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Locating and designing a biorefinery supply chain under uncertainty in Navarre: a stochastic facility location problem case

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Abstract

The need for renewable energy sources is quickly growing in order to reduce the greenhouse gas emissions. Moreover, Navarre, a European region located in Northern Spain is, currently, a global leader in the production and use of renewable energy. Actually, more than 80% of its electricity production comes from renewable sources (mainly wind and water). Then, having the purpose of increasing the renewable energy sources diversification, the region aims to locate a biorefinery plant which mainly serves Northern Spain. Locating decisions are considered strategic, immobilizing a large amount of resources and involving an important group of industrial actors. Therefore, they initially show a significant impact on investment costs, and later, on the operating costs when the facility is already running. This location activity has also important environmental influence due to the usual performance of the biorefinery, involving also the transportation and logistic activities because of the supply chain procurement. Once the biorefinery has been located, another problem arises: the design of the supply chain with its classical operational decisions: which crops are going to be harvested, when they are going to be collected and how we should transport the feedstock to the biorefinery. Apart from this, dealing with farms production is always dealing with uncertainty. Thus, climate and weather, competitors and alternate uses, are key factors which influence the availability of biomass. For that reason, uncertainty must be taken into account in order to avoid stockouts that allow us the optimization of the total expected cost. Moreover, estimated feedstock availability is crucial to determine the optimal plant size. Therefore, the results provide us not only the best location of the biorefinery from the economic point of view, but also the variation on feedstock disposal that eventually the biorefinery could intake along with its final size.

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Keywords: Facility Location Problem; Biorefinery; Uncertainty; Mixed Integer Linear Programming Problem; Biomass.

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1. Introduction

The use of fossil fuels to produce energy and raw materials involved an enormous industrial progress in the last centuries. Oil exploitation from the nineteenth century allowed obtaining affordable fuel source, along with useful raw materials for many industry sectors, including chemical, textile, automotive, construction, etc. However, some signs threaten the economic model based on the petrochemical industry, such as an increased demand from emerging economies, uncertainty in the price or supply and the political and social interest in reducing gas emissions from fossil fuels. Thus, it arises the need to reduce the dependence on petrochemical raw materials by developing new energy alternatives from renewable resources. In this context, industrialized countries have begun to consider the biomass as a suitable feedstock for energy production given its renewable nature and its wide distribution. Therefore, associated to this new technological and industrial paradigm, the "biorefinery" concept was born.
Since the nineties, there have been many tries in order to define what a biorefinery is, when the concept was set up for the first time as a response to new industry tendencies (mainly, increased awareness in renewable resources). Nevertheless, the general idea was connected to upgrading biomass to valuable products by using different processes such us conversion, gasification, or fermentation, among others. Those high-value products include a wide range of different ones including electricity, biofuels and chemical commodities, to name a few (Björn and Pettersson, 2014).

1.1. Geographical Scope.

Navarre, where this case study is held, is currently a remarkable example in green energy production. The region, located in Northern Spain, covers more than 80% of its electricity consumption by renewable sources. This small territory, which accounts for 10,300 km^2, and a population around 640,000 inhabitants (see Figure 1), provides a model of renewable energies development in all fields. For instance, Navarre wind power generation is greater than the one from countries such as Australia, France, Sweden, Ireland, Belgium, Norway, Poland and Finland. (Navarre Energy Balance, 2013). Moreover, considering the total energy consumption (oil, natural gas, electricity…) renewable energy share was, in 2013, 25.20%, five points above the target set by the EU for 2020, and ten points above the Spanish average. Such a production level allowed a saving about 1,000 tons of CO_2, (Navarre Energy Balance, 2013).
As a conclusion, Navarre is an important reference in green energy generation. Wind, water and sun are the main actors in its "green portfolio" accounting with more than 80% of total electricity consumption. For that reason, Navarre aims to set up a biorefinery plant in its territory, using biomass as feedstock from Navarre itself and nearby regions, in order to increase the renewable energy sources diversification keeping, at the same time the paradigmatic position in the renewables market worldwide.

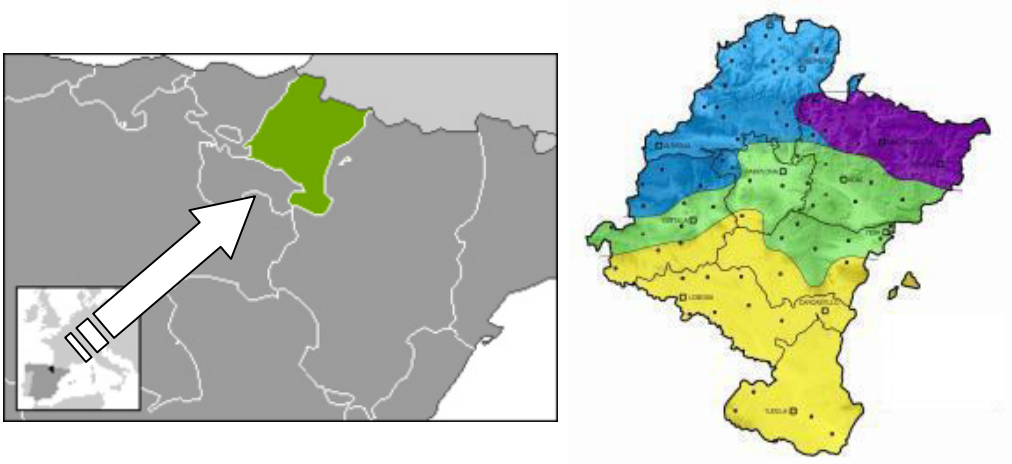

Fig. 1 Navarre location and its climatic areas (blue, Atlantic; purple, Mountain; green, Central Navarre; and yellow, Southern Navarre)