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Irrigated Biofuel Production in Canada

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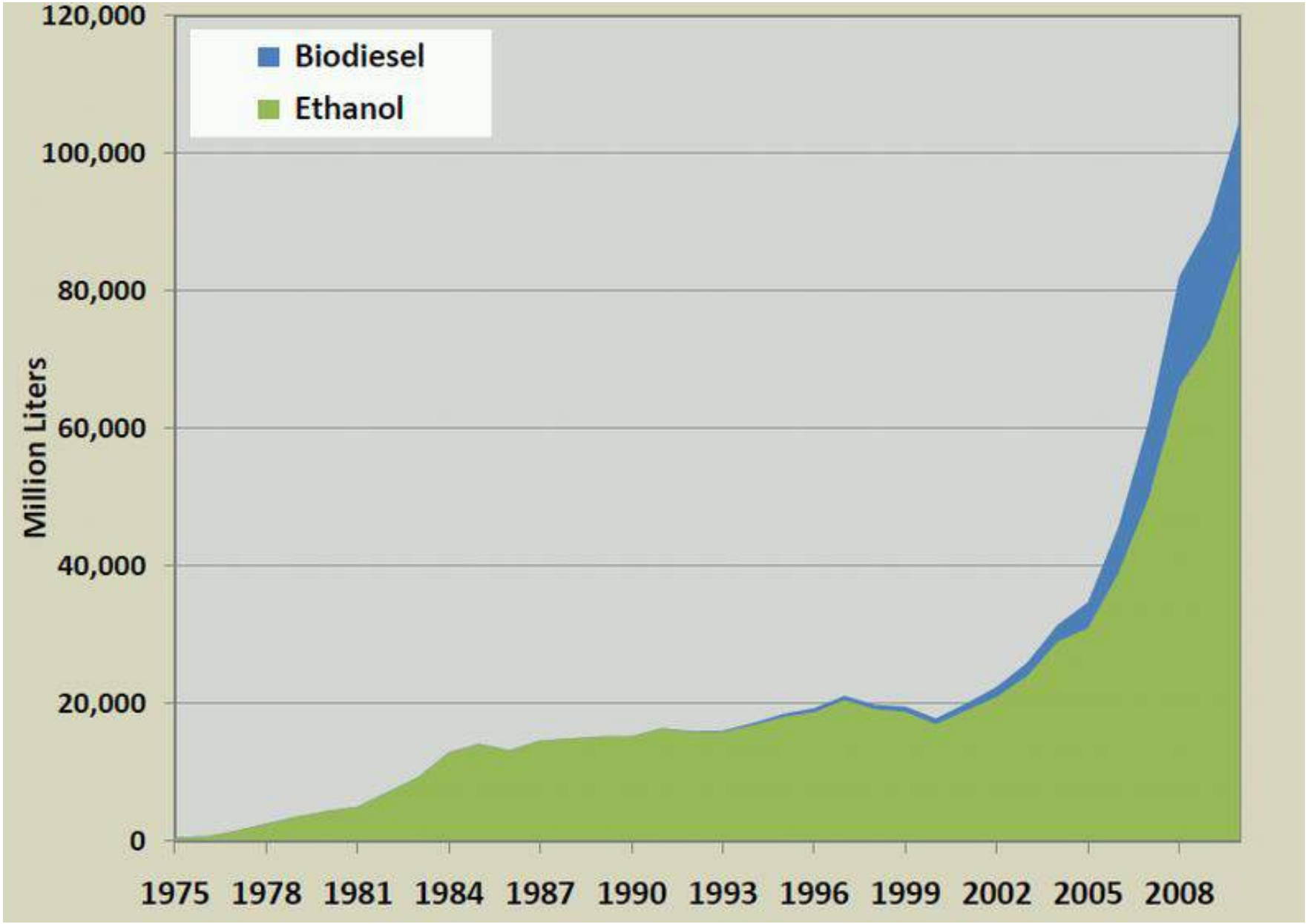
Canada

Global Bioethanol and Biodiesel Production 1975-2011



Global Biofuel Production

Biofuels used for:

- Reduce dependence on fossil fuels
- Reduce net emissions CO_2
- Improve commodity prices, improve farmer income and employment

- Biofuels provided 2.7% of all global fuel for road transportation in 2010; an increase from 2% in 2009.
- Ethanol: 86 billion litres produced worldwide in 2010
- Biodiesel: 20 billion litres produced worldwide in 2010

- Ethanol: produced directly from sugars in crops like sugarcane or sugar beets, or indirectly through hydrolysis of starch from crops such as corn, wheat, cassava. Advanced biofuel technologies, still under development, convert cellulose from agricultural residues, perennial grasses or woody materials.
- The United States is the world's leading ethanol producer (51 billion litres in 2011) and uses corn as feedstock. Brazil produced about 30 billion litres using sugarcane.

- Biodiesel: produced from cooking oils, animal fats or vegetable oil by transesterification to remove glycerine.
- Rapeseed is the primary feedstock in Europe, soya oil in South America and the USA, and palm oil in Southeast Asia.

Global Production of Ethanol

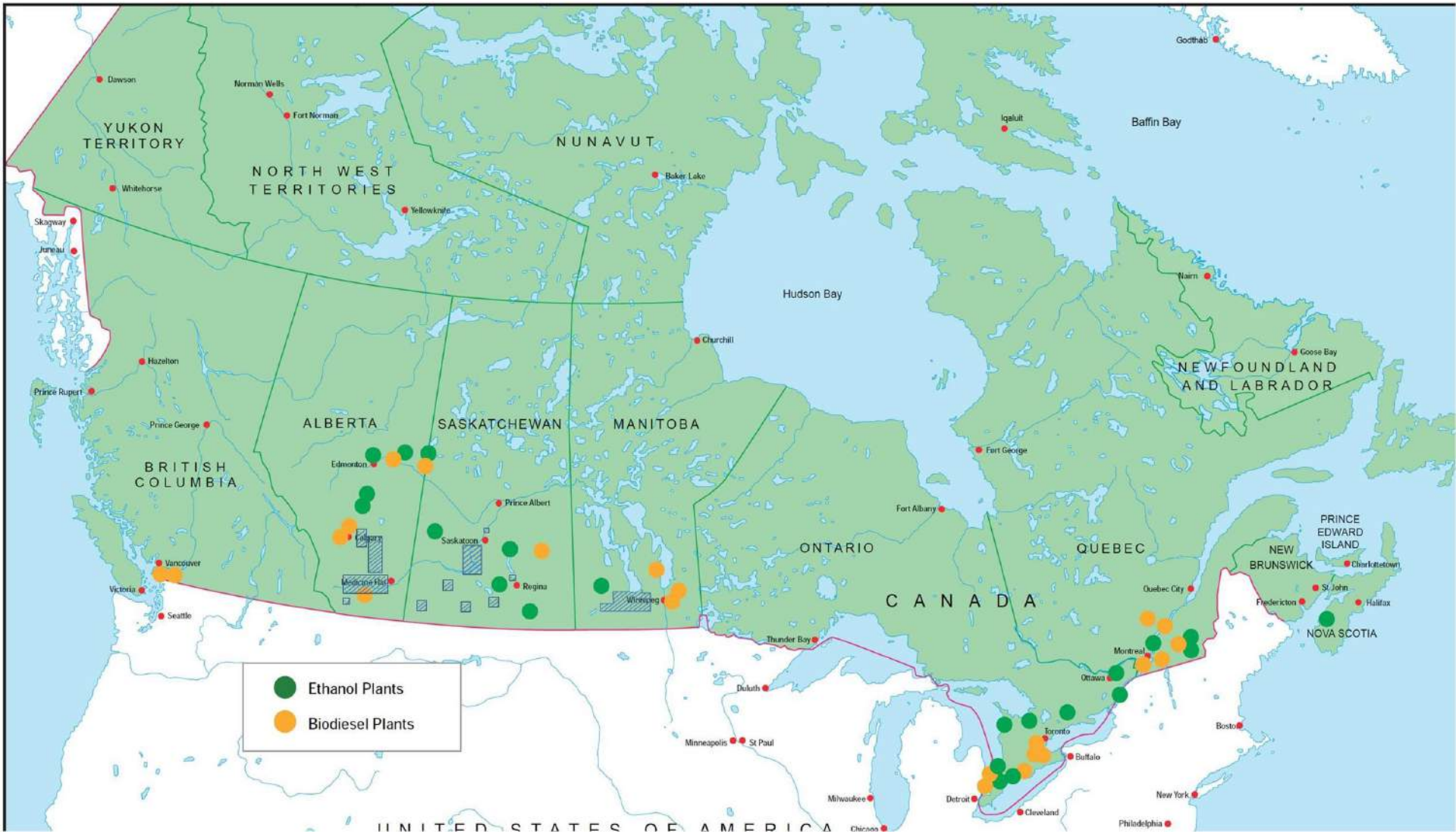
Country	Ethanol Production (millions of litres)		Feedstock crop (proportion of total ethanol production, if known)
	2010 (unless specified)	2011 (estimated)	
United States	49,210	51,100	Corn (100%)
Brazil	28,000	32,500	Sugarcane (100%)
China	2128	2217	Corn (80%) Wheat and rice (20%)
India	1435	1934	Sugarcane molasses (100%)
Canada	1200	1351 to 1800	Corn (75%) wheat(24%)
Germany	1042	1100	Wheat and rye (major feedstocks) Barley, maize and triticale (minor feedstocks)
France	805-1150(2009)	NA	Sugar beet (major feedstock) Wheat, maize (minor feedstocks)
Thailand	426	528	Sugar molasses (80%) Tapioca (20%)
World	**85,800**	**88,700**	

Global Production of Biodiesel

Country	Biodiesel Production (millions of litres)	Feedstock (proportion of total biodiesel production, if known)
	2010	
Germany	2900	Rapeseed
Brazil	2450	Soy bean (80%) Animal tallow (15%) Cotton seed oil (4%)
Argentina	2100	Soybean (100%)
France	2000	Rapeseed
United States	1200	Soybean (60%) Canola (10%) Recycled grease + Animal tallow (20%)
Spain	1100	Imported soy (43%) and palm oil (38%); Animal fats and recycled oils (12%)
Indonesia	700	Palm oil
Thailand	600	Palm oil
Canada	110-200	Animal fats (60%) Canola oil (14%) Yellow grease (13%)
World	**19,884**	

Biofuel Production: The Canadian Picture

Ethanol and Biodiesel Production Plants in Canada



Blue cross-hatch approximates irrigated areas.

Canadian Ethanol Production

- 1.83 billion litres per year
- 75% generated using corn as the feedstock and 24% using wheat.
- Most of Canada's ethanol capacity located in Ontario (63%) and Saskatchewan (18%)
- There are currently 15 operational ethanol production plants in Canada, 5 demonstration plants and 5 plants under construction or proposed
- Canada's Renewable Fuel Standard (RFS) of E5 (5% ethanol in gasoline) means that 2.14 billion litres of ethanol is currently required. Assuming that all plants are built, Canadian ethanol capacity will rise to 2.1 billion litres in the next few years. This indicates that ethanol imports or additional production capacity will be required to meet the RFS as gasoline demand in Canada grows.

Canadian Biodiesel Production

- 0.21 billion litres with Ontario and Quebec accounting for 37% and 29% of total capacity. British Columbia, Alberta and Manitoba share the remaining capacity.
- Currently 13 operational biodiesel plants, 5 proposed and 3 under construction. If all plants are built, biodiesel production capacity will increase to 1.2 billion litres. This is double the amount required to meet the RFS B2 (2% biodiesel) mandate.
- Biodiesel production from tallow (animal fats) is currently 60% but is expected to fall dramatically in 2012 (to 34 %) with the expected completion of a 225 million litre canola-oil feedstock based biodiesel plant in Alberta

Current and Potential Ethanol Production Capacity in Canada

Province	Current Operational Capacity for Ethanol Production		Potential Capacity for Ethanol Production	
	Million litres/year	Proportion of total (%)	Million litres	Proportion of total (%)
Alberta	42	2.3	258	12.2
Saskatchewan	342	18.7	342	16.2
Manitoba	130	7.1	170	8.0
Ontario	1154	63.1	1154	54.5
Quebec	160	8.7	192	9.1
TOTAL	**1828**		**2116**	

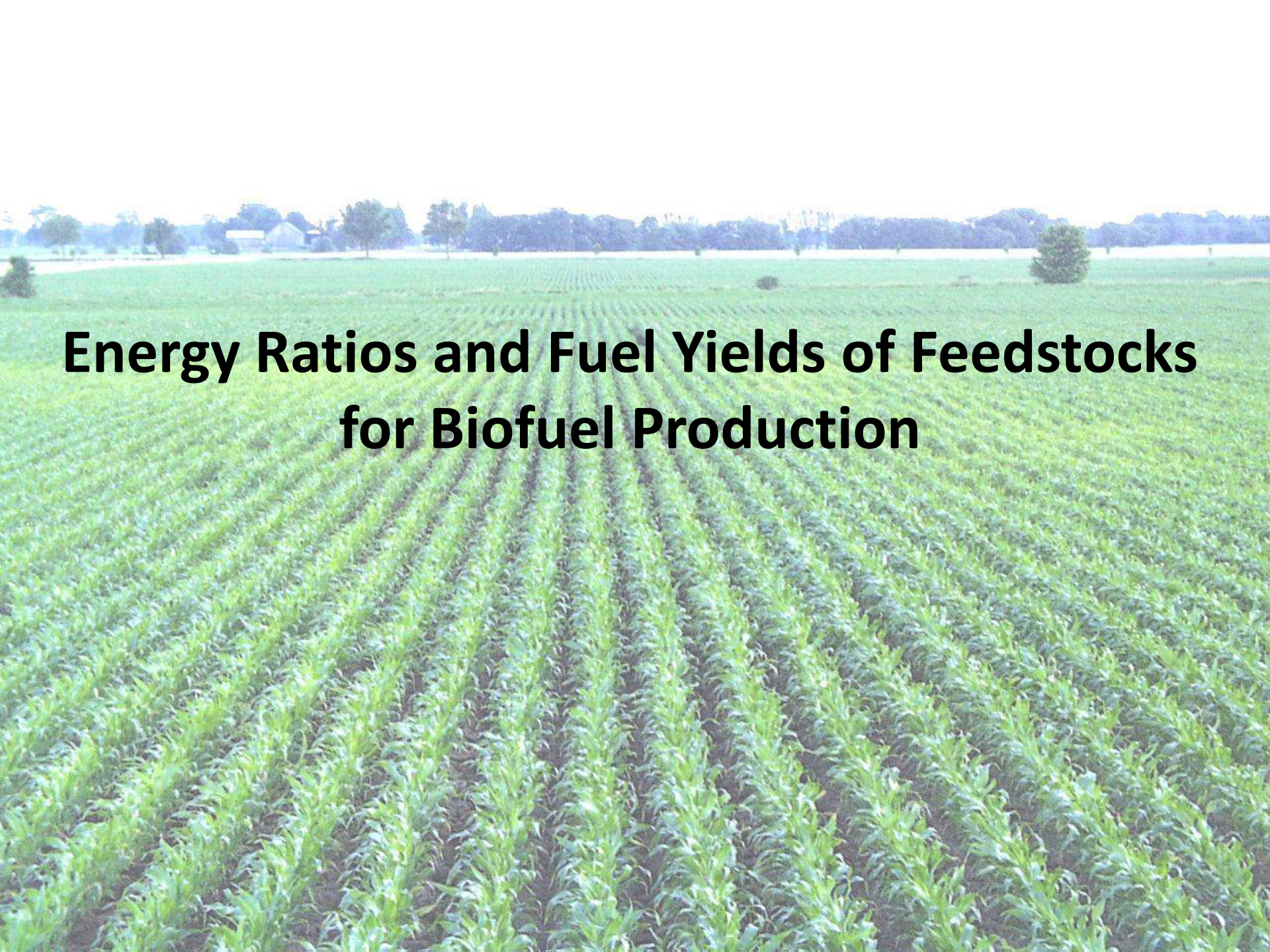
Current and Potential Ethanol Capacity in Canada by Crop

Province	Current Capacity for Ethanol Production		Potential Capacity for Ethanol Production	
	(million litres/year)			
	Wheat	**Corn**	**Wheat**	**Corn**
Alberta	42		222	
Saskatchewan	342		342	
Manitoba	65	65	65	65
Ontario		1152		1152
Quebec		155		155
TOTAL	**449**	**1372**	**629**	**1372**
% of Total Production	**24%**	**75%**	**30%**	**65%**

Biodiesel Production in Canada

Province	Current Operational Capacity of Biodiesel Production		Potential Operational Capacity of Biodiesel Production*	
	Million litres	Proportion of total (%)	Million litres	Proportion of total (%)
British Columbia	21	10	21	2
Alberta	20	10	588	49
Saskatchewan	1		1	
Manitoba	28	14	28	2
Ontario	76	37	363	30
Quebec	60	29	200	17
TOTAL	**206**		**1201**	

Province	Current Capacity for Biodiesel Production by Feedstock (million litres/year)			Potential Capacity* for Biodiesel Production by Feedstock (million litres/year)		
	Canola	**Multi-feedstock**	**Grease/oil**	**Canola**	**Multi-feedstock**	**Grease/oil**
British Columbia			21			21
Alberta	1	19		503	85	
Saskatchewan	1			1		
Manitoba	28			28		
Ontario		66	10		353	10
Quebec		50	10		90	110
TOTAL	**30**	**135**	**41**	**532**	**528**	**141**
% Total Production	**14%**	**66%**	**20%**	**44%**	**44%**	**12%**



Energy Ratios and Fuel Yields of Feedstocks for Biofuel Production

- **Energy ratio**: The amount of energy produced by a unit of biofuel compared to the amount of fossil fuel energy required to produce that unit (ie output vs inputs)
- Biofuel production from crops has two major energy inputs:
    1. Production of the feedstock crop (roughly 35%)
    2. Extraction of ethanol or biodiesel from the crop (roughly 65%)

By-product credit: by-products generated during biofuel production are included in the calculation of the energy ratio as "credits".
Ethanol production from corn: a by-product credit is given for the heat used to prepare dry Distiller's Grain with Solubles (DGS). Including this credit raises the energy ratio from 1.4 to over 1.9.

Sugarcane has the highest energy ratio, producing an output of energy that is about 800% greater than input energy.
Corn and wheat ratios vary from have energy ratios between 1.1 and 2.4 or produce 100 to 140% more energy than is required for inputs.

- **Biofuel yield** depends on the amount of fuel that can be extracted from the crop (conversion ratio) and the crop yield.
- Sugarcane and corn (including grain and stover) both have the potential to produce 7000 litres per hectare although the average is much lower and stover is rarely used.
- In Canada, corn (grain only) yields about 3800 litres ethanol /ha and wheat 1700 litres/ha.

Energy ratios and fuel yields of various feedstock crops

Biofuel type	Energy Ratio	Conversion Rate	Biofuel yield	Country
Crops for: Ethanol	*Output energy/input energy*	*Litres ethanol/t dry crop*	*Litres/ha*	
Corn	1.7 – 2.4*	400	3600-4000	Ontario, Canada
Corn	1.4-1.9*	417	3300; 6900-7500 (from grain +stover)	U.S.
Wheat	1.1-2.1	370-386	1000-3000 1657	E.U. Canada
Triticale		368	1757	Canada
Sugar beet	1.5-2.1	94	3400-8000	E.U.
Sugarcane	8-9.3	70 -83	4900 - 6767	Brazil
Agricultural residues		110-270 310-400 (theoretical)		Canada U.S.
Wood residues		120-300		Canada
Switch grass		98-115 203-222 (theoretical)	2,534–3,720	U.S.
Miscanthus			3963	Kansas, U.S.
Biodiesel		***Litres biodiesel/t dry crop***		
Canola	2.1-4.5	470	676	Canada
Soybean	2-3.6 2.1-2.4		460-520 419	U.S. Canada
Palm oil	4		4800-5675	Malaysia-World
Jatropha	1.4-6.0		1818	World


Greenhouse Gas Emissions Reduction

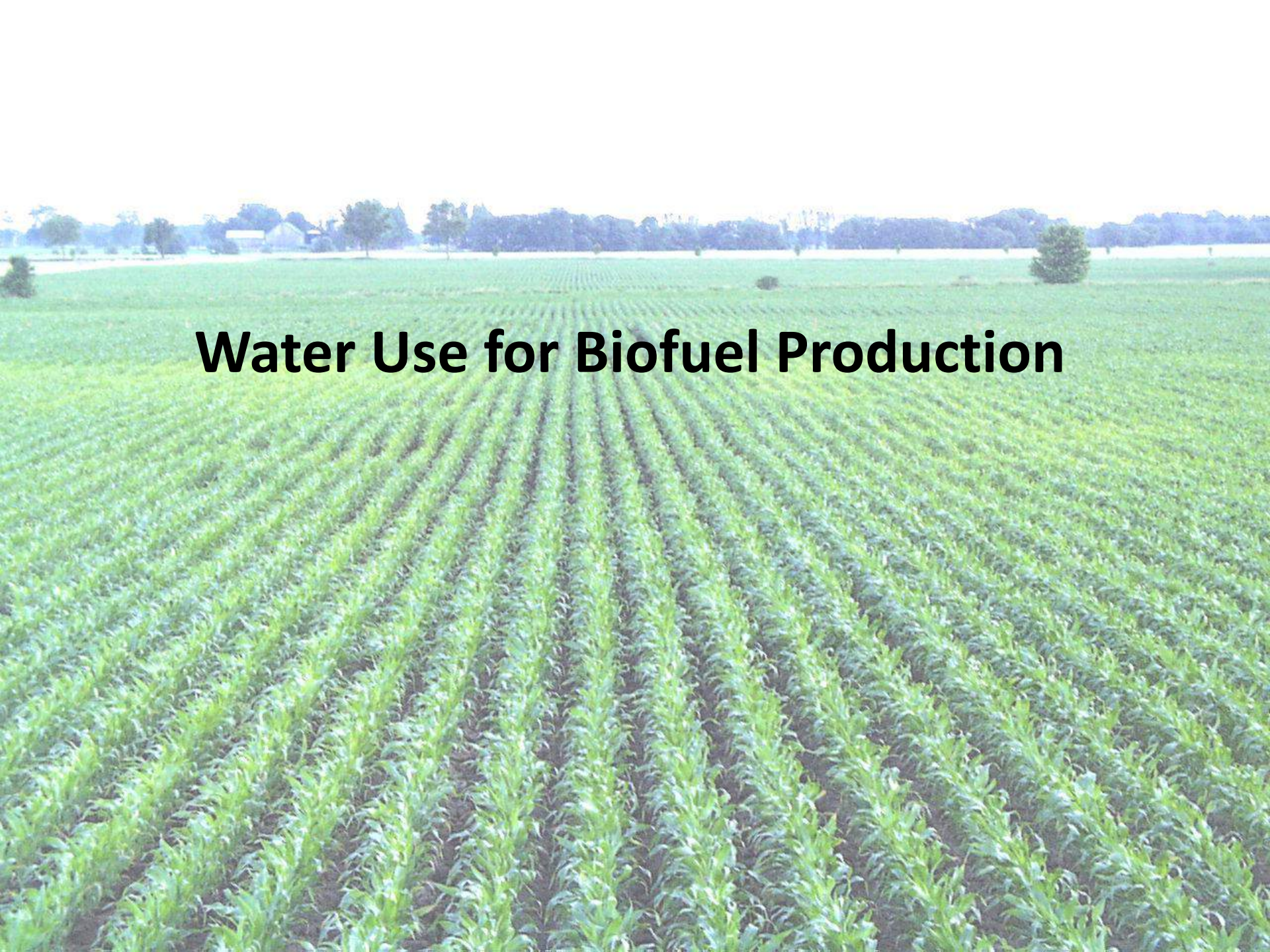
- **GHG emission assessments** are very complex and are related to the full fuel lifecycle from feedstock generation or extraction through the distribution and delivery and use of the finished fuel by the ultimate consumer.
- Direct and indirect emission including significant emissions from land use changes are part of the calculation.
- The resulting Life Cycle Assessment (LCA) value is the percentage increase or decrease in GHG emissions compared to a baseline of gasoline or diesel fuel.

- In the United States there are specific greenhouse gas emission thresholds:
  - 20% reduction in lifecycle GHG emission for any renewable fuel produced at new facilities
  - 50% reduction in order to be classified as biomass-based diesel or advanced biofuel
  - 60% reduction in order to be classified as cellulosic biofuel.
- In the European Union, biofuels must have GHG emissions savings of at least 35%

- GHG emissions vary widely depending on the kind of energy used during biofuel extraction at the processing plant.
- GHG emission reductions are highest when sugarcane, agricultural residues, switchgrass are used to produce ethanol (80 to 128%) and waste oils are used to produce biodiesel (83%).

Change in Greenhouse Gas Emissions due to Biofuel Production

Crop Feedstock	Conversion Method (if known)	Amount GHG emissions are reduced (-) or raised (+)
Ethanol		***%***
Corn	Coal Dry Mill	+13 to +34
Corn	Natural Gas Dry Mill	-16 to +5
Corn	Best Case Natural Gas Dry Mill	-39 to -18
Corn	Biomass Dry Mill with Combined Heat and Power	-47 to -26
Corn Stover		-115
Sugar beet		-52
Sugarcane		-80 to -26
Switchgrass		-128
Biodiesel		
Soy bean		-31 to 4
Rapeseed		-38
Sunflower		-51
Palm oil		-19
Palm oil	Methane capture at oil mill	-56
Waste vegetable or animal oils		-83



Water Use for Biofuel Production

Water and Biofuels

- Biofuels account for 1% water transpired worldwide and 2% water withdrawals
- Main concern irrigated sugar cane and maize

Crop	Annual obtainable fuel yield	Energy yield	Evapotranspiration equivalent	Potential crop evapotranspiration	Rainfed crop evapotranspiration	Irrigated crop water requirement	
	(Litres/ha)	(GJ/ha)	(Litres/litre fuel)	(mm/ha)	(mm/ha)	(mm/ha)[1]	(Litres/litre fuel)
Sugar Cane	6,000	120	2,000	1,400	1,000	800	1,333
Maize	3,500	70	1,357	550	400	300	857
Oil Palm	5,500	193	2,364	1,500	1,300	0	0
Rapeseed	1,200	42	3,333	500	400	0	0

[1] On the assumption of 50 percent irrigation efficiency.
Source FAO, 2008a

- Policies need to support development of biofuels that account for the production and processing of biofuel crops on water availability to meet local needs

- 1 % of the total sugarcane crop in **Brazil** (approximately 40,000 ha) is irrigated although the proportion that is used for ethanol production is uncertain.

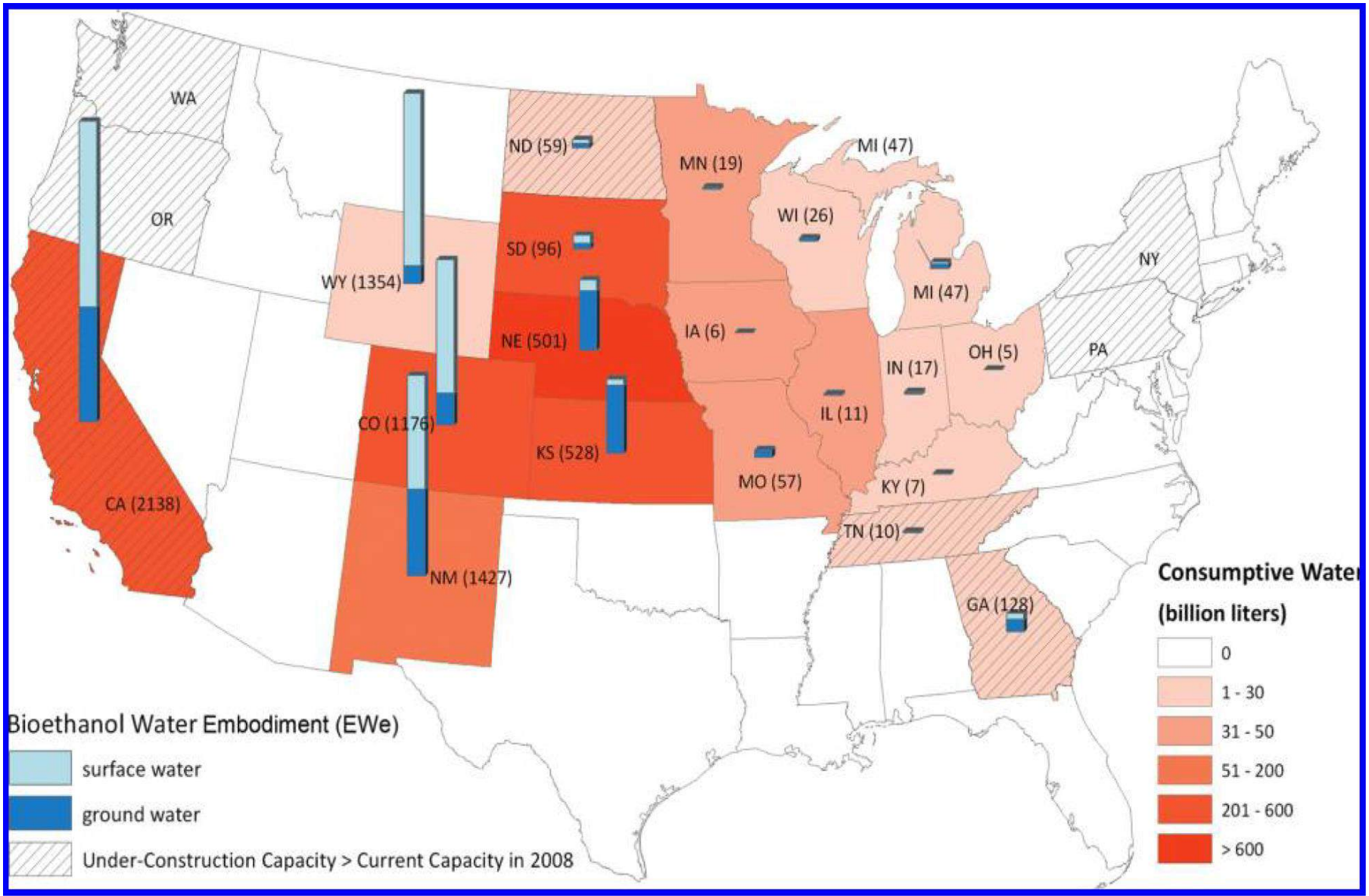
- The major feedstock crops in **Germany and France** (wheat, sugar beet and rapeseed) are not irrigated.

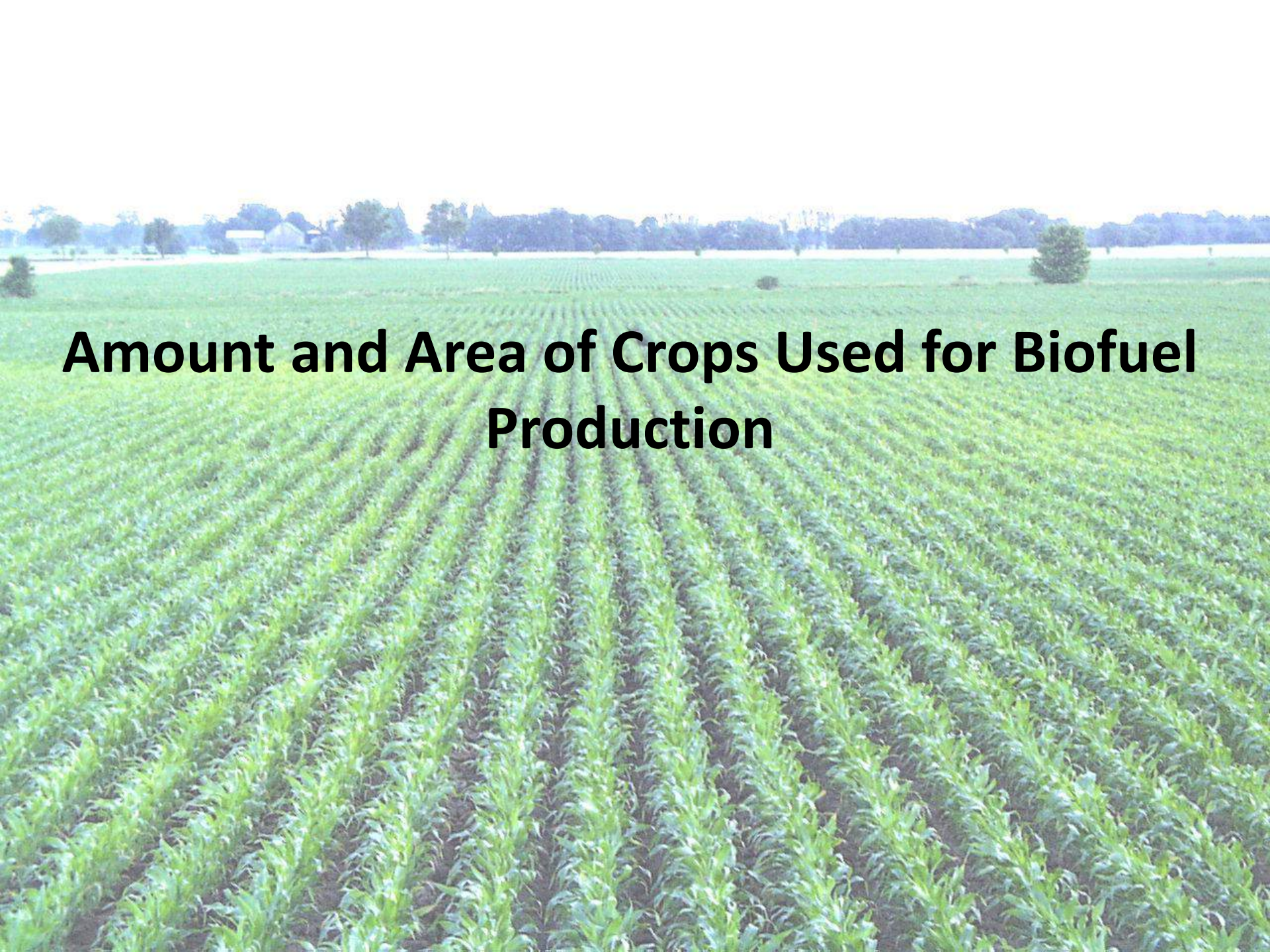
- In **Canada**, corn, wheat and canola used for biofuel production are not presently irrigated
- In **India**, sugarcane is mostly grown under full control irrigation and a litre of ethanol produced from this sugarcane requires 3,500 liters of irrigation water

- In the **United States** about 15% of the corn crop used for ethanol production is irrigated.
- Water used for irrigation and processing in the U.S. varies from 5 to 2138 L per liter of ethanol depending on regional irrigation practices.
- A significant proportion of this water came from the Ogallala reservoir
- The proportion of irrigation water which went to biofuels in the United States was about 3% in 2005. This is projected to rise to 20% in 2030 under current government biofuel mandates.

Irrigation Water Use for Corn Production to Produce Ethanol in the U.S.

The foreground bar shows irrigation water used per litre of ethanol produced. Surface and ground water amounts indicated by colour. Background colour of each state indicates total water consumed.





Amount and Area of Crops Used for Biofuel Production

Amount and Area of Crops Used for Biofuel Feedstocks

Country	Crop	Amount used for ethanol	Year	Area
		Million tonnes		Million hectares
World	All		2006 2011(e) 2050(f)	14 (1% total arable) 30 (2% total arable) 100 (6% total arable)
		3% world's grain supply	2010	
Brazil	Sugarcane	318	2010	4.3 (48% of sugarcane)
E. U.	Cereals	9	2010	
	Sugar beets	10	2010	0.24
	Rapeseed	17	2009-2011	4-5 (60-75% of rapeseed)
	Wheat		2008	0.5
	Wheat		2013 (f)	1.5
Germany	All biofuel crops		2010	(16 % total arable)
U.S.	Corn	117	2010	12.2 (31% total corn)
	Corn	127	2011(e)	13.8 (40 % total corn)
Canada	Corn	2.1	2009	0.23 (21% total corn)
		2.3	2010	0.26 (26% total corn)
		2.6	2011(e)	0.26 (26% total corn)
	Wheat	.65-.71	2010 (e)	0.26-0.28(3%total wheat)

f=forecast; e=estimate.

World: 2% of agricultural land currently used for biofuel production. Estimated to rise to 6% by 2050.

Brazil: almost half of the sugar cane grown is used for ethanol or 1- 2% of total agricultural land.

Germany: 16% of arable land is used to produce all biofuels.

U.S: About 40% of the area used for corn in the U.S. is for ethanol production or about 3% of total farm land.

Canada: ethanol production currently uses about 26% of the corn and 3% of the wheat growing areas.

If all ethanol plants ran at full capacity these numbers would rise to 38 and 4.7% respectively. If planned ethanol plants are built, wheat growing areas would rise to 6.6% of wheat growing area.

Alberta's future biodiesel production will require about 1 million ha of canola. This is roughly 10% of the total land used for canola in Canada.

Crops Used and Land Required to Produce Ethanol in Canada at Current and Potential Capacities

(Assume all ethanol plants run at 100% capacity)

Province	Land Currently Required (hectares)		Land Required at Potential Production Capacity (hectares)	
	wheat	corn	wheat	corn
Alberta	38,600		204,000	
Saskatchewan	314,400		314,000	
Manitoba^	59,800	18,000	59,800	18,000
Ontario		320,000		320,000
Quebec		43,000		43,000
TOTAL AREA	**412,800**	**381,000**	**577,800**	**381,000**
% of Total Wheat or Corn Production in Canada	**4.7%**	**38%**	**6.6%**	**38%**

Land Use Change

Canada: expansion of biofuel production has not caused land-use changes because of improvements in seed, better agricultural practices, continued growth in crop yields, technological improvements in ethanol production.

United States: area planted to corn increased from 29.3 to 32.2 million ha between 2000 and 2009. In 2011, area planted to corn was estimated to be 37 million ha, an additional increase of 13.5% in area over 2009.

This was a result of:

- reduced area planted to other crops such as cotton,
- a shift from uncultivated hay to cropland,
- expansion of double cropping (consecutively producing two crops of either like or unlike commodities on the same land within the same year

Increased conversion of hay or pasture to crop production, or an increase in area which is double-cropped and uses more inputs, may accelerate nutrient runoff and soil erosion.


Canadian Biofuel Feedstocks

Characteristics of Corn used as an Ethanol Feedstock in Canada

Accounts for 75% of ethanol production in Canada
Relatively high starch content (70-72%)
Yields 400 litres ethanol per tonne grain and 3600-4000 litres/ha

Produces by-product, distillers grains with solubles (DGS), a valuable, high-protein animal feed. Can be sold in wet form (WDGS) to local cattle feedlots and dairies although it spoils quickly. Can also be dried (DDGS) and sold as a high-protein ingredient for cattle, swine, poultry, or fish feed.
For every 100 kg corn processed, 30 kg of DGS is produced as well as 30 kg of CO_2 which is used in the food and beverage industry

Energy outputs greater than inputs, but variable depending on credits given for by-products, which may or may not find a market as supplies increase.
Effects of intensive corn crop management on soil fertility and local water quality must be considered.
Ethanol production and cattle feedstock compete directly for corn and there is controversy about how much of recent corn price increases are a result of rising demand for ethanol.

Characteristics of Wheat used as an Ethanol Feedstock in Canada

Accounts for 24% of ethanol production in Canada.
Starch content of wheat ranges from 56-61%.
Canada Western Soft White Spring (CWSWS), Canada Prairie Spring Red (CPSR) and Canada Spring Prairie White (CPSW) classes of wheat have highest starch levels and produced the greatest amount of ethanol (about 380 litres/tonne).
Yields about 1700 litres ethanol/ha

Majority of ethanol production capacity expansion in the medium term will take place in Alberta and will use wheat as a feedstock. If the two proposed plants are built and run at full capacity, they will require 0.5 million tonnes of wheat annually. At a yield of 2.9 tonnes/ha this will require 166,000 hectares. This is in addition to the 38,600 ha of wheat crop already being used.

Wheat generates by-products similar to corn.

Wheat prices in Canada are directly related to international grain prices. The economics of using wheat as a feedstock will depend on the market price of the grain.

Characteristics of Canola used as a Feedstock in Canada

Major crop feedstock for biodiesel production in Canada; produces 14% of biodiesel. Animal fats and yellow grease currently dominate plant production needs.

Canola forecast to rise to 46% of biodiesel production if all planned production plants are built.

Produces 470 litres biodiesel/tonne grain and 670 litres biodiesel/ha

According to the Canola Council for Canada, Canadian farmers are already growing more than enough canola to fill the demand for both food and fuel. The federal government's 2% biodiesel mandate would require about one million tonnes (MT) of canola seed annually.

Historically, food demand has left enough carryover (ending stocks) of canola seed to fill this biofuel demand. This could however, result in lower canola exports.

Use of Lignocellulosic Feedstocks in Canada

Agricultural Residues: Average residues for wheat, barley, and oat, are 1.3, 1.0 and 1.2 tonnes/ha, approximately 60% of straw can be converted to sugars and 394 litres ethanol/dry ton wheat straw produced

The amount of straw that can be removed and utilized should be based on::

- value of straw for soil erosion control;
- equivalent fertilizer value of the nutrients contained within the straw;
- value of the straw for building soil organic matter, soil quality, and soil tilth;
- value of the straw for soil moisture conservation

Switchgrass: perennial grass, native to the prairie region of North America; has high productivity, persistence and wide adaptation.

Yields 100-200 litres ethanol/tonne crop and 2500-3700 litres/ha.

Still in experimental stage

Wood: Hybrid poplar is the target of large breeding programs and plantations for solid wood and pulp and paper production. It can be grown in many regions of the US and Canada but to date the amount of land in industrial plantations is still quite limited. Produces

Economics of Biofuel Production

Baseline for measuring the economics of biofuels is the price of gasoline and diesel.

Rising costs of biofuel feedstocks have increased production costs of biofuels.
Cost of ethanol production from sugarcane, currently the most economical biofuel feedstock to produce, was less than the price of gasoline only one year out of five between 2000 and 2010.

Biodiesel economics are more unfavorable than ethanol. Biodiesel feedstock costs alone have generally been higher than petroleum diesel prices.

Cellulosic feedstocks (switchgrass and corn stover) have low production costs and high initial investment costs. The latter value will decline over time as technology improves.

The amount of energy in ethanol is only 66% that of gasoline which means every litre of gasoline replaced requires 1.24 litres of ethanol to produce the same energy. Drivers who fill their tanks with E5 are getting slightly worse mileage than with pure gas. This makes the economics of ethanol less encouraging.

Approximately 40% of petro-refinery products come from non-fuel products although they may make up only about 5% of the refinery output.
Such high-value products have not yet been developed for biorefineries although it is likely that valuable bioproducts will eventually be developed.

Costs of Producing Biofuels from Various Feedstocks

Feedstock	Country	Net Production Cost USD/litre	Total Project Investment* USD/litre
Corn	United States	0.41-0.79#	0.77
Sugarcane	Brazil	0.30	0.51
Grain-based	E.U.	0.58	NA
Beet-based	E.U.	0.48	NA
Switchgrass^	United States	0.27	.76
Corn stover	United States	0.39	1.10
Soybean	United States	0.53-0.67	0.14

From an informal estimate based on a corn price of USD 7.00/bushel
*Cost for a 45 MM/gal/y plant depreciated over 20 years.
^From research plots dedicated to switchgrass production in Tennessee
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Uncertainties in Predicting Future Biofuel Demands

Biofuel demand in Canada and around the world is driven by:

- Oil prices,
- Cost of other transportation energy alternatives (e.g. electric vehicles)
- Government policies which mandate biofuel use and provide incentives for production.
- Cost of water and land prices and the proximity to feedstock relative to processing plants

It is likely that high and volatile food prices and food insecurity predicted for the future will drive the focus away from the use of food crops for biofuels towards non-food crops.

Biofuel Opportunities in Canada Under Irrigation

Irrigated crops are not currently used for biofuel production in Canada.
Planned expansion of biodiesel production in canola growing areas of Alberta will not use irrigated cropland.
In Saskatchewan and Manitoba, ethanol plants are located at the edge of irrigated areas, but there is no evidence that irrigated crops are currently used as feedstock.

Irrigation can more than double wheat yields when water is limiting and, if infrastructure is already in place, may help to develop a reliable source of biofuel crops in some areas.
The price of water would have to be accounted for in any cost-benefit analysis. Where there is currently no irrigation infrastructure, the investment in off- and on-farm irrigation infrastructure and the costs of operating irrigation equipment are almost certainly not cost effective for producing biofuel feedstock

Biofuel production offers an alternate market for many crops. Multi-feedstock plants that can utilize crops as well as lower cost materials such as waste oils for biodiesel production, or cellulosic materials for ethanol production, would allow the farmer to obtain a fair crop price and reduce the overall price of feedstock to the production plant.
The market will determine if an irrigated crop is viable for use as a biofuel.

Research and Technology Transfer Needs for Sustainable Biofuel Production under Irrigation

- Breeding and agronomics of biofuel crops
- Sustainable management methodologies, which may include irrigation
- Plant processing technologies and by-product development
- Potential for genetically engineering the genes of purpose-grown feedstock for production of really high value by-products, such as pharmaceuticals
- Potential locations for future biofuel plants should be studied and include:
  - long-term economic impacts on the food and fuel sectors
  - environmental impacts,
  - benefits to the farmers and local communities,
  - economics of the processing.

Although research and technology into the use of lignocellulosic feedstocks for ethanol is evolving more slowly than anticipated, perennial grasses and woody production systems are increasingly felt to be the future of ethanol production.

Low water and fertilizer requirements and the fact they are not a food crop and can be grown on marginal crop lands, are strong advantages.