Reviewing the GHG savings of Ethanol

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Briefing prepared by Zoltán Szabó, PhD

Introduction

An enormous challenge faces the world: meet the increasing demand for transport energy from a larger and more affluent population and mitigate the climate impacts of transport. The International Panel on Climate Change[1] urges policymakers to avoid the worst projected impacts of climate change by adopting measures to rapidly reduce emissions.

The European Commission recently proposed reducing EU greenhouse gas (GHG) emissions by 40% below 1990 levels by 2030. Road transport alone contributes one-fifth of total EU GHG emissions. Transport is the EU's only major sector where GHG emissions have not decreased substantially, underscoring the need to focus on practical solutions.

Tilman et al. (2009)[2] argues that society cannot afford to miss out on the GHG emission reductions and social benefits when biofuels are done right, however society also cannot accept biofuels done wrong. Our view is that ethanol's merits and demerits must be considered objectively, based on evidence, and that ethanol production is not in opposition to increased vehicle efficiency or demand side management.

This briefing focuses on the GHG reduction potential of EU produced bioethanol, and the corn ethanol pathway in particular, which is now the dominant pathway in Europe.

GHG accounting rules must consider the full life cycle of ethanol production, including indirect land use change (iLUC). iLUC constitutes such a unique element of climate impacts that it is best considered separately; therefore another briefing focuses on iLUC. Here, we do not get into details; only the outcomes of the best available science are used.

Reducing greenhouse gas (GHG) emissions by displacing fossil fuels

Corn ethanol substitutes renewable for fossil fuels, and the question is whether and how much GHG emissions are reduced by this displacement. Displacement effect is an important factor in the GHG balance of ethanol production. Co-products of ethanol, like DDGS, also displace competing products that require energy to make. DDGS displaces soybean meal in animal rations; the energy saved offsets energy used to produce ethanol.

Outdated figures often used

Although as science matures the uncertainty of ethanol Life Cycle Assessments (LCA) decreases, several issues of large uncertainty remain. Choice of methods (attributional or consequential LCA) and their underlying assumptions as well as changes in the magnitude of sensitive parameters (such as soil N_2O emissions, allocation of co-product credit or land use change) may substantially change results. These are salient in the differences between EU (RED) and US (RFS) LCA methodologies[3].

One of the most critical issues concerns reliability of data. The ethanol industry has undergone substantial innovations in terms of efficiency, which is rarely reflected in

[1] IPCC (2014) Climate Change 2014: Mitigation of Climate Change. WGIII report

[2] Tilman et al., (2009) Energy. Beneficial biofuels--the food, energy, and environment trilemma. Science.;325:270-1.

[3] See: Richardson et al., (2013) LCA in biofuel regulation, comparing the US and EU approaches. Presentation at The 6th International Conference on Life Cycle Management in Gothenburg 2013.

scientific papers. As a result, most of today's ethanol analyses draw conclusions about assets that existed a decade or more ago, instead of what exists today.

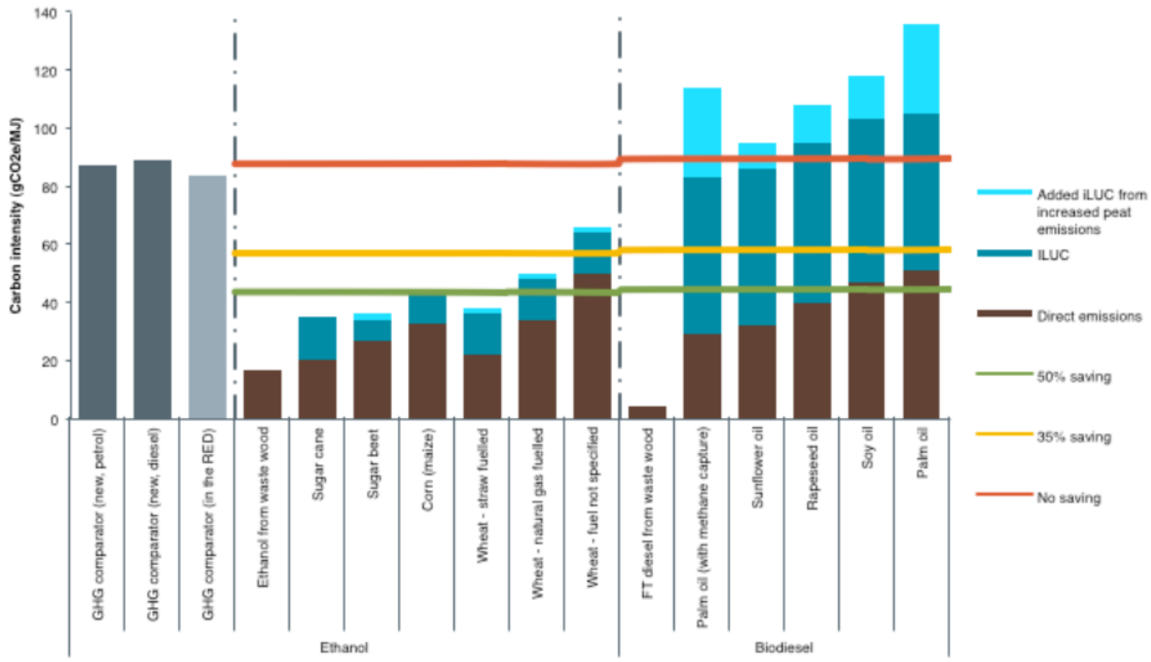
Differences in the vintage of the data used to evaluate ethanol conversion technologies and corn production result in a wide range of results. This stands in stark contrast to the rapid technological development of the bioethanol industry in the past two decades. Using vintage-specific data Chum et al. (2014)[4] finds that "production and use of corn ethanol emitted 44% fewer GHG emissions, consumed 54% less fossil energy and required 44% less land in 2010 compared to 1990 (on a life cycle basis)". Boland and Unnasch (2014)[5] estimate that between 2005 and 2012 average GHG emissions of corn ethanol production in the US showed a 14% improvement, and from 2012 to 2022 a further 15% improvement will be achieved.

de Vries et al. (2010)[6] is a prime example of misleading analysis Using obsolete data (citing Farrell et al. [2006][7]) de Vries concludes that "maize ethanol produc[es] even higher GHG emissions than gasoline". Were de Vries to use actual data instead of obsolete data, the conclusion would have been the opposite. Similar methodological errors affect other ethanol-related studies today, and these studies are difficult to reconcile with the actual results reported by today's ethanol industry and government offices.

Different pathways: bioethanol and biodiesel

Talking about biofuels in general makes little sense when various pathways have substantially differing benefits. Each pathway is associated with different GHG emission intensity. This potential range of biofuels results is illustrated by the figure below.

Emissions from different biofuel pathways



Source: ICCT, 2011: IFPRI-MIRAGE 2011 modelling of indirect land use change

[4] Chum et al., (2014) Understanding the evolution of environmental and energy performance of the US corn ethanol industry: evaluation of selected metrics. Biofuels, Bioprod. Bioref., 8: 224–240.

5 Boland. S. and Unnasch. S. (2014) Carbon Intensity of Marginal Petroleum and Corn Ethanol Fuels. Life Cycle Associates Report

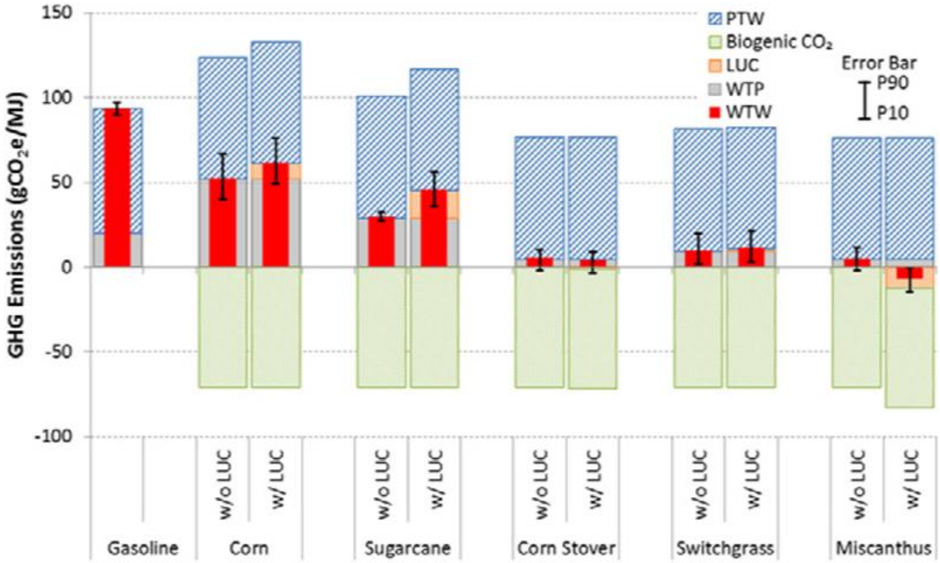
[6] de Vries et al., (2010) Resource use efficiency and environmental performance of nine major biofuel crops, processed by first-generation conversion techniques. Biomass and Bioenergy, 34, 5, p. 588–601

[7] Farrell et al., (2006) Ethanol Can Contribute to Energy and Environmental Goals. Science 311: 506-8

Best available science

Some scientific papers use up to date data to assess ethanol GHG emissions on a life cycle basis. Liska et al. (2009)[8] concludes that the GHG-intensity of corn ethanol produced in the US is estimated at between 38 and 48 gCO2e/MJ, representing a 48-59% GHG emission reductions relative to gasoline (iLUC excluded). Also excluding iLUC emissions Wang et al. (2012)[9] estimate that corn ethanol can reduce well-to-wheels fossil energy use by 57%. Including iLUC, as shown in the figure below, the authors estimate that "ethanol from corn, sugarcane, corn stover, switchgrass and miscanthus can reduce life-cycle GHG emissions by 19–48%, 40–62%, 90–103%, 77–97% and 101–115%, respectively." Including all land use impacts, Dunn et al. (2013)[10] also estimate large life cycle GHG savings from corn ethanol.

Well-to-wheels results for greenhouse gas emissions in CO2e for six pathways



Source: Wang et al. (2012)

Industrial average GHG emissions in the EU

There is now sufficient data to assess actual GHG savings of EU produced ethanol. It is no longer necessary to rely on models uncritically; industry figures are available. The table below shows that EU industry averages improve every year, as results of constant technological innovations are implemented. By 2013, on average, EU produced ethanol emitted roughly 60% less GHGs than petrol, calculated on a well-to-wheels basis.

Actual GHG emissions and savings of EU produced ethanol

	2009	*2010*	*2011*	*2012*	*2013*
Average GHG Emissions (gCO2e/MJ)	42,2	41,6	39,5	36,8	33,9
Average GHG Emission Savings (%)	49,6	50,3	52,8	56,1	59,6

Source: EU industry figures collected by ePURE (2014)
Note: iLUC excluded. Baseline for calculation of savings: GHG emissions of petrol: 83.8 gCO2e/MJ

8 Liska et al., (2009) Improvements in Life Cycle Energy Efficiency and Greenhouse Gas Emissions of Corn-Ethanol, Journal of Industrial Ecology, 13, 58-74 (2009)

9 Wang et al., (2012) Well-to-wheels energy use and greenhouse gas emissions of ethanol from corn, sugarcane and cellulosic biomass for US use. Environmental Research Letters 7 04 5905

10 Dunn et al., (2013) Land-use change and greenhouse gas emissions from corn and cellulosic ethanol. Biotechnology for Biofuels 6:51

These GHG savings are confirmed by UK government reports, which show that from April 2013 to April 2014 bioethanol used in the UK emitted 60% less GHGs than petrol[11].

Increasing GHG savings come from improvements in resource efficiency, use of renewable energy instead of fossil energy in ethanol plants, and greatly expanded co-product production. For instance, pure CO_2 is a by-product of the fermentation process that is normally vented into the atmosphere. In cutting-edge bioethanol plants this CO_2 is captured and sold on the market (e.g. for fizzy drinks, liquid CO_2, dry ice, etc.) to displace geologically mined CO_2[12]. With many ethanol plants still to implement such innovations and with other innovations in the pipeline, it is likely that average GHG savings of EU ethanol plants will continue to improve.

It must be noted that more than half of the GHG emissions associated with bioethanol come from the production of feedstock, including the production and use of fertilisers on croplands. Therefore, in essence, those emissions fall outside the control of bioethanol facilities. The largest part of emissions directly associated with bioethanol production relates to energy use for boilers in the fermentation process. If that heat is produced from renewables (i.e. biomass), GHG emissions directly associated with a bioethanol production drops to around 10 percent of total.

Fossil Fuel Comparator ranges

The fossil fuel comparator is the GHG emissions from the production and use of fossil fuels and the value is determined by RED[13] to be 83.8 gCO_2e/MJ. While GHG emissions from ethanol continue decreasing, fossil fuel emissions seem to gradually go up, in large part because increasing amounts of Europe's fossil fuels come from unconventional sources like tar sands. The RED number was calculated in 2008, and subsequent efforts to quantify average EU petrol emissions by the Commission have yielded higher numbers, culminating in the Commission's current proposal to use a petrol comparator of 93.3 gCO_2e/MJ in the Fuel Quality Directive for 2010 emissions.

As greater volumes of petroleum will be produced from unconventional fossil resources, such as tar sands of which GHG emission intensity are well over 100 gCO_2e/MJ, if ethanol is seen as displacing marginal amounts of unconventional oil (instead of displacing average EU fossil fuels), then current EU produced ethanol would be appreciated as having well over the 60% savings calculated under the RED (excluding iLUC). Likewise, Ecofys (2014)[14] finds that the marginal oil displaced by EU biofuels emits approximately 115 gCO_2e/MJ.

Ethanol blends contribute to reduction in total fuel consumption

As CO_2 emissions result from fuel combustion, increases in engine efficiency will reduce GHG emissions. Ethanol blended in gasoline contributes to reducing total fuel consumption by increasing the octane number of the resulting fuel. In other words, petrol is used more efficiently by the engine when mixed with ethanol than without the ethanol. Geringer et al.[15] find that the use of E20/25 results in an increase by about 5% in average engine efficiency.

[11] UK Department for Transport: https://www.gov.uk/government/collections/biofuels-statistics

[12] Even though will not be officially reflected in accountings, based on the Renewable Energy Directive, CO_2 abated this way may amount to an additional 20 gCO_2e/MJ.

[13] Renewable Energy Directive of the European Union, 2009/28/EC

[14] Ecofys (2014): Greenhouse gas impact of marginal fossil fuel use

[15] Geringer et al., (2014) Meta-analysis for an E20/25 technical development study - Task 2: Meta-analysis of E20/25 trial reports and associated data. TU & IFA, Draft v. 2.0. Theoretically, as a result of lower energy density of ethanol, using E20/25 would increase total fuel consumption by approximately 8%. Geringer finds increased consumption of only 3%, reflecting increased thermodynamic efficiency.

Similar results are shown by various studies; CE Delft (2013)[16] concludes that considerable energy consumption reduction is possible with an alcohol blend in petrol, especially with redesign and re-optimisation of the engine. In practice few vehicles are optimized for E20 yet, so the advantages of increased ethanol content in the fuel remain largely untapped.

Conclusion

In contrast to most climate change mitigation options in the transport sector, bioethanol technology is available, inexpensive[17] and effective. It is worthwhile to underscore the opposite directions petrol and corn ethanol have taken in carbon intensity, with the former rising, and the latter decreasing. Furthermore, the carbon intensity gap is projected to widen further.

Industry and official figures show a considerable climate change mitigation effect of bioethanol. Without indirect land use change considered, bioethanol produced in the EU on average emits around 60% less greenhouse gases than petrol. With iLUC included GHG emissions of the corn ethanol pathway appears to be between two-third and half of petrol. Furthermore, some studies appear to show that ethanol blending increases engine efficiency, and thus contributes to total fuel consumption savings, hence additional GHG savings.

In conclusion, bioethanol can be characterised by substantial GHG savings, large mitigation potential, mature production technology, manageable side effects and relatively cheap abatement cost. All this is unparalleled in the transport sector. It seems that low iLUC risk[18] bioethanol represents today's most economically viable way to decarbonise transport in the EU.

[16] Kampman et al., (2013) Bringing biofuels on the market. Options to increase EU biofuels volumes beyond the current blending limits. CE Delft

[17] McKinsey (2009) found that carbon abatement costs of biofuels are slightly negative, meaning it is cost effective from a social perspective. See McKinsey (2009): Pathways to a Low-Carbon Economy.

[18] Low iLUC bioethanol is largely produced from induced crop yield increases.