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LCA IN BIOFUEL REGULATIONS: COMPARING THE US & EU APPROACHES

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ABSTRACT

This study compares the use of LCA in the rapidly evolving regulations governing biofuels in the US and EU. It focuses specifically on the European Commission Renewable Energy Directive, the US Renewable Fuel Standard II, and the Californian Low Carbon Fuel Standard, with emphasis on the respective LCA methodologies described. All three regulations use Life Cycle Assessment (LCA) to quantify the variation in GHG emissions relative to a fossil baseline fuel. Different definitions for system boundaries and life cycle phases make results difficult to disaggregate and one-to-one comparison of the models difficult. Overall, *co-product allocation*, *N_2O emissions* and *land use change* (LUC) are identified as the major methodological differences. These differences can result in significantly different outcomes when assessing identical pathways.

INTRODUCTION

Policy plays a key role in the biofuels market with the development of several national or regional regulations for biofuels and other renewable energies. Such regulations provide sustainability criteria, compliance rules and greenhouse gases (GHG) emission reduction targets among other requirements for fuel producers or importers.

The scope of this study covers the regulations governing biofuels in the US and Europe, focusing on the following documents:

- European Commission Renewable Energy Directive (RED) (EC, 2009)
- US Renewable Fuel Standard, version 2 of 2010 (RFS2) (EPA, 2010)
- California Low Carbon Fuel Standard (LCFS) (CARB, 2009a)

In all three regulations Life Cycle Assessment (LCA) is used to quantify the net reduction in lifecycle GHG emissions reduction relative to a fossil baseline fuel. However, examination of the values provided by the respective regulations frequently shows vastly different results for the same fuel, produced from the same feedstock. Some of these differences can be explained by differences in geographical location, transport logistics or variation in the fuel production process. Differences in agricultural or process yields and input data also play a role. However, the methodological differences between the three regulations mean that even if an identical pathway were assessed, the results can be different. This paper thus aims to provide an overview and broad understanding of the LCA methodology and calculation approaches taken by the three regulations and to identify key differences.

METHODS

To address the objectives, information was taken from the relevant legislative documents themselves, as well as key documents from the public domain in the form of comments or summaries of the legislation and existing comparative studies. The effect of these methodological differences was then further investigated through case studies for sugarcane ethanol and soybean biodiesel.

RESULTS AND DISCUSSION

While each of the three regulations examined in this report requires the calculation of life cycle GHG emissions of fuels, the structure of the modeling approach, specific tools used and inclusion or exclusion of aspects such as land use change (LUC) exist as obvious differences between the LCA modeling approaches taken. An overview of these and other key methodological differences is given in Table 1. Of particular interest are the GHG emission factors for CH_4 and N_2O, and fossil fuel references which are different in all three regulations.

Table 1: Comparison of LCA methodology in the RED, RFS II and LCFS

Issue	**RED**	**RFS II**	**LCFS**
Unit/metric	gCO_{2eq}/MJ GHG reduction (%) vs fossil reference	gCO_{2eq}/mmBTU GHG reduction (%) vs fossil reference	Carbon intensity (CI) in gCO_{2eq}/MJ, adjusted according to an Energy Economy Ratio (EER)
LCA steps considered	Direct LUC - Biomass production - Biofuel production Biomass + fuel transport -	Domestic LUC International LUC Domestic agriculture International agriculture Biofuel production Biomass + fuel transport Tailpipe emission	LUC (total) - Biomass production - Biofuel production Biomass + fuel transport Tailpipe emission
Reference fossil fuel values	83.8 gCO_{2eq}/MJ	92.9 gCO_{2eq}/MJ	95.85g CO_{2eq}/MJ (gasoline) 94.71g CO_{2eq}/MJ (diesel)
GHG emission factors	CO_2: 1; CH_4: 23 ; N_2O: 296 (IPCC 2001)	CO_2: 1; CH_4: 21; N_2O: 310 (NRC 2010)	CO_2: 1; CH_4: 25; N_2O: 298 (IPCC 2007) Volatile organic compounds (VOCs): 3.1; CO 1.6
GHG emissions from combustion	Zero rating for any GHG	Zero rating for CO_2. CH_4 and N_2O included	Zero rating for CO_2. CH_4, N_2O, CO & VOCs included
Biofuel-use vehicle efficiency	If evidence provided for difference	Not included	Yes, using EER relative to a reference fuel
Modelling tools	Not defined	FASOM, FAPRI-CARD, GREET	CA-GREET – adapted to Californian conditions
Time horizon [i]	20 years	30 years	30 years

i. The length of time during which all emissions are accounted for and attributed to the biofuel, allocated over the volume of fuel produced in that time period (Life Cycle Associates, 2012)

Table 2. Key methodological differences between the LCA modelling approaches

	RED	RFS II	LCFS
Co-product allocation	Allocation by energy content except for heat and excess electricity	System expansion → Displacement method	Varies for different pathways (Displacement, substitution, mass based allocation)
Direct land-use emissions	Default option: No Reference land use in January 2008 or 20 years before raw material was obtained	Yes, using FAPRI-CARD and FASOM models for domestic and international LUC respectively	Yes, using Global Trade Analysis Project (GTAP) model – no split between direct/indirect or domestic/international LUC
Indirect land-use emissions	Not yet included (under review)		
N_2O emissions	IPCC methodology, tier 1 as default, tier 2 or 3 if available	DAYCENT for domestic N_2O emissions, adapted IPCC factors for international N_2O emissions	IPCC and GREET emission factors, crop residues not always accounted for

Overall however, *co-product allocation*, *agricultural* N_2O *emissions* and *LUC* are identified as the major methodological differences, resulting in different outcomes when assessing identical pathways. The different approaches taken by the three regulations on these aspects are summarised in Table 2.

These differences have been identified both internally and in publically available review studies (Khatiwada, Seabra, Silveira, & Walter, 2012; Life Cycle Associates, 2011, 2012). There is little scientific consensus on these issues. It was found that the overall results are highly sensitive to these methodological choices, and that notably different modelling approaches are taken in the three regulations. The effect of these methodological differences is illustrated in Table 3 through case studies for sugarcane ethanol and soybean biodiesel.

Table 3: Comparison between results of different regulations for Brazilian sugarcane ethanol (gCO_{2eq}/MJ)

	Sugarcane Ethanol			Soybean Biodiesel		
Life cycle step	**RED**	**RFS II**	**LCFS**	**RED**	**RFS II**	**LCFS**
Agriculture	14	38	19	19	-9	5,4
Processing	1	-11	-4,9	26	13	8,7
Transport & distribution	9	5	5,5	13	3	2,7
Tailpipe emissions	0	1	0,8	0	1	4,5
Total WtW	**24**	**33**	**20,4**	**58**	**8**	**21,3**
Land use change	0	5	46	0	34	62
Total WtW + LUC	**24**	**38**	**66,4**	**58,0**	**42**	**83,3**
Fossil benchmark	83,8	92,9	95,85	83,8	92,9	94,71
GHG emissions saving	**71%**	**59%**	**31%**	**31%**	**55%**	**12%**
GHG reduction target	60%	50%	>0%*	60%	50%	>0%*

* LCFS uses a credit based system relative to the fossil benchmark

For sugarcane ethanol, the highest emissions savings are achieved using the RED methodology, despite having the lowest fossil benchmark. Agriculture is particularly significant in the RFS II case due to the method by which emissions from crop residues are considered. Allocation of co product electricity credit is especially significant for sugarcane ethanol as the two US regulations both consider the displacement of marginal electricity from natural gas rather than the average mix, while the RED does not give credit for excess electricity.

For soybean biodiesel, the RED deviates from the default IPCC tier 1 methodology and uses emissions as reported by the JEC (2007) for the calculation of N_2O emissions. This is the main cause of the elevated emissions from agriculture. The RFS value for agriculture is negative due to several indirect impacts, not considered by the other two regulations. Co product methodology then causes significant deviation between the three regulations. The RED allocates by energy content and the LCFS by mass, resulting in 66% and 80% allocation to the soy meal co product respectively.

It must be noted that while it is mandated by the RED to calculate dLUC if land use change occurs for a specific feedstock, the RED default values assume that there is no dLUC for either pathway. If dLUC was taken into account, this could increase or decrease the overall result depending on the assumptions taken. While LUC is calculated in both the RFS and LCFS, different results are reported due to the use of different agro-economic equilibrium models. LUC is extremely dominant for both LCFS biofuel pathways, as calculated using the GTAP model. As a result, the lowest emissions savings are found for LCFS results.

It is interesting to note that for sugarcane ethanol, despite varied results, all values result in qualification as a biofuel/low carbon fuel according to the rules set by their respective regulations. They are thus all eligible to contribute towards the overall regional blending and GHG reduction targets set by their respective regulation.

CONCLUSIONS

This study has outlined the current status and understanding of the overview LCA methodology and calculation approaches taken by the three regulations. *Co-product allocation*, *agricultural* N_2O *emissions* and *LUC* are identified as key methodological differences. The nature of the regulations is that of evolution and change. It thus is essential to continue to follow further developments in this field.

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