A Life Cycle Assessment (LCA) of the potential for biofuels to reduce greenhouse gas emissions and fossil fuel consumption: Comparative assessment of two regions in Ontario, Canada

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Summary report from Master of Arts thesis to participants and interested individuals

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Summary

Policy makers in Ontario and throughout the world encourage biofuels as a greenhouse gas reduction measure and energy alternative. Increased biofuel production, timed with fluctuations in energy and cereal prices have sparked questions about the impact of biofuel on other production systems, social impacts, net environmental effects and the need for improved accuracy in accounts of "life cycle" greenhouse and fossil fuel reduction potential.

The production of biofuel occurs over many stages and requires inputs from diverse locations. To date, assessments of the life cycle energy and greenhouse gas costs of producing fossil fuels and biofuel alternatives have largely been oblivious to diversity in local production conditions.

This study employed the life cycle assessment method to assess fossil fuel use and greenhouse gas emissions for E5 fuel and gasoline in Ontario (Canada). Southern Ontario and eastern Ontario regional case studies were compared to assess the extent to which regional variations might alter the potential for biofuels to reduce GHG emissions and fossil fuel consumption. This study also compares these more detailed regional studies to a more generalized provincial case study in order to gauge the value of conducting place based research compared to "reconnaissance" level studies. Overall, this research provides preliminary evidence on the need to incorporate regional variation in biofuel LCA and information on a path towards optimizing biofuel production in diverse locations.

Major Findings

(1) Place matters #1: Place of corn production alters ethanol fuel characteristics.

Corn farming is a highly variable process requiring fuels for machinery, direct inputs to the field and energy to dry grain. Regional variation in inherent physical potential for growing corn and a regional component in dominant farm management practices alter the fossil fuel consumption and GHG emissions associated with grain corn production for ethanol fuels in Ontario.

The E.Ont case represents a region that has a colder climate with lower corn yield than southern Ontario (8.9 tonnes / ha vs. 10.1 tonnes / ha) and relatively low adoption of conservation tillage (19% of crop area of vs. 44%). These regional differences together with differences in rates of fertilization contribute to an estimated 60% fewer GHG emissions and 80% fewer fossil energy consumed in the S.Ont case compared to the E.Ont case. This difference is substantial enough to suggest that (from a GHG and fossil fuel use perspective only) it is justified to truck corn from southern Ontario to eastern Ontario ethanol plants when making E5 fuel.

Regional differences were not seen for all production processes. Most conversion of corn to ethanol in both southern and eastern Ontario occurs in ethanol plants using the same "dry-mill" process, and designed on a similar technical layout suggesting consistent emissions and fossil fuel use for this stage of E5 production across the province.

(2) Place matters #2: E5 production regions combines local and external inputs

E5 fuel inputs include products from the local region as well as products from beyond the region. Both types of inputs must be captured in E5 LCA and it is not appropriate to focus solely on the local region when conducting the more refined regional assessments such as those attempted in this study. The "place" where E5 is produced is a combination of multiple locations of all E5 inputs, some are separated by less than a couple of hundred kilometers (e.g. production of corn compared to the ethanol plant) but others are separated from 1000s of kilometres (e.g., crude oil source compared to gasoline refinery).

In this study the external inputs are highly important to the study outcomes. The Province of Ontario shows a split in gasoline supply origins. The S.Ont E5 case uses gasoline derived from synthetic crude oil from Western Canada (increasingly typical for the region). The E.Ont case, which uses gasoline derived from offshore oil from the North Sea (predominant source for the region) has four times less fossil fuel use and two times less greenhouse gas emissions for the crude oil extraction stage. This contribution is enough to push fossil fuel consumption and GHG emissions for S.Ont E5 higher than those of E.Ont E5.

(3) **Optimizing E blend potential requires sub-provincial assessments**

Province wide studies are adequate for "reconnaissance" level assessments but not sufficient for optimizing reductions in fossil fuel consumption and GHG emissions.

An important first question when considering use of E blend fuels in Ontario is to estimate if the biofuel will provide any GHG and fossil fuel reductions. In this respect the findings of the provincial case study and both regional case studies agree. In each case, life cycle greenhouse gas emissions and fossil fuel use for E5 were estimated to be slightly lower than that of gasoline (savings are range from 0.7% to 1.3%). This indicates that a generic province wide assessment is adequate to answer this first question, and there is little additional value to distinguishing reductions by region. Furthermore, the generic provincial estimate provides a level of information useful enough to observe that fossil energy requirements for Ontario ethanol production are lower that that reported in the North American corn-ethanol literature.

However, when considering exactly where and how to invest in E5, more information is required. Sub-provincial regional assessments help delineate the processes that provide greatest return. This study suggests that it is the southern Ontario region that will provide the greatest return due to relatively low GHG emissions from corn-ethanol production and relatively high GHG emissions from gasoline production. Crude oil extraction is the most important process in this region. For example, this research estimates that substituting conventional crude oil in place of synthetic crude derived gasoline in the S.Ont case would provide four times more GHG reductions than that provided by E5. The presence of conventional oil, synthetic crude oil and bitumen in the gasoline refineries of this region also introduces the possibility that some E5 fuels will have higher fossil fuel use and GHG emissions than some pure gasoline fuels if the gasoline portion of each product is derived from different forms of crude oil. In eastern Ontario, efforts to alter

farm management practices are potentially more rewarding. No- till farming which reduces overall machinery fuel use is not as extensively practiced in eastern Ontario as in the south, and could be targeted.

Shifting the focus to more refined regional studies also offers the opportunity for closer examination of the interactions that contribute to environmental impacts of E5 production. For example, the S.Ont case study farm minimized quantities of fertilizer use by applying manure, regular soil tests, and global positioning system guided application. By studying the particular place where corn was produced, a suite of potential farm management practices was identified that could minimize fossil fuel consumption and GHG emissions in corn-farming across the province.

Finally, the main reason why a provincial scale assessment is adequate to estimate Ontario E5 fossil fuel and GHG benefits is the nature of the E5 blend. Gasoline is 95% of the product and when burned contributes a overwhelming constant portion of total emissions and fossil fuel consumption. In higher ethanol-blends, however, the constant contribution from gasoline use is reduced, and the relative contribution from other regionally divergent life cycle stage contributions increases. This study indicates that for higher (E85) blends, sub-provincial and place based assessments are particularly important to optimize biofuel potential.

7.3 Advancing the research

This research is a part of the larger challenge of evaluating biofuels as an alternative energy source and as a greenhouse gas mitigation measure. It has provided preliminary

information on the need for regional accuracy in biofuel LCA work and on optimizing biofuel production but could be improved in this context by a focus on :

- Extending the research to longer term scenarios. Wider application of biofuels to transport will likely involve greater use of flex fuel vehicles and more use of non-grain feedstocks to make gasoline substitutes. The degree to which optimal locations for production change as these parameters change is worth study.

- Measuring the need to incorporate regional variation in biofuel LCA alongside other challenges that decrease the accuracy of the LCA tool. Transparency in LCA design choices, improving applicability to agricultural systems and integrating GHG emissions from associated land use conversions are all major issues in the use of LCA for biofuels. Meeting these challenges will likely require updating LCA models every few years and expanding the boundary of processes that are considered in the model. Place-based biofuel LCA has a role to play in helping to identify interactions that are relevant to these challenges such as factors in farm level decisions to plant corn, but research into other new forms of biofuel LCA is needed.

- The best locations for farming corn with lower GHG emissions and fossil fuel use could be mapped with data from main contributing activites in the farming stage identified in project such as fertilizer use, grain drying, combine fuel use, and planter fuel use. Coarse level data is available from agricultural census data. Such data

includes fuel use, yields and money spent on farm inputs that would need to be resolved to the level of farm inputs for corn

- Incorporate modelling advances in spatial resolution on important data points such as N_2O emission rates from soil.

Finally, the strategy to pursue GHG reductions by use of E5 blends is estimated to provide only slight savings over gasoline use. The biofuel option must be considered alongside other alternatives to meet the goal of energy reduction and climate change mitigation from the transport sector. A number of research topics are relevant:

- Assess biofuel tradeoffs through study of the economic implications of a new market for grains on food supply, particularly in food insecure regions and households and recommend development of policy options for minimizing vulnerability.

- Consider the non-biofuel options for achieving the same goals. These include regulated vehicle fuel economy, improving public transit infrastructure and carbon taxes. The benefits and tradeoffs associated with these options to reduce fossil energy use and GHG emissions could be measured alongside spatially sensitive biofuel options.

- The impact of biofuel development on rural development and farmer engagement with climate change mitigation options is compelling. The rise of ethanol has lead to

the rise of a new supply chain with incentives for farming communities to diversify and become owners of the production and distribution system of their products. The differences between this supply chain and the conventional food chain in terms of ownership, power relations, and place in the historical trend of agriculture in Ontario and around the world is of interest.

Overall this research has extended the understanding of the potential for biofuels generally, and for E5 fuels specifically, to address societal concerns regarding climate change mitigation and alternatives to fossil fuel use. This thesis suggests that E5 fuels will have at best a modest role in mitigating climate change and substituting for fossil fuel resources. Optimizing the potential for transportation ethanol biofuels to reduce fossil fuel use and GHG emissions requires: understanding of regional factors (e.g. corn yield): of factors external to the region (e.g. source of crude oil); and of the ethanol blend level. Finally, although the application of LCA to biofuel faces challenges, LCA provides a powerful framework to capture not only the long production chain of the commodity but also regional dimensions within the biofuel production chain.