UNDER WHAT CONDITIONS IS THE BIOETHANOL AND BIODIESEL PRODUCED ENTIRELY IN THE BASQUE COUNTRY SUSTAINABLE?

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Biofuels regulatory framework

Owing to the depletion of fossil fuels, there is a need to develop alternative energy sources to the use of oil and its derivatives that would further reduce environmental degradation largely due to the emissions produced by the use of conventional fuels.

Within this context, the European Commission (EC) within the Renewable Energy Directive (2009/28 / EC) has established a common framework for the promotion of energy from renewable sources. It has set mandatory objectives applicable in all of Spain in relation to the share of energy from renewable sources in the gross final consumption of energy and the share of energy originating from renewable sources in transport where, for example, the following objective was set for 2020 in terms of renewable energy:

a 20% reduction in greenhouse gas emissions (GHG, in CO2-eq)

a 20% increase in energy efficiency

20% of energy of the European Union (EU) coming from renewable sources

The EC has also defined a set of sustainability criteria in its Directive to ensure that the use of biofuels will take place in a manner that ensures a real savings of carbon (C) and protects biodiversity. Only those biofuels that meet these criteria may receive support from the government or count towards national renewable energy objectives .

Key Points

- *The process of agricultural production, and especially anything related to the management of fertilisation, largely determines the uncertainty in the estimation of the different environmental impact of biofuel production.*
- *The most widely used methodologies for estimating the impact on biofuel production are not sufficiently precise for the production agricultural stage of the same.*
- *The handling of nitrogen fertilisers and the effect of climatology during the cultivation stage greatly affects nitrous oxide emissions and are the major determinants of the carbon footprint during biofuel production.*
- *Organic fertilisation promotes the reduction of the carbon footprint during the production of biofuels such as wheat-derived ethanol and rapeseed-derived diesel. They in turn increase other effects such as water contamination or the acidification of ecosystems.*
- *There is very little likelihood of meeting the requirement of legislation on biofuel sustainability, which recommends a reduction of at least 35 % in greenhouse gases compared to its equivalent fossil fuel, in the case of the production of ethanol and diesel through the use of crops such as wheat and rapeseed for the current limited fertilisation conditions in those areas vulnerable to nitrate contamination and especially in the case of mineral fertilisers .*
- *While organic fertilisation is more likely to meet the standards of sustainability, the direct impact on the use of the land is even greater than in the case of minerally fertilised crops .*

According to the Directive on fuel quality (2009/30 / EC), three sustainability criteria for biofuels have been given consideration:

-Biofuels must lead to GHG savings of at least 35% compared with fossil fuels. This saving requirement goes up to 50% in 2017 and up to 60% in 2018 but only for new production plants. The saving in greenhouse gases has to consider all emissions taking place during the life cycle of the biofuel. This includes crop-based emissions (agricultural stage), processing and transportation.

-Biofuels cannot be cultivated in lands with high carbon reserves such as wetlands or forests.

-Biofuels cannot be produced from raw materials sourced from land with a high level of biodiversity such as primary forests or pastures rich in biodiversity .

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The indirect land use change (ILUC) through the conversion of grasslands and forests into croplands poses the risk of cancelling out the potential GHG savings that could result from the increase in biofuels due to the fact that grasslands and forests absorb and accumulate normally high levels of CO2. Apart from these 3 sustainability requirements, an amendment was made to both Directives (2009/28/EC, 2009/30/EC) with the purpose of reducing the risk of ILUC, with the European Commission putting forward amendments to the legislation with the purpose of ensuring that:

-Emissions that could be caused by indirect land use change must be included in the fuel supplier reports, as well as in EU countries. This will be done through the estimation in GHG that would take place on a global level when using land for the cultivation of biofuels in the EU instead of cultivating the land for human food and animal feed.

-Only half of the renewable energy target of 10% of each country of the EU in the transport sector will be able to be met through first-generation biofuels (produced from sugars, oilseeds, etc.) while second and third generation biofuels will become increasingly important. These biofuels are produced from materials (urban waste, algae, etc.) that do not compete with food crops and feed .

An innovative methodology for analysing if biofuel production is sustainable

This policy briefing summarises a case study based on scenarios involving the analysis of the sustainability of different biofuels (ethanol and biodiesel) produced entirely in the Basque Country, or more specifically in Araba (Llanada Alavesa) under the climatic conditions taking place over the last 50 years.

The most commonly used method to demonstrate that biofuels comply with the EU's sustainability criteria is to participate in voluntary schemes that have been recognised by the European Commission (i.e. Biograce). Our study suggests an alternative methodology to the one commonly used by such certification schemes. Recent scientific evidence indicates that GHG emissions for example, commonly referred to as the C footprint of biofuels generated from energy crops presents a great degree of variability due to nitrous oxide gas (N2O) produced during the agricultural stage in the soil (following nitrogen fertilisation and/or mineralisation of organic matter in the soil) from biological processes such as denitrification and nitrification, is the one with greatest importance and variability within the entire life cycle of a biofuel of this type Unlike international certification schemes, our methodology is intended to reduce uncertainties in the estimation of the environmental impact taking place during the agricultural stage, and thus shows the effect that the handling of the crop along with the climatic and soil conditions have on this impact (i.e. N2O) as well as on crop yield.

This study sets out to explore the following questions in greater depth: Do the crop management conditions have a considerable influence to determine if a biofuel is sustainable or not? How likely is biofuel to meet the requirements for sustainability set out by present and future legislation depending on the management and the climatic conditions and soil type? What are the limitations of sustainable biofuel production within areas vulnerable to nitrate contamination and therefore also subject to Nitrates Directive legislation (91/676/EEC)?

For this study, the BC3 has developed an innovative methodology that integrates agronomic mathematical models produced in the BC3, such as the SIMSNIC model (Gallejones et al., under publication), within a life cycle analysis study (Gallejones et al., 2015).

The SIMSNIC model (Figure 1), developed entirely in the BC3, is able to predict, during the agricultural or field stage with a certain degree of robustness ,the major effects that fertiliser handling and the soil conditions and weather have on GHG emissions (i.e. N2O), the agricultural productivity per hectare in dry matter, protein and % in oil (important for the case of oilseed crops: i.e.. rapeseed) and other precursor pollutants of diffuse contamination in waters (i.e. nitrate leaching: NO3-) or acid rain (ammonia: NH3). SIMSNIC is a semi-empirical model and has been validated for this area of study in wheat and rapeseed rotations.

The typical model entries are as follows: basic soil characteristics (i.e. texture), daily meteorology (maximum temperature, minimum temperature and precipitation) and the past and current handling of the land (i.e. dose, date and type of fertilisation, planting date, type of tillage, irrigation, etc). The model calculates the nitrogen (N) cycle and the water balance for the different stages of crop growth and the periods between crops. It simulates the effect that the environmental conditions may also have on the biological and physical-chemical processes that regulate the production at the plant and the transformations and yields of the system in the form of the different forms of N (N2, N2O, NOx and NO3-).

The case study: wheat and rapeseed-derived diesel and ethanol

In order to quantify the likelihood of each biofuel type studied (ethanol from wheat and diesel from rapeseed) complying with the requirements of sustainability that are set by a particular bioenergy directive or even other ones such as the European Nitrate Directive (91/676/EEC), a Monte Carlo-type uncertainty analysis was carried out based on 1000 different simulations of the model for the past 50 climatological years in the La Llanada Alavesa area.

This study is part of the framework of the project ENERKROP: Development and application of agronomic models for environmental assessment of energy and the production of biofuels in the Basque Country. SAIOTEK Program (Industry, Innovation, Trade and Tourism; Basque Government) and is part of the doctoral thesis by Patricia Gallejones entitled: "Mass-balance modelling and measurements to study GHG mitigation strategies using energy cropping systems under humid Mediterranean climate.

The field rapeseed or wheat production stage represented the stage where the highest environmental impact studied the entire production cycle of biofuels took place. N2O emissions from soil, influenced largely by the fertilisation type and dose, as well as climatology, represented the most important source in terms of Carbon footprint impact.

While GHG emissions calculated in our study are somewhat higher than the average observed in current studies in rapeseed-derived diesel, such emissions fall into the range of studied emissions. Our calculations in terms of wheat-derived ethanol came in at an average of the ones listed in the different studies carried out worldwide.

In our case, Biofuel production was always more energy efficient than the production of petrol or diesel produced from fossil fuels (Figure 2). However, biofuels only reduced their impact on the carbon footprint in terms of fossil fuels (Figure 3).under certain field handling conditions , as well as depending on the climatological year. For example, biofuels generated through high mineral fertilisation processes (i.e. 200 Kg N/ha year as ammonium nitrate, case 3 in Figure 3) would generate a greater impact on GHG emissions by approximately 40 and 70% of the occasions for bioethanol and biodiesel, respectively (Figure 3: crossing of the red vertical line with the curves number 3).

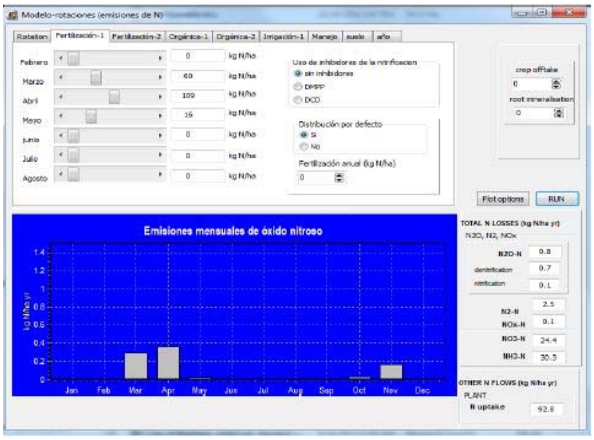

Figure 1. Image illustrating the interface model SIMSNIC

Considering that the area of study may partly fall into the areas declared vulnerable to nitrate contamination, being therefore subject to legislation contained in the Action Plan on the areas declared vulnerable to water contamination caused by nitrates from agricultural activity, which limits the use of mineral or organic nitrogen fertiliser, among others, of up to 170 kg N/ha year, we might think that the current conditions of fertilisation of the area must come close to these 170 kg kg N/ha year. Thus, while there would be an improvement in the carbon footprint compared with fossil fuels in the majority of cases involving the use of a mineral fertilisation (i.e., ammonium nitrate or urea), it would only meet the criteria of sustainability of the European Directive on renewable energies, which recommends at least a 35 per cent reduction in greenhouse gases compared with its equivalent fossil fuel, in the case of fertilisation with urea and by approximately 30% and 40% for ethanol and biodiesel, respectively (Figure 3) .

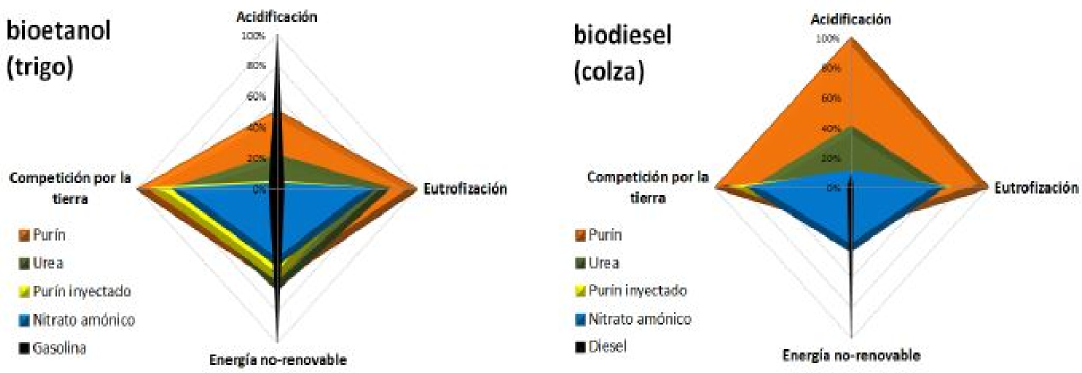

Figure 2. Environmental Impact (except GHG emissions) in terms of the bioethanol and biodiesel production life cycle relating in each impact category to handling (fertilisation) of the biofuel or equivalent fossil fuel equivalent agricultural stage presenting a greater impact (represented as 100 %).

Biofuels produced from organically fertilised crops showed a higher likelihood of the scenarios involving mineral fertilisation meeting the renewable energy sustainability criteria of the European Directive. However, they led to greater environmental losses in gases with acidifier capacity and contamination in the waters, with the need for a larger surface to produce the same amount of biofuel (Figure 2). The injection of this slurry, as a land application technical measure, would visibly reduce the NH3 volatilisation impact (i.e. acidification), as well as possibly reducing the impact on eutrophication and from competition for the use of the land.

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Final Considerations

Biofuel production in the case we are dealing with has a much greater impact than fossil fuels in terms of the contamination of water and, very importantly, in terms of higher competition for the use of land. Furthermore, the effects associated with the acidification of soil in the case of biodiesel were higher than those for fossil fuels (diesel) (Figure 2). This information suggests that it is essential for energy crops to be grown on land without any ecological or agricultural interest, where any promotion that may take place must do so taking into account that this is not for GHG reduction reasons, in order to avoid competition with food production, even though this is not a part of the study.

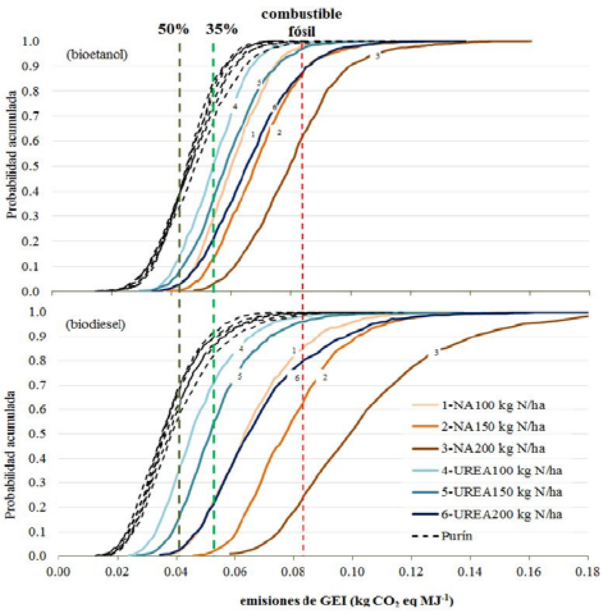

Figure 3. Cumulative likelihood of GHG emissions in the production of ethanol and biodiesel for the different scenarios assessed. NA: fertilised with ammonium nitrate, Urea: fertilised with urea. The vertical lines represent 35 and 50% of emissions reduced in comparison with fossil fuel. The dotted curves represent scenarios fertilised with liquid manure.

It is important to emphasise that the handling in fertilisation during the agricultural stage was essential as a factor for the degree of environmental impact of the biofuel. Such differences would not be reflected in a methodology of the proposals on international voluntary schemes.

Our methodology that includes different analysis and uncertainty techniques has allowed us to be able to quantify the likelihood of biofuel produced in the Basque Country meeting the requirements of sustainability that are determined by the European Directive on renewable energy. We have also been able to show the effect that the Nitrates Directive may exert on the different types of environmental impact from the production of biofuels. This integrated approach allows further knowledge to be gained and offers practical and realistic solutions that may lead to a reduction in GHG emissions with minor secondary environmental effects.

The information generated in this study provides results that could be used in the strategic design of policies on bioenergy, agriculture and Nitrates Directives.

The relevance of the results of this research may very much lean towards bioenergy management public policy. The ultimate purpose of this approach is to determine the best methods in relation to the implementation of bioenergy production systems that are fully located in the entire production chain in the Basque Country.

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