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Assessment of optimal biofuel supply chain planning in Iran: Technical, economic, and agricultural perspectives

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Contribution to satisfying the final energy demand, the necessities arises from waste minimization, and rural area's developments are the main incentives for biofuel usage in the Iranian energy supply system. This paper develops a model for the supply chain of bioethanol and bioETBE from the farms to the end users which integrates the temporal and spatial scales. It considers the techno-economical evaluations of first and second generation biofuels. The results provide practical insights for decision makers to introduce the biofuel into the Iranian energy systems. Here, the optimal designs of transition pathways of biofuel supply chain are available which successfully assesses the benefits and barriers to the decision maker.

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Contents

1. Introduction

Sustainable and secure energy supply system for the future are of great importance to decision makers, researchers, and industry. Biofuels have been clearly emerged as a promising alternative in recent years. Europe will be able to produce biofuel more than 10 percent of gasoline and diesel demand by 2020 [1]. Several studies have reviewed the potential of biofuels [2,3]. Kim and Dale estimated the global potential production of 491 GL of bioethanol from wasted crops and crop residues which may be replaced with 32 percent of total gasoline consumption [4]. In addition, 458 TW h of electricity and 2.6 EJ of steam may be generated from the lignin-based residue of the production process. The main usage of ethanol is as an oxygenated fuel additive. However, it is mixed with gasoline and provides several advantages [5]. Taken into account different activities in the production of biofuels, their supply chain models in different countries and regions have recently received attention [6–10]. Akgul et al. have developed a corn-based bioethanol supply chain minimizing the total cost [11]. Roy et al. evaluated the life cycle of bioethanol production from rice straw in Japan [12]. Zhang et al. design an efficient switch grass-based supply chain for production of bioethanol [13]. They minimized the cost of the system on North Dakota state in the United States [13]. Akgul et al. proposed a supply chain model for

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Nomenclature

List of symbols

$Al_{tie\tau}$	Land area of technology type τ for energy carrier e in region i, ha
$Al_{\max,tie\tau}$	maximum land available to be utilized
$co_{ltie\tau}$	operating cost per flow of energy carrier e from technology τ in region i at time t in level l
$cc_{ltie\tau}$	capital cost of technology type τ for energy carrier e in region i at time t in level l
$CF_{tie\tau}$	land capacity production, t/ha
$Dl_{tie\tau}$	average land degradation factor in time t and region i for energy carrier e and technology type τ
h	harvest residue generation fraction
hr	harvest residue recoverability fraction
HI	harvest index
X_{ltie}	flow in level l at time t in region i for carrier e
$OC_{lt\tau}$	operating cost of technology type τ in level l at time t
$CC_{lt\tau}$	capital cost of technology type τ in level l at time t
$pc_{tie\tau}$	potential of cultivation for energy carrier e in region i for technology type τ
r	discount rate
Y	capacity

Greek symbols

η	technology efficiency in each level
τ	subscript for technology type τ

Subscripts

A	level of end products
B	level of distribution
C	level of conversion
D	level of transport
e	subscript for energy carrier
E	level of supply systems
F	level of resources
HC	historical capacity
i,j,k	subscript for region
l	subscript for level
lt	life time of each technology
t	time horizon $t=1,\ldots,T$.
up	upper bound on variables
yr	time point

first and second generation biofuels in the UK [14]. Amigun et al. perform a prefeasibility analysis to evaluate the feedstock and technology options to produce bioethanol in South Africa [15]. They show the economic challenges for ethanol producers in South Africa. However, further economic analysis is required for simultaneous variations in parameters [15]. Corsano et al. propose a Mixed Integer Nonlinear Programming (MINLP) for the design of the sugar/ethanol plant [16]. Giarola et al. propose an optimization model for the future Italian biomass-based ethanol production from corn grain and stover [17].

These models may be categorized by their objective function, spatial dimensions, the biomass feed stocks, time horizons, etc. The literature regarding biofuel supply chains is restricted on particular aspects of the supply chain. In addition, no work has been adapted to consider the relevant concerns in Iran.

Currently agricultural wastes are not used for energy production in Iran. The increasing demand of the gasoline in recent years causes some challenges in energy supply system. The government made legislations about the fuel's quota for each vehicle. Thus, there is a need to the efforts toward the sustainable energy systems such that the fuel demand of the country is satisfied. In this context, biofuels are very interesting options. Moreover, they will improve the production of fuel additives in Iran. They provide opportunities for the waste minimization and create job opportunities especially in rural areas. Finally, their development will protect fossil fuel resources. These motivations will guide us toward developing a tool in order to evaluate the biomass potential to produce biofuels in Iran.

Previously, Najafi et al. [18] reported the annual potential of 4.91 GL of bioethanol in Iran. They found wheat, sugar cane bagasse, rice, barley, and corn as the most attractive crops [18]. According to Ghobadian et al., the potential of bioenergy is less studied in Iran in comparison to other renewable energy resources [19]. Taleghan site will only provide the energy for hydrogen usage. On the other side, applying the biofuels improves the waste minimization in Iran. Hamzeh et al. [20] have estimated the bioenergy potential of the country as 8.78×10^6, 7.7×10^6, and 3×10^6 t from agriculture, animal, and municipal wastes, respectively. Ghobadian [21] also predicts that bioethanol and biodiesel may sufficiently carry out the demand of E10 and B10 by 2026.

Since different aspects are involved in the introduction of biofuels in an energy system, a comprehensive supply chain model should be developed. Recently, Avami [22] presented a supply chain model to evaluate the potential of applying biodiesel in Iranian energy systems. Taking into the account the problem complexities and the needs of applying the current potentials, the present work has been conducted. In this work, the supply chain model adopted to consider the issues of bioethanol production in Iran. The main biomass feedstocks to produce bioethanol are the wastes, the crops residues and energy crops which are not completely concluded in the previous studies. This paper assesses the most important supporting plans to regionally introduce bioethanol and bioETBE in Iran for the next 28 years. The main concepts and equations are explained in Section 2. To solve different problems, several scenarios are considered in which the results are presented in Section 3. The results are analyzed and the implications are introduced to the policies. Section 4 concludes the paper with a short summary.

2. Model characteristics

This section introduces the main concepts of the current supply chain model as the basics are previously described by Avami [22]. The regional model, as depicted in Fig. 1, consists of different levels: resources, supply system, transport, conversion, distribution, and end-products. Thus, it enables us to encompass the variety of biomass feedstocks, conversion technologies, geographical diversity, and economics. It analyzes the most critical issues in the supply side of the bioethanol supply chain management and provides the optimal economic pathway over the temporal scale regarding the technical and geographical constraints.

Biomass to potentially produce bioethanol is classified as sugar-based, starch-based, and lingocellulosic feed stocks. The largest potential producer of bioethanol is Asia in which rice straw, wheat straw, and corn stover are the most important feedstocks [4]. Wheat straw and corn stover are the main potential feedstock in Europe (the second largest candidate) and North America, respectively [4]. The major feedstock in Brazil, the largest producer of

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