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Economic feasibility of algal biodiesel under alternative public policies

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ABSTRACT

The motivation for this research was to determine the influence of public policies on economic feasibility of producing algal biodiesel in a system that produced all its energy needs internally. To achieve this, a steady-state mass balance/unit operation system was modeled first. Open raceway technology was assumed for the production of algal feedstock, and the residual biomass after oil extraction was assumed fermented to produce ethanol for the transesterification process. The project assumed the production of 50 million gallons of biodiesel per year and using about 14% of the diesel output to supplement internal energy requirements. It sold the remainder biodiesel and ethanol as pure biofuels to maximize the rents from the renewable fuel standards quota system. Assuming a peak daily yield of 500 kg algal biomass (dry basis)/ha, the results show that production of algal biodiesel under the foregoing constraints is only economically feasible with direct and indirect public policy intervention. For example, the renewable fuel standards' tracking RIN (Renewable fuel Identification Number) system provides a treasury-neutral value for biofuel producers as does the reinstatement of the renewable fuel tax credit. Additionally, the capital costs of an integrated system are such that some form of capital cost grant from the government would support the economic feasibility of the algal biodiesel production.

1. Introduction

Renewable energy's potential to address the environmental problems posed by fossil fuels and contribute to addressing the energy security challenges are stimulating action in governments, businesses and research institutions. Public policies are being developed to facilitate the continued emergence and growth of the renewable energy sector. The success of these initiatives is reflected in the sector's global revenues topping $500 billion in 2011, representing a compound annual growth rate of about 3.7% between 2007 and 2011 [10].

Despite their promise, renewable energy production is not uncontroversial. Hydroelectric power development often impacts arable land availability and human communities that depend on it while wind energy development in certain places has been accused of destroying the vistas. For bioenergy, the controversy has centered around its effects on food prices resulting from diversion of food products to energy feedstock and the increase in input prices resulting from the increase in their demand for non-food feedstock production [15].

Bioenergy solutions to these controversies have focused on using cellulosic feedstock [24] and non-food oilseeds and plants [17]. Algae have been presented as a promising biomass feedstock for a long time [3,21]. Its advantages have been described by some to include reliability as a feedstock, higher energy yield per unit production area and year-round batch-wise harvesting that supersedes all other biomass sources [11]. At their most conservative oil content level, Mata et al. note that microalgae oil output per unit area is about 92 times that of soybeans. These extrapolations form the crux of the debate in the research community about algae's technical and economic feasibility as an effective biofuel feedstock [4,14,17,27].

This paper contributes to the debate from a different perspective. First, it seeks to develop a carbon-neutral production system for algal biodiesel, implying that the production system must not lead to an overall increase in carbon release to the atmosphere. Next, it evaluates the economic feasibility of such a production under prevailing public policies and plausible alternative policies. It achieves these objectives using a mass balance/unit operation approach [7] to ensure that carbon-neutrality is maintained, and assesses the economic feasibility using net present value approach

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to capital investment decision-making. The next section provides an overview of the bioenergy policies in the U.S. against a backdrop of fossil energy's entrenched incumbency advantages. The assumptions driving the system dynamic model used are presented in the subsequent section and the penultimate section presents the results. The summary and conclusions are presented in the final section.

1.1. U.S. bioenergy policy overview

Public policies supporting bioenergy in the U.S. have only become prominent in the last two decades or so. At the forefront of these policies is the EPAct (Energy Policy Act) of 1992, which directed that more studies be conducted on biofuels and provided guidance for federal programs for increased implementation of biofuel programs. Title III of the EPAct (1992) amended the Energy Policy and Conservation Act of 1975 and directed the Secretary of Energy to acquire vehicles using alternative fuel for federal fleet, among other directives. Title IV of this EPAct (1992) also amended the Energy Policy and Conservation Act of 1975 to authorize appropriations from Fiscal 1993 through 1995 for alternative fuel commercial trucks application program. It also amended the Motor Vehicle Information and Cost Savings Act of 1972 to reflect the alternative fuel provisions of EPAct (1992). Title IV also authorized the Secretary of Transportation to establish a low-interest loan program to encourage small businesses to adopt vehicles using alternative fuel. Finally, it directed the Secretary of Energy to promote the use of alternative fuels through public education and information. The Federal Trade Commission was also directed under the Act to formulate regulations and guidelines for labeling alternative fuels and vehicles using such fuels. Thus, EPAct (1992) seemed to set the market development process in place in preparation for the development of the biofuel products.

The Energy Policy Act of 2005 put programs in place to encourage the use and production of biofuels, such as ethanol and biodiesel. It directed the pursuit of research and development of renewable energy using agricultural biomass as a feedstock and provided tax incentives for individuals and firms using and/or producing biofuels. There were specific instructions for the Secretary of Energy to ensure reduction in petroleum-fueled vehicles in the federal fleet. It also established compliance rules for the use of alternative fuels, with clear non-compliance penalties. Title VII of EPAct (2005) directed the establishment of programs to improve the commercialization of hybrid/flex fuel vehicles and plug-in/flex fuel vehicles. But Section D of Title IX focused specifically on research and development of agricultural biomass, directing the Secretaries of Agriculture and Energy to look into new feedstock for conversion into biofuels and bio-based products, including the development of technologies for converting cellulosic biomass into biofuel. The Secretary of Agriculture was also directed to establish education and outreach programs on bio-based fuels and bio-based products. Section D of Title XIII of EPAct (2005) established tax incentives for investments in alternative energy, including fuel cells and hybrid vehicles. Section 1342 provided a 30% tax credit for the cost of installing a commercial or residential refueling property to dispense fuels containing at least 85% ethanol or biodiesel up to a $30,000 maximum. Additionally, producers could claim a $1.00 per gallon tax credit for biodiesel produced from new agricultural feedstock, including biomass feedstock, and $0.50 per gallon for biodiesel produced from used feedstock, such as fryer grease. This tax credit was set to expire on December 31, 2009.

The EISA (Energy Independence and Security Act) of 2007 was an omnibus energy policy act with four of its 16 titles related directly to alternative fuels. Title I allow automobile manufacturers tax credits towards the production of alternative-fueled vehicles, extending such credits through 2019. It also allowed vehicles operating a blend of 20% biodiesel and 80% petroleum to be considered for CAFE (corporate average fuel economy) credits. Title II of the EISA specifically focused on increasing energy security through biofuels. It increased the original biofuel production target of 7.5 billion gallons originally established under the RFS (Renewable Fuel Standard) of the EPAct (2005) to 36 billion gallons by 2022. The revised standards, referred to as Renewable Fuel Standards II (RFS II), comprised 15 billion gallons of conventional biofuels, 4 billion gallons of advanced biofuels, 16 billion gallons of cellulosic biofuels and 1 billion gallons of biomass-based diesel. It also stipulated that an increasing amount of renewable fuels must be sourced from feedstock other than corn, with the expectation that these types of fuels will reach 21 billion gallons by 2022. Title IX of the law provided grants and loans for the development, construction and retrofitting of commercial scale refineries to produce biofuels. These specific policy initiatives provided an invitation to researchers to revisit algae as a potential feedstock in biodiesel production and for refineries and interested entrepreneurs to consider the technical and economic issues involved in using algae as a sustainable feedstock in biodiesel production. To ensure environmental sustainability, EISA required the application of lifecycle greenhouse gas performance to guarantee that renewable fuels produced lower levels of greenhouse gases than the petroleum fuels they replace.

In addition to the foregoing, three specific tax credits are stipulated under Title VIII of the Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010. They are: $1.00 per gallon biodiesel mixture credit; $1.00 per gallon of biodiesel that is not in a mixture with diesel fuel; and $0.10 per gallon up to 15 million gallons of agri-biodiesel produced by small producers. These credits expired in December 2011, and a new legislation, Biodiesel Tax Incentive Reform and Extension Act (H.R. 2238), seeking to extend the $1 per gallon biodiesel tax credit to 2014 and change the tax incentive to a production excise tax credit remains with the House Committee on Ways and Means since June 2011 (Library of Congress, n.d.).

The RIN (Renewable fuel Identification Number) is a serial number assigned to each batch of renewable fuel, traveling with the fuel through the supply chain. The Environmental Protection Agency uses it to track the performance of manufacturers, refineries, blenders, and importers in fulfilling their renewable fuel sale obligations, and in consequence, progress towards the national mandatory biofuel targets under EISA (2007). The agency establishes an annual quota of biofuels based on total motor fuels consumed. Each manufacturer, refinery, blender or importer is then obliged to use a minimum of the specified biofuel quota in its operations. For example, the 2010 quota of 7.95% obliged firms to use no less than 7.95% of renewable fuels in their blends. Recognizing that there will be surpluses and shortages across the industry, the EPA allows firms to trade excess RINs to meet their renewable fuel quotas obligations. RINs have provided a treasury-neutral support for biofuel manufacturers who sell to manufacturers, refineries, blenders, and importers who need renewable fuel to meet their obligations.

The foregoing policy initiatives have contributed to increasing annual U.S. biodiesel production capacity to about 2.11 billion gallons as of September 2012, distributed across 105 biodiesel plants in 36 states, with an average production capacity of about 13.8 million gallons and a standard deviation of about 13.9 million gallons [25]. The nine-month total B100 production increased from 268 million gallons in 2010 to 648 million gallons in 2011 and further to 748 million gallons at the end of September 2012. Despite the consistent growth in production, this production level is only 61% of the 2013 biomass-based diesel volume