Life Cycle Associates

Indirect Land Use Conversion for Washington Clean Fuels Standard

Prepared by Stefan Unnasch, Life Cycle Associates, LLC

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Primary Point of Contact
Stefan Unnasch
Managing Director
Life Cycle Associates

884 Portola Road
Suite A11,
Portola Valley
CA 94028

Phone Number: +1.650.461.9048
Email address: Unnasch@lifecycleassociates.com

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Abbreviations and Acronyms

Abbreviation/Acronym	Definition
GHG	Greenhouse gases
LUC	Land Use change
LCA	Life Cycle Assessment
iLUC	Indirect land use change
CO_2e	Carbon dioxide equivalent
MJ	Mega Joule
CCLUB	Carbon Calculator for Land Use change from Biofuel Production
Washington CFS	Washington Clean Fuel Standard
LCFS	(California) Low Carbon Fuels Standard
GTAP	Global Trade Analysis Project model

1. Indirect Land Use Conversion

In addition to greenhouse gases that are directly emitted from the production and use of biofuels, there are other emissions that result from increased demand for biofuel feedstocks - the crops used to make the fuel - caused by a change in regulatory policies such as clean fuel standards. There is a presumed increase in acreage needed to meet that increased demand that could lead to non-agricultural or underproductive lands being converted to cropland. In the conversion process, carbon that may have remained or otherwise been sequestered in soils and cover vegetation is emitted. This is referred to as indirect land use change or ILUC.

The correlation between LUC and an expansion in biofuel is typically estimated with agro-economic models. Indirect land use conversion (iLUC) corresponds the emissions associated with the land conversion associated with the introduction of a new demand for biofuels. Economic models that simulate market behavior (particularly those in the agricultural sector) are often linked to predict the location of land cover change and the emissions associated with conversion to crops as illustrated in Figure 1. Results from economic models that predict the location and type of land conversion are combined with emission estimates associated with land conversion. The results are amortized over a time horizon to develop an iLUC estimate.

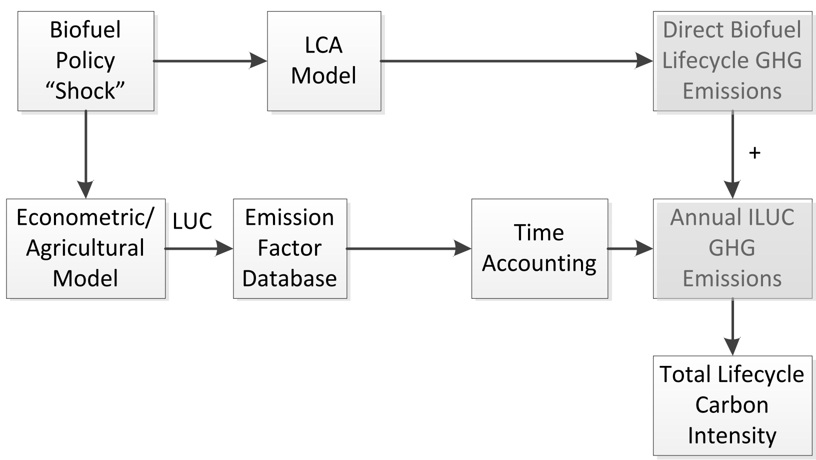

Figure 1. Modeling Flow for Determination of Total Biofuel Lifecycle Carbon Intensity, Including Both Direct and Indirect Effects.

2. Range of iLUC Estimates

iLUC values have evolved over time with refinements in modeling and contributions from numerous researchers. Figure 2 shows a range of values estimated for corn ethanol. The results from different studies have not provided a strong consensus on the most representative value which depends on numerous factors including the extent of biofuel usage as well as agricultural modeling and land conversion emission factors.

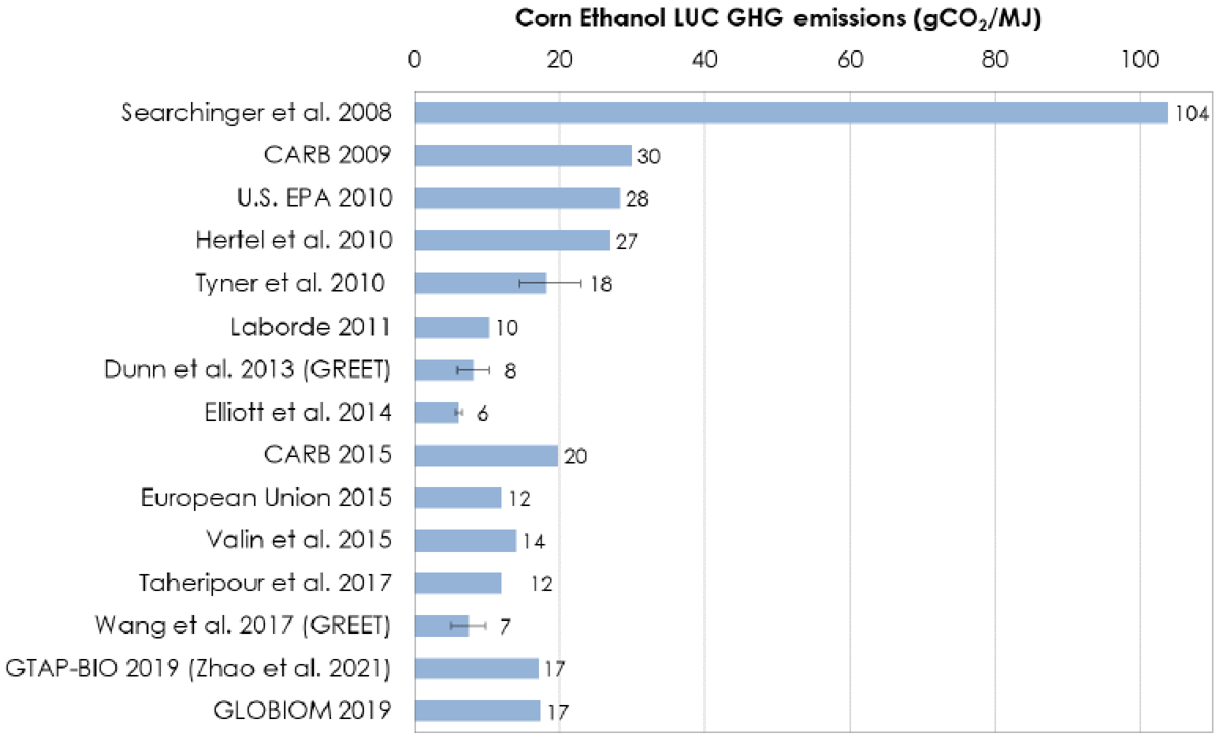

Figure 2. Range of iLUC estimates for corn ethanol[1].

Analysis or the iLUC values is found in various publications supporting both higher[2,3] and lower[4,5]values. The debate over iLUC includes evaluations of land cover predictions as well as carbon stocks for different land cover types.

3. iLUC Values for Washington CFS

Washington's Clean Fuel Standard includes a requirement to include iLUC emissions. The science of quantifying ILUC has developed over time through several key academic institutions under the direction of the California Air Resources Board and the Argonne National Laboratory (ANL). CARB has included iLUC values for several feedstocks in the LCFS regulation. ANL has

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[1] Wang, M., U. Lee, H. Kwon, and M. Wu (2021). Retrospective Analysis of U.S. Corn Ethanol GHG Emissions for 2005 – 2019. 2021 Fuel Ethanol Workshop, De Moines, IA

[2] Malins, C., Plevin, R., & Edwards, R. (2020). How robust are reductions in modeled estimates from GTAP-BIO of the indirect land use change induced by conventional biofuels? Journal of Cleaner Production, 258, 120716.

[3] Lark, T. J., Hendricks, N. P., Smith, A., Pates, N., Spawn-Lee, S. A., Bougie, M., ... & Gibbs, H. K. (2022). Environmental outcomes of the US Renewable Fuel Standard. Proceedings of the National Academy of Sciences, 119(9).

[4] Scully, M. J., Norris, G. A., Falconi, T. M. A., & MacIntosh, D. L. (2021). Carbon intensity of corn ethanol in the United States: state of the science. Environmental Research Letters, 16(4), 043001.

[5] Taheripour, F., Mueller, S., & Kwon, H. (2021). Response to "how robust are reductions in modeled estimates from GTAP-BIO of the indirect land use change induced by conventional biofuels?". Journal of Cleaner Production, 310, 127431.

evaluated the iLUC for corn and soy further[6]. The analysis of iLUC was reviewed by the Oregon Department of Environmental Quality (DEQ). The analysis here follows the approach taken by Oregon based on the input provided by experts as well as presentations made at the EPA RFS workshop. Oregon preferred the Argonne ILUC for corn ethanol because they felt it was more accurate for U.S. corn ethanol production which supplies the fuels to the region.

Table 1 shows iLUC values that have been used in fuel policy. The original EPA RFS2 analysis[7] and 2009 CARB values[8] were consistent for corn ethanol. These values were reduced further with the updated LCFS regulation[9]. Subsequent analyses from ANL are provided by the CCLUB model. CCLUB generates a range of iLUC values for corn ethanol as well as soy biodiesel. The model results in different estimates based on the specific GTAP database that is implemented for the calculations. The CCLUB model is updated regularly, with the latest value of 3.9 g CO_2e/MJ for corn ethanol.

Table 1. Range or iLUC Values Used in Fuel Policy.

		Ethanol				Biodiesel/ Renewable Diesel			
Study	**Model**	**Corn**	**Sorghum**	**Sugar cane**	**Corn Stover**	**Soy**	**Canola**	**Palm**	**Carinata**
iLUC (g CO_2e/MJ Fuel)									
EPA 2010	FASOM/FAPRI	26.3	28.0	5.1		31.9			
CARB 2009	GTAP BIO	30	45	46		42		N/A	
CARB 2014	GTAP BIO ADV	19.8	19.4	11.8		29.1	14.5	71.4	
OR LCFS	GTAP BIO ADV	7.6	19.4	11.8	0	29.1	14.5		
ANL 2018	CCLUB GTAP 2011	7.4				7.9			
ANL 2018	CCLUB GTAP 2013	3.9							
		ATJ	**ATJ**	**ATJ**	**ATJ**	**SPK**	**SPK**	**SPK**	**SPK**
CORSIA	GTAP BIO ADV	22.1		7.3		27	24.1	39.1	-21.4
Recommended WA CFS		**7.6**	**7.6**	**11.8**	**0**	**29.1**	**14.5**	**71.4**	**0**

ATJ = Alcohol to Jet. SPK = Synthetic Paraffinic Kerosene.

The iLUC values in the bottom row of Table 1 are recommended based on consistency with other fuel programs and the following rational.

[6] Dunn, J. B., Qin, Z., Mueller, S., Kwon, H. Y., Wander, M. M., & Wang, M. (2017). Carbon calculator for land use change from biofuels production (CCLUB) users' manual and technical documentation (No. ANL-/ESD/12-5 Rev. 4). Argonne National Lab. (ANL), Argonne, IL (United States).

[7] EPA (2010). Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis. EPA Report EPA-420-r-10-006.

[8] CARB (2009). Proposed regulation to implement the low carbon fuel standard. Staff Report: Initial statement of reasons. https://www.arb.ca.gov/regact/2009/lcfs09/lcfsisor1.pdf. (Accessed 02/08/2019).

[9] CARB (2015). Calculating carbon intensity values from indirect land use change and crop-based biofuels. Appendix I: Detailed analysis for indirect land use change. California Air Resources Board. https://www.arb.ca.gov/fuels/lcfs/iluc_assessment/iluc_analysis.pdf.

Corn and Sorghum Ethanol. CCLUB – based iLUC of 7.6 g/MJ to be consistent with OR CFP and latest analysis by ANL. Note that Oregon did not select the lower iLUC for sorghum but allowing significantly different values for corn and sorghum is not consistent with the fact that these grains are substitutes for each other. The sorghum value would be slightly lower if scaled to the LCFS values (19.4/19.8); however, absent a model outcome for sorghum, the same value as that or corn ethanol is recommended.

Vegetable Oils. Soy, Canola, and Palm values of 29.1, 14.5, and 71.4 g/MJ respectively. These are the same values used in the 2014 California LCFS analysis. Recent modeling from ANL results in a lower value for soy oil; however, concern over the fungibility of vegetable oils with palm oil does not indicate that a lower iLUC value is warranted. Note that the iLUC for renewable diesel and biodiesel are the same despite slightly different oil to fuel yields. This approach is consistent with the simplifying assumptions used in biofuel regulations.

Sugarcane Ethanol. 11.8 g/MJ which is consistent with the California and Oregon value. A change in this value is not supported by significant further modeling.

Others. An iLUC or 0 g/MJ for cover crops, corn fiber, and crop residue and 71.4 g/MJ for palm oil biodiesel and renewable diesel is consistent with the California and Oregon programs. Cover crops would need to demonstrate that they are a secondary crop that does not displace another crop. The zero value is conservative but provides cover crops with a value to generate credits under the CFS.

4. Model Implementation

The iLUC values are implemented in the Washington GREET model and Tier 1 calculators for starch ethanol, biodiesel and renewable diesel, and sugarcane ethanol. The implementation of the iLUC values is on an additive basis without adjustment for yield. The iLUC values in Table 1 are assigned to each fuel pathway.