

HEDGING THE BET: INTRODUCING BIOCROPS IN THE LUXEMBOURGISH AGRICULTURAL SYSTEM

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ABSTRACT

In the context of fulfilling EU targets for bioenergy use by 2020, the use of Consequential Life Cycle Assessment has shown to be a suitable method to monitor the environmental performance of future energy scenarios and strategies. Hence, the aim of this study was to analyse the environmental consequences linked to an increase in maize production for bioenergy purposes, for the specific case of Luxembourg. Different land use change scenarios were modeled through the use of an auxiliary partial equilibrium model based on farmers' revenue maximization. Results showed minor, but increasing shifts in environmental impacts related to an additional production of 80,000 t of maize, and the environmental profile of the final biomethane product is higher than that of conventional natural gas.

INTRODUCTION

Luxembourg should comply with the EU 2020 targets to reduce GHG emissions by increasing its share of total energy production arriving from renewable sources to 20% by 2020, including 11% of biofuels in final energy consumption (EC, 2007). Due to the domestic limitations of using other energy sources, the use of biomass for biogas generation in power plants is a key strategy promoted by authorities to meet the targets. However, the use of agricultural crops for producing energy has shown to cause important impacts in other environmental issues (e.g. toxicity). Moreover, recent studies have demonstrated the minimal GHG emissions reductions that some biocrops generate due to land use changes—LUCs (Searchinger et al. 2008). Thanks to its comprehensiveness, the use of Life Cycle Assessment (LCA) appears as an appropriate method to evaluate the actual environmental suitability of biofuel production and policies. However, it should be noted that since an attributional-LCA (A-LCA) perspective does not consider the indirect consequences linked to increased biocrops cultivation, a consequential-LCA approach (C-LCA) may be more suitable to understand how physical flows and the derived environmental impacts vary in response to the changes, including potential changes associated with the expansion, displacement or intensification of crops (Kløverpris et al., 2008). The main aim of this study is to evaluate the environmental consequences of increasing maize production for biomethane in Luxembourg in the 2009-2020 timeframe using C-LCA, by modeling a series of scenarios based on a partial equilibrium model (PEM) to determine the LUCs.

METHODS

An additional 80,000 tonnes of maize production for energy generation were modeled, considering that the target of 144 GWh of energy produced from biogas in Luxembourg would be arriving from maize crops exclusively. The LUCs expected in the Luxembourgish agricultural system were modeled by using the PEM that was created for the study. The structure of the model was based on the maximization of revenues by farmers, by maximizing the sum of all opportunity values which are subject to restrictions of the maximum possible replacement allowed for each crop. Therefore, opportunity values were calculated individually for each crop considering different operational inputs, such as subsidies, fertilizers, variable and fixed costs, as well as the yield or market prices. Thereafter, the model was computed using GAMS (Rosenthal, 2011). Nevertheless, it should be noted that two different perspectives were assumed when developing the model. The first perspective only included the costs and revenues related to the crops themselves, while the second one accounted also for livestock activities in order to consider also the opportunities of reducing costs related to fodder and feed products. Three main approaches were followed to calculate the environmental consequences associated with LUCs. The first one, *Approach A*, monitored the crop rotation patterns from a revenue maximization perspective without the inclusion of the shock (i.e. 80,000 tonnes), to understand the natural evolution of the agricultural system in the period 2009-2020 without any policy or strategy implementation regarding biogas. *Approach B* considers the entire shock of increase maize production in a farmer's perspective to maximize the revenues while integrating the bioenergy strategy in the system. Finally, *Approach C* enlarges the scope by adding a full policy oriented perspective, to analyze not only the consequences on the agricultural system in Luxembourg, but also the import/export flows and the final energy consequences.

Functional unit and system boundaries

The functional unit (FU) considered for each approach was based on their specific function. In *Approach A* the FU was the entire Luxembourgish agricultural system, while in *Approach B* the FU was the shock of 80,000 tonnes on the agricultural system. Finally, in *Approach C*, where the main function is to provide environmentally robust results to support policy-makers, the FU was fixed at 1 MJ of biogas injected in the grid from the described shock. Therefore it shall be noted that the three approaches are not directly comparable. Unlike in an A-LCA approach, the system boundaries in C-LCA are flexible, due to the need to enlarge the boundaries based on the consequences that may be generated by the shock that is exerted on the main production system. In fact, in Approaches *A* and *B* the system boundaries were limited to the Luxembourgish agricultural system, in *Approach C* these boundaries were amplified to include the entire production chain of biomethane production, as well as the environmental consequences occurring outside Luxembourg's national borders due to changes in the agricultural system. Finally, while livestock was included to compute the LUCs, they were not included in the LCA under the assumption that it will not change significantly between 2009 and 2020 (any change would be, however, rather unpredictable).

Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) methods

The LCI varied slightly between approaches to meet the data requirements of the different functions. Background processes were based on the ecoinvent® database, while primary data were retrieved based on national and EU databases. Biomethane production from maize was

modeled on Jury et al. (2010). For the assessment method, ReCiPe endpoint was used to compute the results (Goedkoop et al., 2009).

RESULTS

The LUCs, which are reflected in more detail in Vázquez-Rowe et al. (2013a; 2013b), varied substantially between scenarios, mainly associated with the inclusion or exclusion of livestock activities in the PEM. As shown in Fig. 1, the natural flow of the agricultural system in Luxembourg is expected to present considerable shifts in environmental impacts depending on the assumptions, especially in terms of land use and climate change.

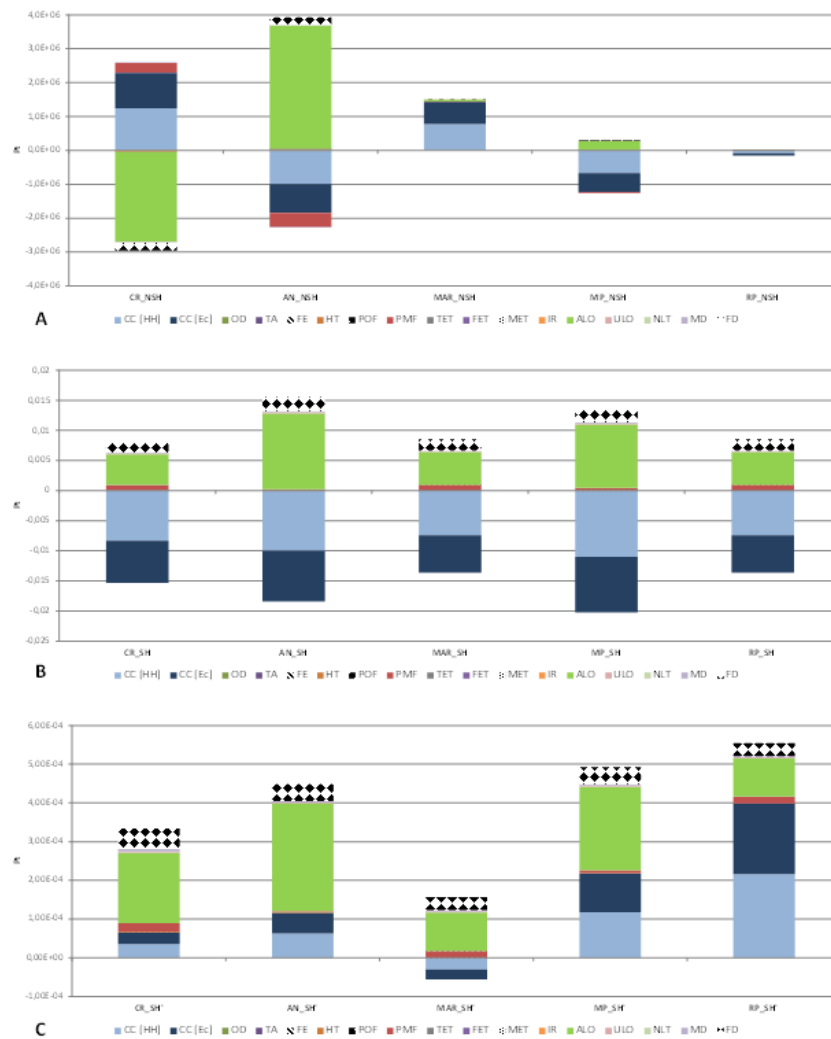


Figure 1. Single score endpoint values for each scenario in all three approaches¹

¹ NSH= no shock applied in the PEM; SH= shock of 80,000 t applied in the PEM; SH'= shock of 80,000 tonnes applied to the model plus new import/export flows; CR= scenario 1 – exclusion of livestock in PEM; AN= scenario 2 – inclusion of livestock in PEM; MAR= scenario 3 – decrease in the minimum feed requirement for livestock; MP= scenario 4 – inclusion of meadows and pastures in the PEM; RP= scenario 5 – higher LUC rate allowed for rapeseed.

In *Approach B*, however, small environmental improvements were identified as compared to the baseline scenario in the different scenarios, ranging from 2% to 8%. These improvements are associated with sharp reductions in climate change impacts due to higher carbon sequestration in fields, which manage to compensate the strong increase in land use and fossil depletion impacts. Finally, in *Approach C* the environmental benefits shown in the previous approach are neutralized due to the inclusion of a higher detail of consequences, which is linked to higher environmental impacts in the post-agricultural stages of biogas production, making the overall environmental impacts of biomethane production up to 20-25% higher than those of using natural gas.

DISCUSSION AND CONCLUSIONS

The results shown in this case study show the effects that increased bioenergy production in Luxembourg may have on the agricultural sector. Direct variations in LUCs demonstrate a clear reduction of the availability of arable land for the production of food and feed due to crop displacement and, therefore, a subsequent outsourcing of uses of land to produce feed outside Luxembourgish borders. However, domestic LUCs did not trigger significant changes in the environmental impacts. In fact, domestic impacts are slightly more favorable when the shock is considered due to the higher aerial sequestration of carbon in maize cultivations. However, the results presented for *Approach C* show an increase of environmental impacts as compared to the baseline scenario in 2009 due to the new import/export flows of food and fodder products. Therefore, the use of maize-based biofuels has shown to increase GHG emissions and other environmental impacts (e.g. land occupation or fossil depletion). However, these increases are considerably lower than those occurring in other areas of the planet (e.g. Brazil) due to the current status quo regarding arable land extension in many European countries, which tends to remain stable. Therefore, in terms of policy support, the results suggest minor environmental benefits of implementing biocrops production strategies. Finally, the PEM demonstrated to provide an accurate analysis on the Luxembourgish agricultural LUCs through the collection of economic data that allowed forecasting future equilibriums between supply and demand.

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