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Research paper

# An integrated Multi-Regional Input-Output (MRIO) Analysis of miscanthus biomass production in France: Socio-economic and climate change consequences

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ABSTRACT

Several European policies have been designed over the last decades to address the challenge of climate change and several measures have been put in place to accelerate the development and deployment of cost-effective low carbon technologies. The domestic nature of the resource and its great potential availability in Europe make biomass conversion technologies relevant mitigation options to be considered. In this context, the project "Logistics for Energy Crops Biomass (LogistEC)" aims to develop new or improve technologies of biomass logistics chain. In this project, the sustainability of different types of biomass is analysed in terms of environmental, economic and social impacts, based on the supply chain of two existing plants. The objective of this paper is to present the main results obtained in the socio-economic analysis of the French case and its climate change consequences. The Input-Output Analysis (IOA) has been seen as the most appropriate method to estimate these impacts using a Multiregional Input-Output Table from the World Input-Output Database project. Socio-economic effects have been estimated in terms of additional economic activity, added value and job creation. By extending the IOA with environmental accounts, greenhouse gas (GHG) emissions have also been estimated. Additionally, the most stimulated sectors have been identified. Results highlight the importance of biomass at a national level.



## 1. Introduction

The EU members states adopted in 2009 the 2020 climate and energy package [1–3] which is a part of the Europe 2020 strategy for smart, sustainable and inclusive growth [4]. Under this strategy, the European Union aims to reduce its GHG emissions by at least 20%, increase the share of renewable energy to at least 20% of consumption, and achieve energy savings of 20% or more [3,4]. All EU countries must also achieve a 10% share of renewable energy in their transport sector.

Recently, European countries have agreed on a new 2030 Framework for climate and energy, including EU- targets and policy objectives for the period between 2020 and 2030. These targets aim to help the EU achieve a more competitive, secure and sustainable energy system and to meet its long-term 2050 GHG reductions target. [5].

Different strategies are required to attain the energy system transformation required to meet these ambitious goals. In order to accomplish a sustainable energy system, while meeting the GHG reductions targets, the European Strategic Energy Technology plan (SET-plan) [6], communicated in 2007, promotes the development of competitive and affordable low-carbon technologies.

Bioenergy is expected to play an important role towards this energy transition. Biomass is a domestic resource, available in many European regions that can be stored to generate the energy on demand [7]. However, there are still many barriers to overcome for biomass to be deployed to a large scale. The European Innovation Partnership Agricultural Productivity and Sustainability (EIP-AGRI) identified the main barriers for the development of bioenergy, and proposed tools and measures to overcome them (EIP-AGRI, 2015). The technical difficulties, the cost of biomass logistics, the economic challenges due to price fluctuations and competition from other uses as well as the farmers' scepticism are some of the most mentioned [8].

Additionally, and due to the domestic nature of the resource,

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bioenergy can also promote local economy and employment. These positive socioeconomic impacts should be taken into account when designing a successful bioenergy policy. To trigger its relevance in the future energy mixes, this resource should be cost-efficient, environmental-friendly and socially sustainable, besides economic and environmental efficient. The Logistics for Energy Crops Biomass (LogistEC) project [9], funded by the 7th Framework Programme (FP7), aims to develop new or improve technologies of biomass logistics chain by considering the environmental, economic and social aspects of sustainability. The project focuses on improving all biomass value chain components. It analyses different types of biomass for two existing plants. To include the three pillars of sustainability, the analyses are conducted under a common framework that enables, firstly, an economic optimization based on feedstock models, predictions of the most probable location of future fields and distances, and then, the environmental and socio-economic assessment considering the different life cycle stages from “cradle to gate”. The environmental analyses are carried out following the Life Cycle Assessment method, while the socio-economic analysis is based on Multi-regional Input-Output (MRIO) Analysis.

In this paper, we present the socio-economic impacts from the production of energy from miscanthus at Bourgogne Pellets plant, located in the Burgundy region of Eastern France. Although it is out of the project scope, we have also extended the MRIO Analysis with environmental accounts to estimate the GHG emissions associated to the system.

This paper is organized as follows: we describe the method in section 2. Section 3 presents the case study and main hypothesis. Section 4 discusses the results of the study. Finally, we draw the main conclusions in section 5.

## 2. Method

The methodology used to estimate the socio-economic effects of the production of bioenergy of miscanthus is the Input-Output (IO) Analysis, extended with sectorial employment vectors as well as sectorial GHG emissions vectors and considering the trade between the different economies of the world.

IO Analysis has been commonly used to estimate macro-economic impacts of industries within the national or regional economy. This analysis was developed by Wassile Leontief for which he was awarded with the Nobel Prize in Economics in 1973. IO analysis describes, through symmetrical tables, the interdependencies between activity sectors within an economy [10,11]. The IO tables are built based on statistical data for a given economy that could be at regional or national level and describe the flows of goods and services in monetary terms between different activity sectors and demands or between producers and consumers. The IO tables can be divided into two main components, the inter-industry flows or transaction matrix, which describes the flows from sector $i$ to sector $j$ and the final demand. Intermediate goods and services are further processed by other sectors [12].

An IO table represents the production cost components in columns, accounting for the resources consumed from other sectors to obtain a certain production in each sector, while in rows the distribution of one sector's production among the other sectors is described. Table 1 shows an example of an input-output table.

Therefore, the total output from each sector is defined by:

$$\mathrm{x_i = z_{i1} + z_{i2} + \ldots + z_{in}} + y_i \tag{1}$$

This equation will be set for all sectors included in the IO table. We can use the matrix notation to describe the different elements of the equations system as:

$$x = \begin{bmatrix} x_1 \\ \ldots \\ x_n \end{bmatrix}; \; Z = \begin{bmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nn} \end{bmatrix}; \; y = \begin{bmatrix} y_1 \\ \ldots \\ y_n \end{bmatrix} \tag{2}$$

where $x$ is a vector that expresses the total output, $Z$ is the IO matrix and $y$ is the final demand vector.

The IO matrix can be expressed with the technical coefficients, which represent the ratio of input to output, that is the amount required by one sector from other sector to produce one monetary unit of output. The technical coefficients are denoted as:

$$\mathrm{a_{ij} = z_{i1}/x_j} \tag{3}$$

The technical coefficients can be expressed as a matrix, the $A$ matrix. We substitute $z_{ij}$ in Equation (1) for the technical coefficients and the total output is defined by the following matrix equation:

$$\mathrm{x = Ax + y} \tag{4}$$

Reorganizing Equation (4), we get the following expression:

$$\mathrm{x} = (I - A)^{-1}\mathrm{y} \tag{5}$$

where $(I - A)^{-1}$ is the Leontief inverse matrix, or the multiplier matrix, that expresses the total production of each sector required to satisfy the final demand. That is the direct and indirect requirements per unit of final demand.

Through the IO analysis, we can estimate the total output in monetary terms that will be produced by the different sectors in the economy in order to satisfy the intermediate and final demand of goods and services. Equation (5) can be also decomposed as follows:

$$x = (I + A + AA + AAA + \ldots + A^n)y \tag{6}$$

where $Iy$ are the direct impacts and $Ay + AAy + \ldots + A^n y$ are the indirect impacts.

The IO analysis began as a method to analyze national or regional economies. However, production processes have become less domestic, and national economies are part of a global economy. Supply chains are increasingly fragmented across borders and this fundamentally modifies the nature of international trade with important consequences for the location of production as well as other related impacts. MRIO modeling provides the opportunity to analyze the consequences of this fragmentation in a comprehensive way by including different regions and their trade relationships.

The MRIO tables follow a similar structure than the IO tables, but there are interregional and intraregional transactions, being

**Table 1**
Example of input-output table.

| | | Processing sectors (intermediate demand) | | | | Final demand | Total output |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | … | n | | |
| Processing sectors | 1 | $z_{11}$ | $z_{12}$ | … | $z_{1n}$ | Y | x |
| | 2 | $z_{21}$ | $z_{22}$ | … | $z_{2n}$ | | |
| | … | $z_{31}$ | $z_{32}$ | … | $z_{\cdot\cdot n}$ | | |
| | n | $z_{n1}$ | $z_{n2}$ | … | $z_{nn}$ | | |
| Payment sectors | Value added | $v_1$ | $v_2$ | … | $v_n$ | | |
| | Import | $m_1$ | $m_2$ | … | $m_n$ | | |
| Total outlays | | x | | | | | |

Source: [11].