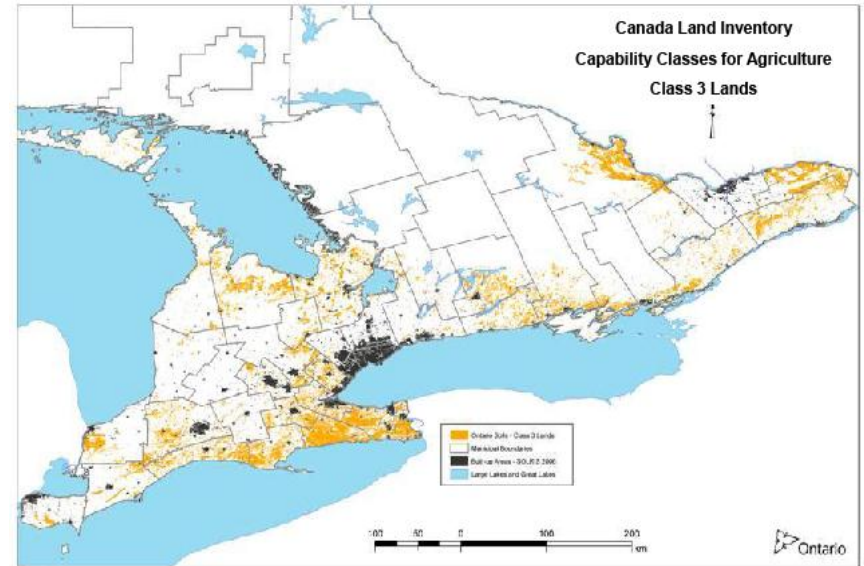
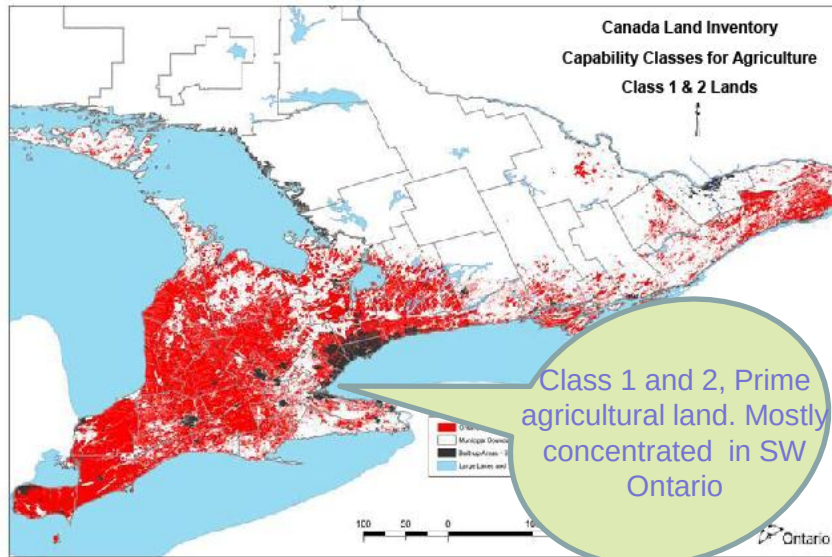
- Total number of Farms 51,950¹
- Total Area of farms 5,126,653 ha¹
- Total Crop Land 3,613,821 ha¹ (70% of farm land)
- Pasture 661,081 ha¹ (13% of farm land)
- Farm Cash Receipts \$11.8 Billion²
- Agri. Food sector GDP 34 Billion ³
- Employment 710,000 jobs (11% of jobs in Ontario)

1 Source: Statistics Canada, 2011 Census of Agriculture.

2 Source: Statistics Canada

3 Source: OMAFRA, statistics 2012.

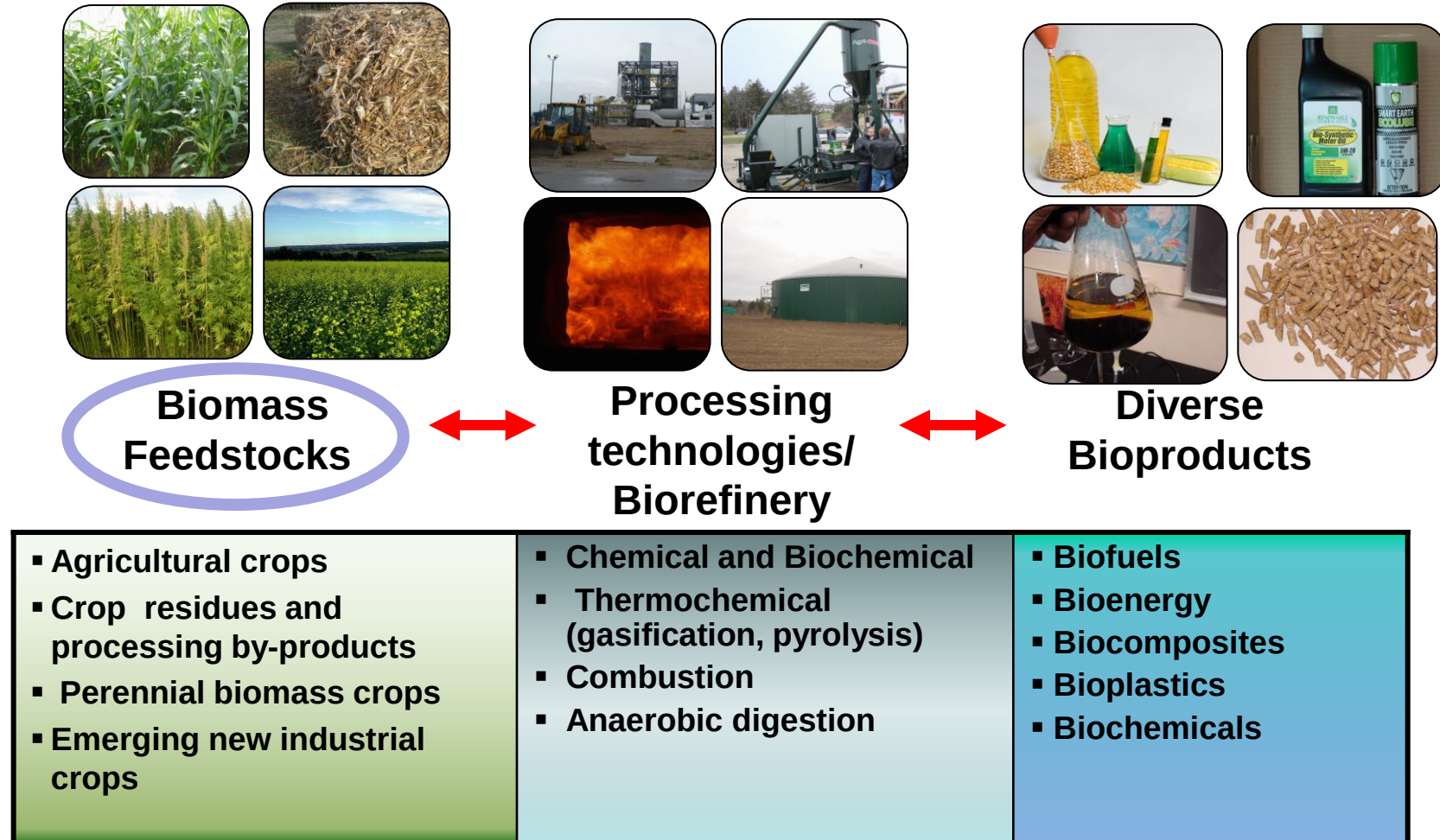
Land Base for Agricultural Biomass



The Bioeconomy System

What is the Bioeconomy?

Bioeconomy basically is described as an economy based on the sustainable manufacture of bioproducts, in whole or in part, from renewable resources.

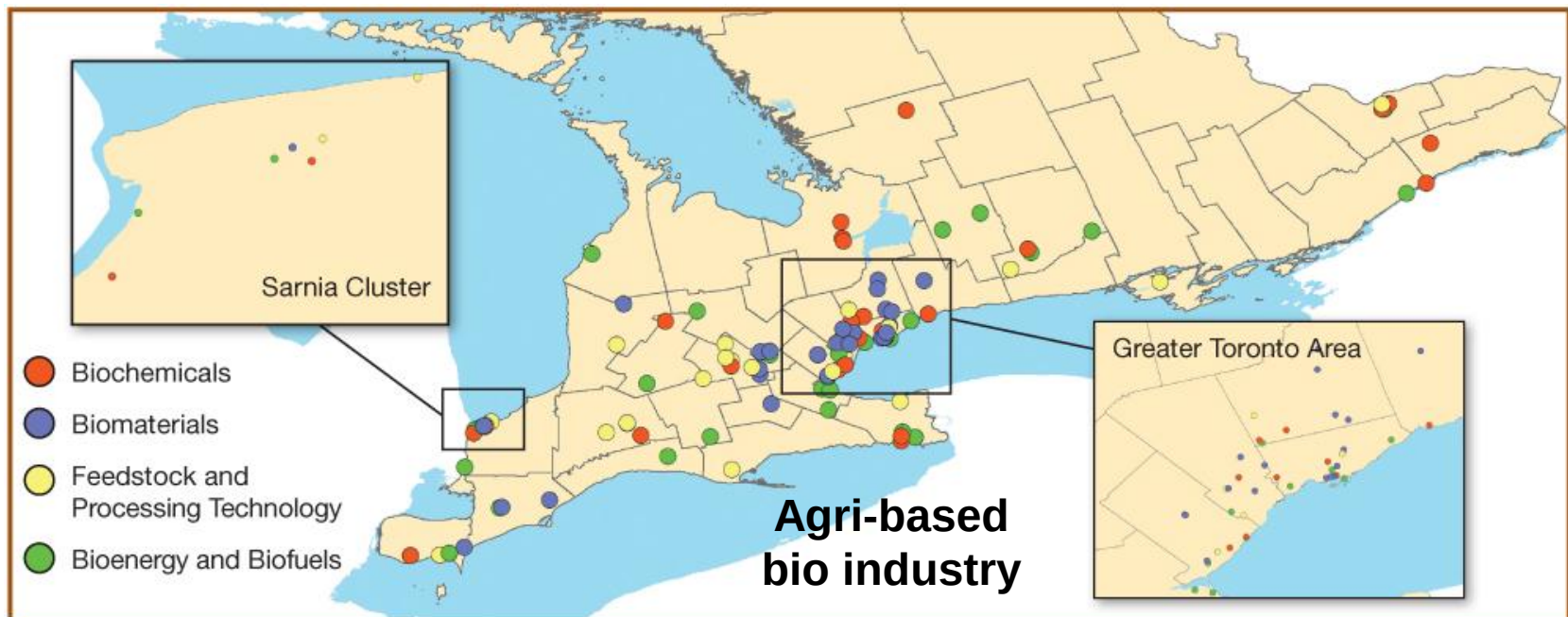


Bioproducts Represent New Opportunities for the Agricultural Sector

The Bioeconomy Benefits

The emerging bioeconomy offers can contribute significant socioeconomic, environmental and health benefits

- For Growers: crop diversification and new uses for agricultural feedstock to reduce risk and increased farm revenue; further benefit through participation or ownership positions in various components of the value chain.
- significant benefit to rural economies and job creation
- societal benefits with reduced exposure to toxic chemicals,
- new economic opportunities through manufacture of high value products based on renewable resources.



Agricultural Biomass for Ontario

- **Grains**
 - Corn, soybean, cereals, beans, canola, other
 - Dedicated or off spec
- **Forages**
 - Dedicated harvest or off spec hay crops
- **Crop Residues**
 - Corn stover, soybean stubble, cereal straw, other
- **Purpose grown biomass crops** (switchgrass, miscanthus, short rotation willow)
- **Emerging Industrial Crops**
 - Camelina, Carinata, Castor, Lesquella, Kenaf,
- **By-Products**
 - Food processing residues, Distillers Dried Grains (DDG's)
- **Other**
 - Livestock manure, landscape trimmings, organic wastes

Field Crop Production and Annual Renewable Carbon yield for Bioeconomy

Crops	Acres ¹ Seeded (2013)	Production (tonnes)	Annual Carbon ² Yield ^a (tonnes)
Grain Corn	2,225,000	9,007,300	3,783,066
Winter Wheat	1,060,000	2,277,900	956,718
Spring Wheat	80,000	113,600	47,712
Barley	115,000	134,600	56,532
Oats	70,000	58,000	24,360
Summary of Starch crops	3,550,000	11,591,400	4,868,388
Soybeans	2,500,000	3,078,100	1,539,050
Canola	55,000	44,200	22,100
Summary of Oil crops	2,555,000	3,122,300	1,561,150
Hay	2,000,000	4,399,800	1,847,916
Fodder Corn	260,000	4,889,700	2,053,674
Summary of forage crops	2,260,000	9,289,500	3,901,590
Total	8,365,000	24,003,200	10,331,128

Ref.

1. OMAF statistics: <http://www.omafra.gov.on.ca/english/stats/welcome.html>

2. Carbon content is assumed to be 50% of oil seed crops and 42% of starch seed crops and forages
http://www.biocap.ca/images/pdfs/BIOCAP_Biomass_Inventory.pdf

Potential crop residues and annual carbon yield

Field Crop ^{``}	Annual production (tonnes/year)	Grain to straw ratio ^a	Moisture content % ^a	Residue removal Factor % ^a		Collectible agricultural residues (dry tonnes/ year)	
				Lower	Upper	Lower	Upper
Grain corn	9,007,300	1:1	15.50%	33.00%	50.00%	2,511,685	3,805,584
Winter wheat	2,277,900	1:1.7	15.00%	30.00%	50.00%	987,469	1,645,782
Barley	134,600	1:1.5	15.00%	30.00%	50.00%	51,485	85,807
Spring wheat	113,600	1:1.3	15.00%	30.00%	50.00%	37,658	62,764
Oats	58,000	1:2	15.00%	30.00%	50.00%	29,580	49,300
Soybeans	3,078,100	1:1	15.00%	30.00%	50.00%	784,915	1,308,192
Canola	44,200	1:1	15.00%	30.00%	50.00%	11,271	18,785
Total			From different study reports - U of G study: 1.1 to 7.05 M tonnes/yr Aung O0 , BIC, Sarnia 3.12 M tonnes/yr			4,414,083	6,976,214
Carbon ^b yield				Sustainably available (%) ?		1,986,337	3,139,296

Ref

a. Reference for calculation J. Air & Waste Management Association, 57: 919-933

b. Carbon content based on an average of 45% C in OD biomass (Bioenergy conversion factors)

c. http://www.ofa.on.ca/uploads/userfiles/files/biomass_crop_residues_availability_for_bioprocessing_final_oct_2_2012.pdf

Potential Dedicated Perennial Biomass Species



Characteristics

- Efficient conversion of sunlight into biomass
- Efficient water and nutrient use
- Low input requirements
- Adaptation to marginal lands

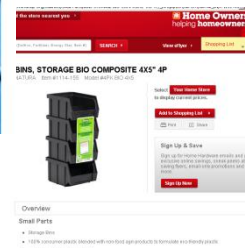
Bio-Bins Are U of G Innovation

Canadian retailers sell storage bins made with U of G biocomposite formula

By Andrew Vowles
Thursday, May 5, 2011



Perennial biomass
crop fibre based
biobins



Biomass crops are grown on approximately 3,000 acres in Ontario (mainly, miscanthus and switchgrass)

Key industry players for Miscanthus and Switchgrass in ON

New Energy Farms, Leamington, ON

- Developed unique, CEEDS (Crop, Expansion, Encapsulation and Delivery System), an 'artificial seed' technology for use with feedstock crops such as Miscanthus, napier grass, sugar cane, energycane,
- Fully scalable, reduced planting weight from 1.5 t to 250 Kg Ha (Miscanhtus X Giganteus)



Aims

To make perennial energy crop establishment as simple as drilling a row crop, scalable, low cost and maximize the yield potential of a cultivar.



<http://www.newenergyfarms.com/>

<http://faculty.agron.iastate.edu/heaton/docs/2013%20Biomass%20Workshop%20-%20Tiessen.pdf>

Switch Energy Corp, Clinton, ON

- Leading farm in ON with highest Switchgrass acreage (around 400 acres)
- Developing new markets for switchgrass biofibres and integrating with recycled agricultural plastic for biocomposite applications

<http://www.switchenergycorp.com/>



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Home Switch Grass Bale Wrap Program Web Management Routing Switchgrass Production





Industrial Fibre Crops



Potential Markets

Bast fibre

- Reinforcing in Biocomposties
- Insulation
- Textiles
- Woven and non- woven mats

Hurds/ Shives

- Animal bedding
- Construction
- Garden mulch
- Absorbent for liquid spills
- Dust
- Fuel pellets



Hemp

Kenaf

Stalk Yields (t/ha)

2.6-14

7.0-19.0

Fibre

Bast (75%), Core (25%)

Bast (40%), Core (60%)

Ref: Jim Todd, OMAF & MRA

Industrial Carbohydrate Crops



Jerusalem Artichoke



Chicory



Root/ tuber contains high proportion of storage carbohydrate **Inulin**, a polymer of fructose

Uses:

- As a functional food and as a low- calorie sweetening agent
- Production of fructose syrups
- Fermented to ethanol/butanol
- Production of bioplastics

Chicory

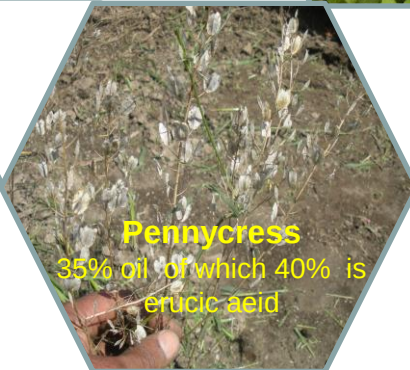
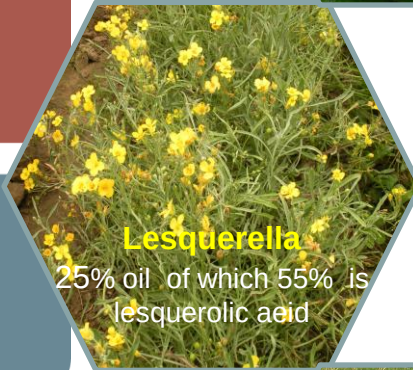
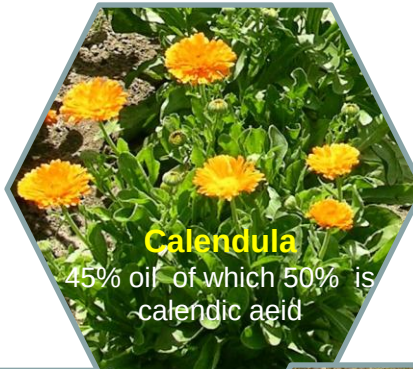
Jerusalem Artichoke

Inulin Yields (t/ha)
(est. from EU data)

20-25

10-13

Industrial Oilseed Crops



- For use in high value, personal care cosmetics and skin creams products
- Seed oil can be used in a wide array of products, including in paints, lubricants, greases, inks, polymers, waxes, plastics
- As biodiesel feedstocks

Other Industrial Crops



Russian Dandelion (*Taraxacum kok-saghyz*)

- The roots contain a high quality latex similar to that obtained from the Hevea rubber tree
- The roots and shoots also contain inulin, sugar with nutritional and industrial uses
- Rubber demand in NA: 2.7 billion lbs./yr (\$6 B)
- Breeding and agronomy research work at Guelph University

Ref: Jim Todd, OMAF & MRA



Sweet Stalk Millet



Sweet Stalk Sorghum

Sweet Sorghum and Sweet Millet

- Stalk juice brix 17 to 19%
- Sugars for ethanol and chemicals use
- For forage purpose
- AERC In, ON- agro-seed company specializing in the development of sorghum and millet hybrids for grain and forage

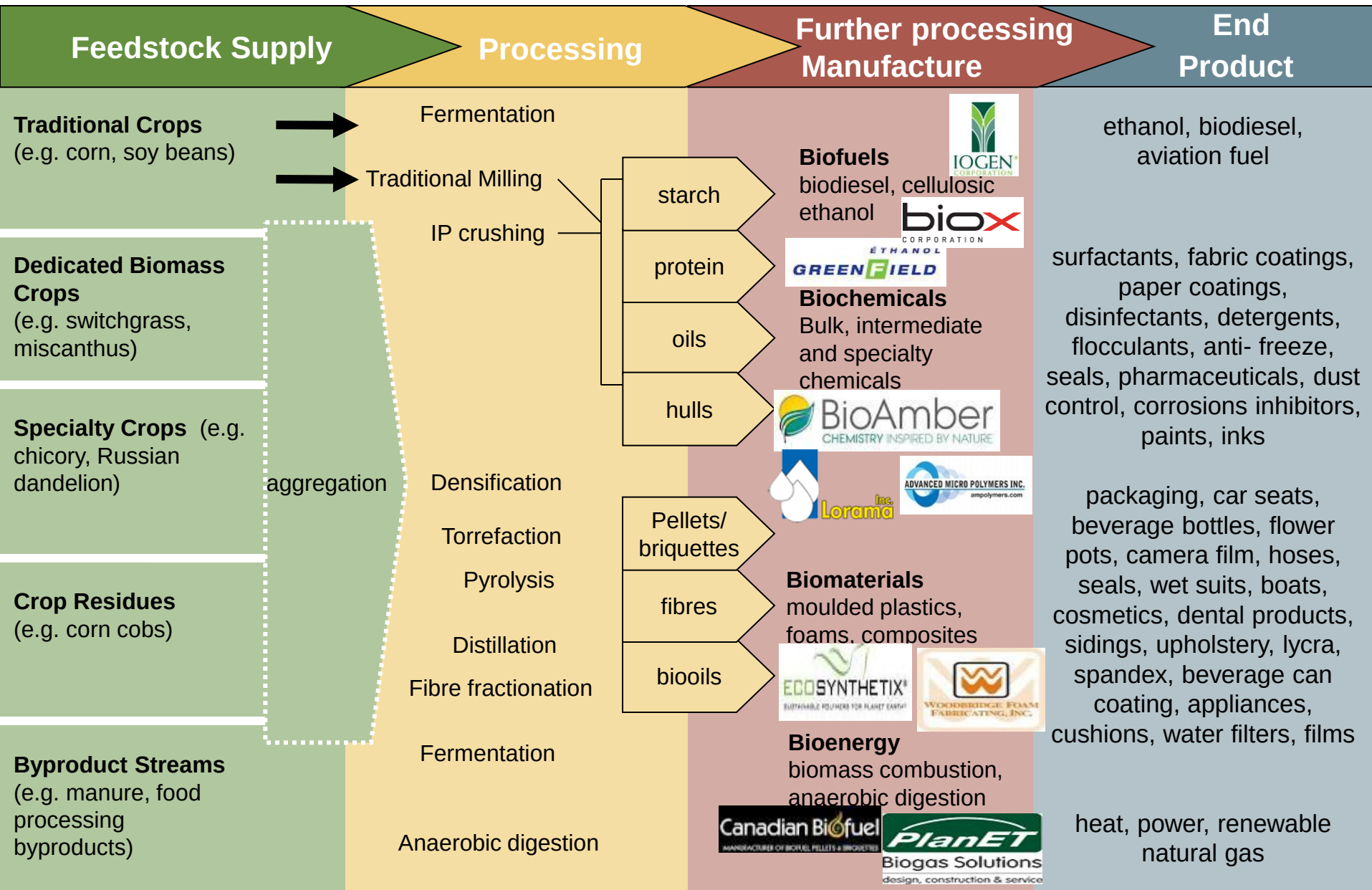


AERC Inc.

Agriculture Environmental Renewal Canada Inc.

Opportunities - Bioeconomy Supply Chain

- Opportunities for participation range from feedstock supply, aggregation, to processing to end product use



Thank You

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