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Design and planning of infrastructures for bioethanol and sugar production under demand uncertainty

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ABSTRACT

In this paper, we address the strategic planning of integrated bioethanol–sugar supply chains (SC) under uncertainty in the demand. The design task is formulated as a multi-scenario mixed-integer linear programming (MILP) problem that decides on the capacity expansions of the production and storage facilities of the network over time along with the associated planning decisions (i.e., production rates, sales, etc.). The MILP model seeks to optimize the expected performance of the SC under several financial risk mitigation options. This consideration gives a rise to a multi-objective formulation, whose solution is given by a set of network designs that respond in different ways to the actual realization of the demand (the uncertain parameter). The capabilities of our approach are demonstrated through a case study based on the Argentinean sugarcane industry. Results include the investment strategy for the optimal SC configuration along with an analysis of the effect of demand uncertainty on the economic performance of several biofuels SC structures.

Keywords: Supply chain optimization; Planning; Bioethanol supply chain; Sugar supply chain; Financial risk management; Stochastic programming

1. Introduction

Ethanol is nowadays regarded as a successful example of a global shift away from fossil sources of energy to bio-based fuels. The use of ethanol as a transport fuel began in the 1970s, and was motivated by the oil crisis and the need to develop alternative fuel programs for reducing the dependence on oil. Among the various alternative fuels, ethanol is one of the most suitable ones for spark-ignition engines. It is produced from renewable sources and does not contain the impurities present in petroleum-derived products, such as sulphur compounds and carcinogenic aromatics, which are the main sources of pollution in large metropolitan areas. Ethanol and ethanol–gasoline blends have several advantages over conventional gasoline such as the reduction of fossil-originated CO_2 emissions, better anti-knock characteristics, and higher power output and fuel economy (Hsieh et al., 2002). Moreover, the higher auto-ignition temperature and flash point of ethanol lead to lower evaporation loses (Niven, 2005). The use of ethanol has also some disadvantages such as the increase of NO_x and noise emissions (Bayraktar, 2005; Keshkin, 2010). In addition, the gasoline blends with ethanol have a tendency to absorb water and therefore require special storage conditions to prevent a degradation of fuel properties (Muzikova et al., 2009).

Fuel ethanol was firstly adopted by Henry Ford in 1896. The large-scale production of ethanol for the transportation sector, however, did not begin until the late 1970s, and took place mainly in Brazil and US. In 1975, Brazil launched the national alcohol program *Pró-álcool* sponsoring the development of ethanol-fueled cars. By 1986, 72.6% of light vehicles sold in Brazil operated exclusively with pure ethanol (ANFAVEA,

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