USING LCA AS A TOOL TO REGULATE BIOFUELS – A CONSIDERATION OF UNCERTAINTIES IN CULTIVATION

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ABSTRACT

According to the EU Renewable Energy Directive, biofuels must reduce GHG emissions with at least 35% compared to fossil fuel. Cultivation of raw material represents a large proportion of biofuels´ GHG emissions, however these emissions are associated with major uncertainties. The aim of this paper is to study the uncertainty in GHG emissions for ethanol, considering measuring uncertainty and variability in data for wheat cultivation in Sweden. The results show that uncertainty in emissions from cultivation is large, but when using bioenergy as a process fuel in the ethanol production, the risk of exceeding the savings threshold is small. However, there are many uncertainties to be considered; the Directive does for example presently not include indirect land use change.

INTRODUCTION

In 2009, EU adopted the Renewable Energy Directive (Directive 2009/28/EC). The Directive mandates that all Member States shall have 10% biofuels in the transport sector by 2020. In order for a biofuel to be accounted within the national reporting, and to receive financial supports such as tax exemption, it must meet a number of sustainability criteria. One of the sustainability criteria is that the use of a biofuel must reduce GHG emissions with at least 35% compared with the use of a reference fossil fuel, increasing to 50% and 60% over time. For these calculations, the Directive mandates LCA methodology to be used.

Further, cultivation of raw material represents a large proportion of biofuels´ GHG emissions. However, emissions from cultivation are associated with major uncertainties e.g. quantification of N_2O emissions from fields and variability in yields between different regions and years. The question arise, are the uncertainties so large that we risk using biofuels in fact not meeting the GHG sustainability criteria?

Generally speaking, there are three levels of uncertainty in GHG calculations: (1) technical uncertainties connected to quality and appropriateness of data; (2) methodological uncertainties connected to model layout and structure; and (3) epistemological uncertainties connected to lack of knowledge of system behavior (Björklund, 2002; Spielmann et al., 2005).

Epistemological uncertainties are difficult to diminish; a reduction of epistemological uncertainties implies making known what one does not know. The EU Renewable Energy

Directive help reduce methodological uncertainties to some extent, since the Directive gives guidelines on methods and choice of data. However, the technical uncertainties remain. Two types of technical uncertainties can be distinguished; measuring uncertainty and variability. Variability is an inherent property of a system and, unlike measuring uncertainty, it cannot be reduced by more accurate measurement (Björklund, 2002; Johnson et al., 2011). In LCA of agricultural products, variability arises for example due to variations in yield between different regions and years, but also within regions in a particular year.

The aim of this paper is to study the uncertainty in GHG emissions for ethanol calculated according to the EU Renewable Energy Directive, considering measuring uncertainty and variability in data at farm level for wheat cultivation in Sweden.

MATERIALS AND METHODS

The calculations of the GHG emissions from biofuel production was based on the EU renewable energy Directive 2009/28/EC (Annex V), which is based on an attributional LCA approach. In short, the methodology requires allocation based on lower heating value, straw and manure are not allocated any emissions. Changes in soil carbon are not accounted for unless there is a land use change (e.g. from forest to agriculture). Land use change was not relevant for Swedish wheat cultivation why emissions from land use change was not included in the uncertainty evaluation.

The uncertainty analysis included both measuring uncertainty, which describes the precision with which the parameters can be collected on a real-life farm, as well as variation which describes the variation between farms due to differing farming systems, technical solutions and energy efficiencies. The uncertainty was quantified using Monte Carlo simulation in which parameters are described by a probability distribution. The calculation of GHG emissions are repeated a number of times (here 10,000), each time randomly drawing a parameter value from the probability distribution describing the input data. The result gives an indication of the probability of different results from the GHG emissions calculation.

The farm level parameters used in the simulations are presented in Table 1. All other input parameters for the farm LCA calculations (e.g. production of potassium and phosphorus fertilisers) were kept constant, as they in other studies have shown to have little impact on the results.

Table 1: Variables used in the calculation of GHG emissions from wheat cultivation for ethanol production. Variation and uncertainty expressed as the geometric standard deviation for a lognormal distribution (approximate percentage value corresponding to 95% conf. interval) unless otherwise stated. For full explanation and references to chosen data, see (Ahlgren et al., 2012).

	Variation	**Measuring uncertainty**
Yield	Data collected from real farms	1.01 (± 2%)
Amount of mineral N	Data collected from real farms	1.05 (± 10%)
Amount of organic N	Data collected from real farms	1.05 (± 10%)
Field N_2O emissions	0.01 kg N_2O-N per kg added N, uncertainty range 0.003-0.03 (lognormal distribution)	
Emissions from the production of mineral fertilisers	Discrete distribution: 3.1 kg CO_2e/kgN – 60% (Yara) 8.1 kg CO_2e/kgN – 24% (Russia) 7.8 kg CO_2e/kgN – 16% (EU)	1.1 (± 20%)
Amount of fuel for field operations	1.30 (± 60%) (25-108 l/ha)	1.05 (± 10%)
Emissions from grain drying	Discrete distribution: 16 g CO_2e/kg grain – 25% (central drying) 21 g CO_2e/kg grain – 63% (hot air farm drying) 11 g CO_2e/kg grain – 12% (cold air farm drying)	1.25 (± 50%) for central drying, 1.1 (± 20%) for hot on-farm drying 1.2 (± 35%) for cold on-farm drying

RESULTS

In Figure 1, the GHG emissions per MJ ethanol is presented for two cases; in the first case with bioenergy as process fuel in the ethanol production and in the second with natural gas as process fuel. The data for process emissions and transports is taken from the Directive. The cultivation data is from the modeling, the green blocks represent the mean value for cultivation of winter wheat in the county of Uppsala in Sweden. The variation and measuring uncertainty that was simulated in the model is shown as black bars (2.5-97.5 percentiles). The GHG reduction thresholds as given in the Directive (35, 50 and 60% reduction) are also plotted. As can be seen, the ethanol produced with bioenergy process fuel is well below the 60% savings threshold, however using natural gas risks missing the 50% target.

The variability in yields between farms was a major cause for the uncertainty. The reason for the variability is difficult to establish. In general, there is a direct positive correlation between amount of nitrogen applied and yield level. However, yield is often influenced by many other factors such as weather conditions during the growing season, soil texture, weed pressure, soil phosphate level and disease pressure.

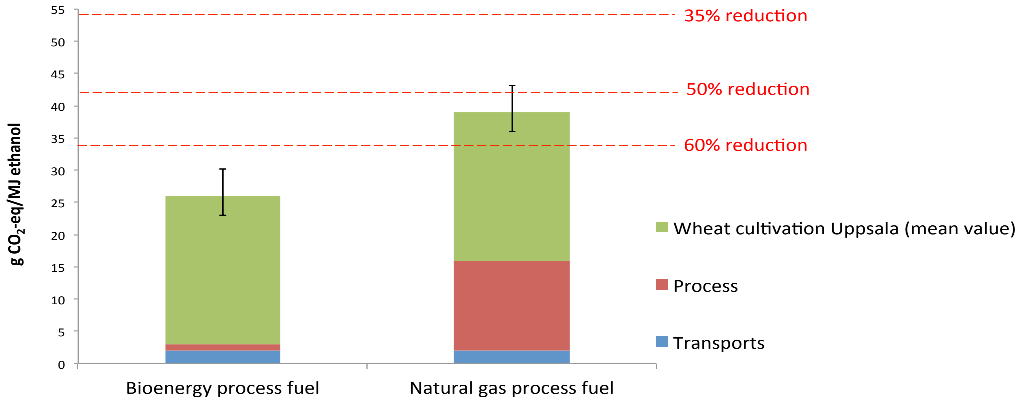

Figure 1. GHG emissions from ethanol production using bioenergy or natural gas as process fuel, calculated according to methodology in EU Renewable Energy Directive. Savings compared to fossil reference (35, 50 and 60%) and uncertainty bars (2.5-97.5 percentiles) for emissions from cultivation of winter wheat in Uppsala, Sweden, are plotted.

DISCUSSION

In addition to uncertainty connected to data described in this study, a further problem with the current EU regulation of the GHG emissions of biofuels is the exclusion of indirect effects. Indirect effects can be market induced, for example an increased production of bioenergy affects the price of agricultural products, which in turn will affect the way farmers use their land. Indirect effects are difficult to quantify and tend to be very uncertain, but can potentially be large enough to change the GHG balance. In the EU it is widely recognized that indirect land-use change (ILUC) GHG emissions need to be accounted for in the assessment of the carbon balance of biofuels and the European Commission is currently working on ways to including ILUC in the Directive sustainability certification system.

CONCLUSIONS

The results show that uncertainty in emissions from cultivation is large, but when using bioenergy as process fuel in the ethanol production the risk of exceeding the savings threshold is small. We also conclude that should ILUC be included in the EU regulation, a new type of uncertainty would be introduced. We suggest that work on the direct GHG emissions of biofuels should progress in parallel with work on the indirect GHG emissions.

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