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Economic competitiveness of ethanol production from cellulosic feedstock in Tennessee

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ABSTRACT

Transformation of the renewable and abundant biomass resources into a cost competitive, high performance biofuel can reduce Tennessee's dependence on fossil fuel and enhance energy security. However, there is limited understanding of the potential of biofuel resources, their utilization, and economic potential. This study evaluates the economic feasibility of selected bioenergy crops for Tennessee and compares their cost competitiveness. The selected lignocellulosic feedstock consists of switchgrass and *Miscanthus*.

Financial analysis was used to select feasible feedstock for biofuel production. For each feedstock, net return, feedstock cost per Btu, feedstock cost per gallon of ethanol, breakeven price of feedstock and breakeven price of ethanol were calculated. The analysis focused feedstock for biofuel production over 25 year project period. Preliminary research shows that under current conversion rate, the annual equivalent net revenue from ethanol production from switchgrass and miscanthus was $363/acre and $752/acre respectively. Sensitivity analysis showed that the feedstock cost for gallon of ethanol from switchgrass and miscanthus ranges from $0.52–$0.78 and $0.44–$0.66 per gallon respectively. The estimated breakeven price of ethanol from switchgrass ranges from $1.53 to $1.79/gallon and for miscanthus $1.41–1.67/gallon.

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1. Introduction

The growing concern with rising oil prices and global warming and its consequences are the immediate justification for reducing dependence on fossil fuels. Next generation of biofuel feedstock will be composed of cellulose-rich organic materials, which are harvested for their total biomass [1]. Cellulosic biomass such as grass species, woody plants and crop residues are much more abundant than food crops, can be harvested with less interference to the food economy, and places less strain on land, air, and water resources. However, cellulosic-based ethanol has major economic and technical hurdles to overcome before it can be competitive with corn-based ethanol [2]. The current energy balance for corn grain ethanol is 1.4 [3]. This means that a unit input of fossil fuel energy is needed to produce 1.4 units of bio-energy; but if corn stalk instead of grain is used as feedstock, one unit of fossil fuel energy can produce 10 units of bioenergy. However, ethanol producing nations like the USA continue to produce ethanol from corn grain rather from cellulosic stalk because it costs them only about $1.03 to produce a gallon of ethanol but cost of producing same volume from cellulose material is much higher under current technology. The US Department of Energy aims to lower the production cost of cellulosic ethanol to $1.07/gallon by 2012 [3].

Biofuel processing facilities or refineries and feedstock vary with the biofuel to be produced and the processing method used. The various pathways that connect energy crops to feedstock, processing method, and the desired biofuel have been investigated. A system has been developed that makes it economically feasible to convey biomass into cellulose ethanol using combination of thermal, chemical and biochemical techniques [4]. Research efforts are underway examining the feasibility of the use of enzymes instead of acids for the hydrolysis process to convey lignocellulose to sugar. The US department of Energy has indicated that this route will offer good prospects for cost effective ethanol production [5]. Biofuels offer alternative benefits on several fronts. These include energy benefits, environmental benefits [6], and industrial growth and employment opportunities. In the short to medium term, renewable energy can help diversify energy sources, thus improving the security of energy supply necessary for sustainable economic development.

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Since cellulose ethanol production is at relatively early stages, there is an information gap in feedstock production as well as processing. For example, producers are concern of risk and uncertainty associated with feedstock production and marketing. Producers need to have credible information on feedstock selection, various costs associated during production. Specifically information on reliable benefit:cost estimation is essential to attract growers for energy crop farming.

2. Rationale and significance

Per capita energy consumption goal in Tennessee for 2012 was 284.3 million Btu, out of that 28 percent account for transportation sector which is the second largest energy consuming sector of the State's economy [7]. Accordingly State per capita motor gasoline consumption is 522 gallons [8]. This dependency makes Tennessee's economy very vulnerable to price fluctuations and shortages in petroleum production. However, State's energy security could improve from diversification with renewable energy sources. Local production of biofuel would not only improve Tennessee' economic security but also provide employment opportunities for Tennessee's people. However according to Energy information administration only about 3 percent of the energy is produced from bio-renewables [9].

According to 2007 Census of Agriculture statistics, Tennessee has 80,000 farms representing 11 million acres of crop land hence the State has great potential in producing bioenergy [10]. According to the estimates, state has more than 4.5 million acres of crop land with the right soil and climate conditions for switchgrass cultivation. It is estimated that on Conservation Reserve Program (CRP) land alone, 1.4 million dry tons of switchgrass and 1.1 million dry tons of willow and hybrid poplar could be produced annually. Not all of the crop land can or should be diverted from its current uses, but if it were, it could potentially grow enough switchgrass to produce between 1 and 6 billion gallons of ethanol, depending on the maturity of the switchgrass breeding and conversion technology. In addition, there is potential to convert abandoned mine lands for the production of switchgrass [11].

Tennessee is poised to become a national leader in the growth of switchgrass and production of cellulosic ethanol [12]. Though the cellulosic biofuel production is at its relatively early stage, as part of the initiative, the University of Tennessee recently launched a joint venture with Mascoma Corporation to build the nation's first switchgrass-based ethanol plant. The Vonore, TN facility in south of Knoxville, processes 170 tons of switchgrass, wood chips and other forest and agricultural biomass per day to produce 250,000 gallons of ethanol per year – a fuel already trademarked as Grassoline [13]. Tennessee has favorable environmental conditions for energy crop production and a substantial amount of land suitable for agriculture. Identification and study of switchgrass suitable for cultivation in several US States have been carried out in recent times [14–21]. The most promising crops for fiber production include grass species: switchgrass (*Panicum Virgatum*) and *Miscanthus* (*Miscanthus* x giganteus). These two crops have high potential as dedicated energy crops for lignocellulosic ethanol production in Tennessee.

To ensure success of the Tennessee's biofuel production program, continuous supply of biofuel feedstock is essential. Moreover, cellulosic biofuel production is expected to be commercialized in future, accelerating demand for biomass feedstock [22]. Hence, there is a need to continue research in the area of biofuel, particularly cellulose ethanol production in Tennessee for the future energy sustainability of the State. The paper compares the economic feasibility of feedstock production from switchgrass and Miscanthus under Tennessees growing condition.

3. Analytical framework and data sources

The economic analysis of projects is similar in form to financial analysis since both appraise the profit of an investment. The financial analysis of a project estimates the profit accruing to the project-operating entity or to the project, whereas economic analysis measures the effect of the project on the national economy. If a project is not financially sustainable, economic benefits will not be realized [23].

Given the wide range of feedstock available for the production of biofuel under Tennessee's growing conditions, feedstock evaluation has become a priority. Therefore, the financial analysis is mainly focused on the farmer's point of view concerning feedstock supply for biofuel production. This information is also useful to biofuel producers interested in identifying least cost feedstock options for future biofuel production. Hence, a primary focus was given to the private account stance in evaluating feedstock production for the producers. Financial analysis does not capture all local, regional and national impacts of a particular project hence accounting all economic impacts of a given project are needed for policy implementation. A limitation of data is a major barrier to adequately analyze the overall impact of biofuel production at this stage. However, the potential regional impacts on a broader view were identified and briefly discussed.

From a financial or private accounting stance, costs and returns are measured from the producers' perspective: market or administered prices are used; externalities are not usually fully internalized; taxes are treated as a cost; and subsidies are considered a benefit [24]. This can be measured through the indicators such as net present value and private benefit cost ratio etc.

In biofuel feedstock production, the cost of producing each feedstock includes commonly used cost categories from land preparation to harvesting. The analysis assumes that feedstock production is on non-prime land under rainfed conditions hence irrigation was not considered. Although the analysis concentrates on the production of feedstock, energy conversion assumptions are also utilized such that preliminary analysis involving the processing of feedstock to biofuels can be conducted.

It should be noted that certain field operations are not performed regularly and uniformly year after year, therefore, annual costs may differ over the crop's life. From an economic point of view, the overall approach is to estimate average annual costs and returns over the entire economic life of the crop, which allows for direct comparison among different crops. To calculate costs and revenues in annual equivalent terms, the present values of all costs and revenues over the useful life of the crop were transformed into an equivalent annuity. The following procedure was adopted in estimating annual equivalent costs and revenues [25].

1. Present value of the total investment over a 25-year period was estimated as:

$$\mathrm{PVC}_{ij} = \sum_{t=1}^{n} \frac{\mathrm{TCP}_{ij}}{(1+r)^n} \quad \mathrm{PVB}_{ij} = \sum_{t=1}^{n} \frac{\mathrm{GR}_{ij}}{(1+r)^n}$$

where: PVC_{ij} = Present value of production cost of *i*th crop in *j*th farm ($/acre), TCP_{ij} = Total cost of production of *i*th crop in *j*th farm ($/acre), PVB_{ij} = Present value of benefits of *i*th crop in *j*th farm ($/acre), GR_{ij} = Gross revenue of *i*th crop in *j*th farm ($/acre), r = discount rate, n = project duration (years).

In this analysis, n was assumed equal to 25 years and r was 4.5% (average historical discount rate during 1986–2006 from Federal Reserve System [26].

Feedstock cost of ethanol per 1000 Btu was estimated by dividing the cost per acre of producing each feedstock by the