Regional Strategic, LTD.

Modeling Assumptions Utilized in Estimating the State-level Economic Impacts of Utilizing Corn Stover to Replace Coal in the Electricity Generation Process

Mark Imerman
Regional Strategic, Ltd.
August 2017

This analysis was sponsored by Larksen, LLC. The views and opinions in this report are those of the author and do not necessarily represent those of Larksen LLC.

The author acknowledges and thanks

- David Swenson, Department of Economics at Iowa State University
- Eric Thompson, Department of Economics at the University of Nebraska-Lincoln
- Brigid Tuck, University of Minnesota Extension

whose helpful comments and suggestions generated notable improvements in this work. Any errors or omissions that remain, however, are entirely the responsibility of the author.

Suggested Citation:
Imerman, Mark (2017). *Modeling Assumptions Utilized in Estimating the State-level Economic Impacts of Utilizing Corn Stover to Replace Coal in the Electricity Generation Process.* Report for Larksen, LLC. San Diego, CA.

mark@regionalstrategic.com • Phone: 515.802.0938 • P.O. Box 36534 • Des Moines, Iowa 50320

INTRODUCTION

This study was commissioned by Larksen, LLC. to document the assumptions used for a series of related state-level reports which will estimate the economic impact of collecting, processing, and delivering corn stover to replace coal in electricity generation. Corn stover, on its own, is generally not considered to be an economically viable replacement for coal in energy generation.

Low Carbon Fuel Standards and Clean Fuel Standards (LCFS/CFS), which are in place in California, Oregon, and British Columbia and are being considered by other jurisdictions, make credits available to ethanol consumption (as an alternative to fossil fuels). Ethanol produced in the Midwest and sold in LCFS/CFS jurisdictions is eligible for these carbon credits that are negotiable in the market. Credits are awarded based on the carbon footprint of the entire production cycle of ethanol – including corn production – relative to the carbon footprint of gasoline. Credits can be increased to the extent by-products of the production process are also shown to displace higher-carbon fuel sources. Larksen, LLC is working with other firms (independently of this study) to quantify the feasibility of partially replacing coal with processed corn stover in the commercial production of electricity.

If feasibility is established, there is potential for increased economic activity in corn producing areas through

- Gathering corn stover in the fields
- Transporting gathered stover to processing facilities
- Processing stover for use as fuel in coal-fired electrical power plants
- Transporting processed stover fuel to power plants

There will also be economic activity involved in building stover processing facilities and in retrofitting existing coal-fired electrical power plants to accommodate dual fuel streams.

This study documents the assumptions utilized in a series of state-level economic impact reports estimating these potential increases in economic activity.[1] Information for developing these assumptions were sourced from:

Information from Larksen, LLC

- Potential harvestable corn stover estimates
- Estimated processing facility operating costs
- Estimated cost of processing facility set-up
- Estimated equivalences between corn stover and coal in electricity generation
- Estimated costs of retrofitting existing coal-fired electricity generation facilities (derived from the U.S. Energy Information Administration's National Energy Modeling System)

Energy Information Administration 2016 Annual Coal Report

- Information on coal production and utilization

Environmental Protection Agency Greenhouse Gas Inventory (ghgdata.epa.gov/ghgp/main.do)

- Information on coal-fired power plants

[1] These assumptions and related state-level reports are not intended to establish the feasibility of replacing coal with processed corn stover in the electrical generation process. Additionally, this is not a proposal to establish the carbon footprints of Midwest ethanol or corn stover or their relationships with similar measures in gasoline or coal. This effort is engaged only in estimating state-level economic activities if coal is replaced with corn stover in the process of generating electricity.

Shah, Ajay, "Techno-economic analysis and life cycle assessment of the corn stover biomass feedstock supply chain system for a Midwest-based first-generation cellulosic biorefinery" (2013). Iowa State University. Graduate Theses and Dissertations. Paper 13493

- Estimated field costs of corn stover collection

Sokhansanj, S., and Anthony Turhollow, "Biomass densification – Cubing operations and costs for corn stover" (2004). Applied Engineering in Agriculture, American Society of Agricultural Engineers.

- Ballpark corroboration of estimates cited elsewhere

Economic estimates provided in related state-level reports are generated utilizing IMPLAN PRO economic impact modeling software with IMPLAN data for 2015 and subsequent years as it becomes available. Model and data details will be identified in each state-level report.

PRODUCTION POTENTIAL

There are several general parameters that define the overall amount of corn stover that can be made available for this process and the amount of coal that can be replaced.

First, while corn is widely grown throughout the United States, only the amount of corn stover harvestable from land associated with or equivalent to land producing corn for ethanol production is available for LCFS/CFS credits. Most corn stover will never be eligible for LCFS/CFS credits and, therefore, is not expected to be an economically viable substitute for coal in electricity generation. Additionally, the cost of transporting corn stover relative to its value will likely require that corn stover collection be done in relatively compact geographic areas. Corn and ethanol production in viable areas must be geographically dense.

There are six states in the U.S. that currently produce over one billion gallons of ethanol per year:

Iowa
Nebraska
Illinois
Minnesota
Indiana
South Dakota

These states produce nearly eleven billion gallons of ethanol per year. Larksen LLC. estimates that corn utilized in the production of this ethanol also produces approximately 43.63 million tons of harvestable corn stover per year.[2] Corn stover replacement rates for coal in the electrical generation process depend upon stover and coal quality (energy yield). Properly collected, stored, and processed, Larksen estimates a ton of corn stover can replace approximately 0.8 to 0.9 tons of coal. For the purposes of this discussion and associated state-level studies, a replacement rate of 0.85 ton of coal per ton of corn stover pellets is assumed.

Given this assumption, it is conceivable that 43.63 million tons of harvestable corn stover associated with ethanol production in these six states could replace approximately 37 million tons of coal in the generation of electricity. This is equivalent to five percent of the 738 million tons of coal utilized in U.S. electricity generation in 2015.

[2] Assuming the production of 2.7 gallons of ethanol per bushel, 21.5 dry kg of dry corn stover per bushel, and an average sustainable stover harvest rate of 0.5 ton per every ton of stover production.

These states either do not produce coal or produce only minimal amounts. The local economic impact of collecting, processing, and delivering corn stover to replace coal has little or no local opportunity cost in lost coal production. If the process is shown to be economically feasible, the local economic impacts are potentially significant.

STRUCTURING CORN STOVER COLLECTION, PROCESSING, AND DELIVERY AS AN INDUSTRY FOR ECONOMIC IMPACT MODELING

An initial issue in modeling an industry that collects, processes, and delivers corn stover to replace coal in the electricity generation process is that such an industry does not exist. The process must be defined in a manner that can be analyzed utilizing existing models that do not recognize it. There is only limited federal or state data to identify activities within the process. There is also no ownership structure in place for the process. A structure must be imposed so a model can be applied.

A few assumptions are made at the outset:

1. The corn stover collection, processing, and delivery process is modeled as a single end-to-end industry rather than as purchases from multiple independent enterprises. An unused sector in the IMPLAN PRO model was modified to treat this process as an existing industry. A production function was developed and total expected industry output was fed into the model to generate indirect impacts (due to the industrial supply chain serving the corn stover industry) and induced impacts (due to the expenditures of wages and salaries by people employed in the industry and supply chain).

2. Corn stover processing facility set-up and retrofitting existing coal-fired electricity generation facilities are modeled as one-time construction processes at the beginning of each scenario.

3. Existing coal-fired retrofits are not considered beyond the construction phase. This is because additions to the fuel feeding capacity on the corn stover side will reduce utilization and capacity needs on the coal side. It is assumed that the retrofitted fuel feeding system will have the same life and replacement requirements as the original installation, so no additional economic impact is to be expected. Outside of the initial fuel-feed retrofit, it is assumed that corn stover replacement of coal as fuel in electricity generation will have no effect on the electricity generation facilities.

4. There is no initial start-up investment impact in the corn stover collection process. Much of the equipment needed (tractors, windrowers, balers and handling equipment, etc.) is already in place in the viable collection areas. While stover is not currently collected at the scale necessary for coal replacement, existing equipment used in other forage and farm operations is expected to be reallocated to the collection purpose.

The production function developed for the process of collecting, processing, and delivering corn stover pellets for the replacement of coal in electricity generation is presented in TABLE 1. It consists of 14 input commodities, labor income, other property-type income, and proprietor income (which is a residual). It is initially assumed that corn stover pellets will generate revenue of $105 per ton. After all input commodities are purchased, labor is paid, and other property income are accounted for any residual accrues to proprietor’s income.

It was originally assumed that field collection process budgets would be developed from state-specific production budgets for hay and corn fodder. These budgets, however, generally assume farm-specific activities with inconsistent product. The industrial size envisioned for corn stover pellet production, the cost of transport, and the volume of material handled led to following the controlled process depicted in Shah. Shah estimates costs reflecting the consistent use of uniform square bales to improve storage, handling, and transport efficiency and to minimize deterioration of stover due to handling and exposure. Shah also provides a consistent base of assumptions and directly-gathered data that can be directly tested and modified, whereas most university outreach estimates are largely survey based – reflecting local conventions and self-reporting biases. As a result, the overall production function is consistent across states unless noted otherwise in future state-level reports.

Production function assumptions[3] are:

> Electric power (IMPLAN commodity 3049) – From information provided by Larksen, LLC. regarding the operation of processing facilities, electricity is calculated to consume $2.37 per ton of corn stover pellets.
>
> Natural gas (IMPLAN commodity 3050) – Derived as a ratio of natural gas to electricity consumption in the Flour Milling industry (IMPLAN industry 67) applied to electric power consumption estimates provided by Larksen, LLC. The result is $0.63 per ton of corn stover pellets.
>
> Water/Sewage (IMPLAN commodity 3051) – Usage is calculated at 10 gallons per day per employee plus 250 gallons per day for maintenance purposes during the three-month (91.5 days) collection-processing period (baseline). Service costs equal $16.50 per thousand gallons (representative rural fees for areas served by Des Moines Water Works in Iowa). Baseline cost is multiplied by 9/39.3 for the three-month processing-only period and by 2/39.3 for the six-month period between seasons. Additionally, one $7.00 per month connection fee is assumed. The resulting water/sewage cost is $0.02 per ton of corn stover pellets.
>
> Twine and cordage (IMPLAN commodity 3122) – Twine is an input in baling corn stover. $1.81 per ton is derived from Shah, page 117.
>
> Petroleum and lubricants (IMPLAN commodity 3156) – Energy used in the field collection process ($4.71 per ton) is derived from Shah, pages 116 and 117.
>
> Nitrogenous fertilizers (IMPLAN commodity 3169) and Phosphatic fertilizers (including Potassium) (IMPLAN commodity 3170) – Fertilizer depletion and replacement costs due to corn stover removal are estimated at $9.06 per ton and $14.49 per ton on the basis of Shah, page 116.[4]
>
> Truck transportation (IMPLAN commodity 3411) - $4.50 per ton was derived from Larksen, LLC. estimates of delivery costs of stover from the field to the processing facility.
>
> Rail transportation (IMPLAN commodity 3409) - $8.00 per ton reflects Larksen, LLC estimated costs for stover delivered from the processing facility to the electricity generating plant.

---

[3] Per ton estimates of field operations are taken from Shah. Estimates of processing facility and transportation are based on operating projections and equipment bids provided by Larksen LLC., industry ratios from IMPLAN, and reviews of representative business costs. Where scale matters, estimates are based on a standard processing facility producing 66,560 tons of corn stover pellets annually while operating for six months with two shifts.

[4] Shah bases nutrient replacement costs on an analysis of nutrients contained in the stover itself. This assumes that all stover-based nutrients would eventually be integrated into the soil in usable form. There is also some debate as to whether nitrogen removal may be partially offset by improved nitrogen quality in the soil due to corn stover harvest. For these reasons, nutrient replacement costs may be overstated. No attempt, however, is made to evaluate these observations or adjust Shah's nutrient replacement cost estimates.

Interest and finance expense (IMPLAN commodity 3433) – All operating costs other than interest are assumed to be carried on a line of credit with and average carry of 6 months. Additionally, 75% of processing facility capital investment is amortized over 10 years, with total interest costs from that amortization spread over the 15-year estimated life of facility equipment. The estimate of $2.76 per ton is derived from operational and capital cost estimates provided by Larksen, LLC.[5]

Insurance (IMPLAN commodity 3438) – The estimate of $0.52 per ton was derived from operational estimates provided by Larksen, LLC.

Industrial building rental or leasing (IMPLAN commodity 3440) – It is assumed that processing facilities will be housed in leased facilities. The per-ton estimate of $1.50 was derived from Larksen, LLC. estimates of facility operation.

Business support services (IMPLAN commodity 3465) was estimated on the basis of online estimates of the costs of service provision. Payroll is estimated at $10 per paycheck for all employees paid semimonthly. Bookkeeping is estimated at $40 per hour, 10 hours per month for six months of operations plus a $150 per month minimum retainer for the off-season. Corporate tax preparation fees are estimated at $806 federal average (per IRS surveys) and $403 for state. Final estimate per ton is $0.11. All other administrative needs are assumed to be absorbed into existing administration functions either on-farm or in participation cooperatives and agribusiness.

Machinery and equipment maintenance and repair (IMPLAN commodity 3507) – This includes repair and maintenance estimates for field operations derived from Shah, pages 116 and 117 and estimates of processing plant maintenance from Larksen, LLC. $8.21 per ton.

Labor income – Field collection labor cost of $4.4826 per ton per ton is derived from hours per year (Shah, page 82) and labor cost per ton (Shah, pages 116 and 117). Assumptions yield a labor rate of $19.70 per hour for field labor on the assumption of quarter-time employment (3 months per year). Operating estimates for a representative stover processing facility call for operating two shifts six months of the year (approximately October/November through March/April). Each facility will employ one full-time manager. Each shift will include four operating personnel. Using estimated operating costs provided by Larksen, the resulting labor cost estimate per ton over the entire process is $7.56.

Other property-type income approximates depreciation or capital consumption of the processing plant portion of one-time start-up costs and ownership costs of corn stover collection machinery. Processing plant equipment (based on estimates provided by Larksen, LLC.) is estimated to have a 15-year useful life, so equipment cost and installation estimates are divided by 15 for annual depreciation estimates. The annual depreciation is then divided by 66,560 to give annual depreciation per ton of $3.42. Stover collection machinery ownership costs per ton are $19.93 (derived from Shah, pages 116 and 117), for total other property-type income of $22.35 per ton.[6]

---

[5] Some economic impact modelers remove finance expenses from the production function and include them in "Other property-type income" with depreciation and other non-cashflow expenses. This was not done here, as interest is expected to be a payable expense and the banking industry (IMLAN commodity 3433, Monetary authorities and depository credit intermediation) provides intermediation services in the production functions of a wide variety of related industries.

[6] How depreciation and non-cashflow expenses are handled in the model has important implications for local economic activity. In the industry as it is defined here, the model assumes that these expenses are only partially allocated to capital replacement on the basis of national averages. This assumes partial capital consumption, as not all depreciation on a national basis is reinvested. In addition, this reinvestment is not attributable to the industry or facility being modelled. It is attributed to the economy as a whole. While this does not reduce impacts due strictly to production, it does reduce the total local economic activity due to maintaining and operating the modelled facility or industry, and, thus, affects the local

Proprietor's income is the residual after all other costs per ton are deducted from revenue of $105 per ton.[7]

TABLE 1: Corn stover pellet industry production function

IMPLAN Code	Item description	$ per ton	Production Coefficients
	Revenue	105.0000	1.0000
3049	Electric power generation	2.3738	0.0226
3050	Natural gas	0.6253	0.0060
3051	Water/sewage	0.0175	0.0002
3122	Twine and cordage	1.8111	0.0172
3156	Refined petroleum products	4.7090	0.0448
3169	Nitrogenous fertilizers	9.0557	0.0862
3170	Phosphatic fertilizers	14.4891	0.1380
3411	Truck transportation	4.5000	0.0429
3409	Rail transportation	8.0000	0.0762
3433	Finance expense	2.7560	0.0262
3438	Insurance	0.5178	0.0049
3440	Building lease	1.5024	0.0143
3465	Business support services	0.1131	0.0011
3507	Machinery maintenance and repair	8.2128	0.0782
	Labor (cube plant and field)	7.5552	0.0720
	Other property-type income	22.3488	0.2128
	Proprietor income (residual)	16.4125	0.1563
	Absorption of input commodities	58.6834	0.5589

Source: Regional Strategic, Ltd.

The industry set up in IMPLAN with this production function is initially identified as having:

- 39.3 employees between field and processing operations. This includes
  - 1 full-time processing plant manager
  - 8 half-time processing plant production workers (2 shifts for 6 months)

economic results by limiting or ignoring local effects of reinvestment in that industry or facility. While this is consistent with National Income and Product Accounting, it ignores the ability to make local decisions regarding capital maintenance and capital consumption within the industry as it is specified here. Any non-cashflow expense remainder that is not attributed to capital replacement becomes payments to investors (return of capital). This increases investor incomes, and, thus, affects induced effects (which are derived from expenditures from income).

[7] In a traditional row-crop environment, a portion of labor payments would also be expected to accrue to the proprietor as the proprietor generally provides at least part of the labor in farm operations.

    - 30.3 quarter-time field positions for stover collection
- $6,988,800 in total output prior to any activities in the state-level reports
- $502,876 in employee compensation (an average of $12,796 per employee)
- $1,487,536 in other property-type income (depreciation)
- $1,092,418 in proprietor income
- Input absorption equals 55.89% of total revenue (output)
- Value added (labor, other property-type income, and proprietor income) equals 44.11% of total revenue

This industry provides the basis for estimating the economic effects of the corn stover pellet industry's development in all associated state reports.[8,9]

INITIAL CONSTRUCTION AND INVESTMENT

In addition to modeling the impacts of increases in corn stover pellet processing, the accompanying state reports assume that every increase in processing is an initiation of activity. As a result, one-time construction costs are assumed and modeled in addition to the ongoing processing impacts. There are two parts to this initial investment:

1. Development of the corn stover pellet processing facilities
2. Retrofitting existing coal-fired electricity generating facilities to handle dual fuel streams

These are each modeled as a single-year event in IMPLAN PRO. Developing processing facilities requires inputs or purchases from four industries shown in TABLE 2. Estimated prices per ton for development of the corn stover pellet processing facility are derived from facility operating cost information provided by Larksen, LLC. and reflect per-ton construction costs of the same standard 66,560-ton facility used to estimate processing costs per ton. The construction necessary to retrofit existing coal-fired electricity generation facilities is estimated by Larksen LLC. staff utilizing the National Energy Modeling System from the U.S. Energy Information Administration.[10]

---

[8] This analysis assumes that the state in question has no active coal production industry. Where a coal production industry exists, the replacement of coal by corn stover has local opportunity costs. In these cases, the production function for coal-fired electricity will be modified to explicitly replace coal consumption with the corn stover pellets generated by the industry described here. Loss of labor, output, and income from the coal production industry will be netted out of corn stover pellet industry gains.

[9] Stover replacement of coal might affect the coal hauling component of rail transportation. A review of coal-by-rail estimates for Nebraska (which routes a significant portion of eastbound coal from the Powder River Basin) included in Appendix 2 of "The Economic and Tax Revenue Impact of the Coal Industry in Nebraska" (Dr. Eric Thompson, Bureau of Business Research, Department of Economics, University of Nebraska - Lincoln, 2014) indicates that if 40% of coal crossing Nebraska in 2012 bound for the six states identified on page 2 of this report was displaced, it would amount to about 14% of coal crossing Nebraska by rail and 5.2% of Nebraska's 2015 rail service supply (IMPLAN). This loss would accrue over several years as a corn stover processing industry evolved across multiple states, and would easily fit within current trends in coal utilization for the generation of electricity. Energy Information Administration data show that, nationwide, coal utilization in electricity generation fell by more than 10% in the three years from 2012 to 2015. There would be merit in an investigation of all the factors that influence both fuel sources in electricity generation and rail freight trends, but it is beyond the scope of this undertaking.

[10] Calculations provided by Larksen represented cost per 100,000 ton per year capacity: CapEx = 526 $/kW; Capacity Factor = 0.65; Higher heating value conversion efficiency = 0.32; Higher heating value of Biomass = 15 MJ/kg.

These estimates are multiplied by the ton per year capacity of interest in each of the related state-level impact reports and run as an event in the IMPLAN PRO modeling system.

Investment in the corn stover processing facilities will be funded by individual industry investors. The source of investment to retrofit existing coal-fired power plants depends upon a wide range of factors, including resource management plans, specific requirements for specialty energy sources from significant energy consumers, regulatory uncertainty, economic development options, and public policy towards energy, agriculture, and industrial development. The source of investment for retrofitting existing coal-fired power plants is yet to be determined and is being actively discussed as part of the industry development process.

TABLE 2: Start-up estimation

IMPLAN Industry		
	Corn Stover Pellet Processing Facility	**$ Per Ton**
267	Stover Processing Machinery	39.523
507	Machinery and Equipment Installation	4.515
411	Truck Transport	0.604
449	Engineering Services	6.696
	Retrofitting Existing Coal-fired Generator	**$ Per Ton Per Year Capacity**
54	Construction of New Power Plant Facilities[11]	123.200

Source: Regional Strategic, Ltd.

A NOTE ON LOCAL PURCHASE PERCENTAGES

Local economic impacts are strongly influenced by Local Purchase Percentage (LPP), an IMPLAN PRO model parameter indicating how much of any expenditure stays in the local economy (as opposed to purchases that must consist of non-local imports. Three assumptions are generally made in the state-level estimates associated with this report:

1. Local Purchase Percentage for the corn stover pellet industry created here is set at 100%. This reflects the requirement that corn stover be associated with locally-produced ethanol.

2. Local Purchase Percentages for IMPLAN industries 507, 411, and 449 (TABLE 2) utilized in estimating the impact of processing facility set-up are an average of the IMPLAN default SAM[12] purchasing percentages of each industry and the Local Purchase Percentage default for industry 267. For example, if the default

[11] Retrofitting existing coal-fired power plants is modelled under new construction of power plant facilities in the IMPLAN model. This does not account for the possibility that labor, material, and capital requirements for the retrofit may be quite different than requirements for new construction. In the absence of retrofit details and/or a bill of goods necessary for the work, however, it is assumed that new power plant construction is the closest reasonable match available.

[12] SAM refers to Social Accounting Matrix and reflects the distribution of industries and income within and among the regions of the IMPLAN modelling system.

LPP for industry 507 is 96.5% and the default LPP for industry 267 is 6.7%, the simple average (51.60%) is used for industry 507 in the start-up impact calculation. Equipment for handling stover bales, industrial grinding/chopping/milling bales, pelletizing ground fodder, and loading pellets out is relatively common in the feed, forage, and food processing industries and may be sourced from multiple locations. Changing the Local Purchase Coefficients reflects an assumption that, at initial start-up, engineering, transport, and installation relationships will be strongly influenced by the initial vendor, regardless of where that vendor is located.

3. In all other instances, Local Purchase Percentages are set at IMPLAN default SAM values.

ESTIMATING SCENARIOS

For each of the state-level impact reports associated with this effort, several development scenarios are presented. This reflects the fact that this industry is not "on the ground," yet. The size of individual developments and facility capacities is still the subject of discussion, and several viable options for starting up exist. Three to five scenarios will be illustrated, as is appropriate to the state under consideration:

1. Development of a single corn stover pellet processing plant with a capacity of 66,560 tons per year.

2. Development of enough corn stover pellet processing capacity to replace 10% of the coal consumed by the state's average coal-fired electricity generation facility.

3. Development of enough corn stover pellet processing capacity to either replace 10% of coal consumed in all of the state's coal-fired generating facilities or consume all of the state's harvestable ethanol-affiliated corn stover (whichever is lower).

4. Development of enough corn stover pellet processing capacity to either replace 40% of coal consumed in all of the state's coal-fired generating facilities or consume all of the state's harvestable ethanol-affiliated corn stover (whichever is lower).

5. Where there is more harvestable ethanol-affiliated corn stover than the state's power plants can consume at a 40% replacement rate, developing enough corn stover pellet processing capacity to consume all available stover with the intent to export any residual that cannot be used by the state's power plants. This would require building more processing capacity than in the previous scenario, but would cap coal-fired retrofitting activities at the 40% replacement limit.

Scenario 1 provides a building-block or supply-side perspective. While a single plant will be insufficient to provide enough corn stover to replace 10% of the coal in an average electricity generation facility, this is a scale at which local stover processing facilities can be operationalized. Scenario 1 illustrates the processing plant investor perspective.

Scenarios 2 through 5 can be viewed as stepping-stones for industry growth. Scenario 2 illustrates the initiation of coal replacement by a single coal-fired processing plant. As such, it illustrates the individual power plant's perspective. Scenarios 3 through 5 illustrate a progression of industry-wide perspectives. Scenario 3 illustrates industry-wide initiation of coal replacement. Scenarios 4 and 5 illustrate maximum industry-wide coal replacement and maximum farm-level consumption of ethanol-affiliated corn stover.

States of interest (page 2) are all characterized by high concentrations of corn production that make start-ups at a Scenario 1 level viable virtually wherever local investors initiate processing within the state. Major factors in where start-ups will happen within states will be driven by investor interest, ethanol facility proximity (if LCFS/CFS regulation require a direct connection between stover collection and corn delivery), and the decisions of individual electrical generation plants to co-fire.

Scenario limits of 10% (scenarios 2 & 3) and 40% (scenarios 4 & 5) are based on commercial and test burn experience in the US and in Europe. Cofiring at a rate of 10% biomass is assumed to be a reasonable starting point for biomass use in electricity generation, while this analysis assumes 40% for a maximum production scenario.[13]

It is not anticipated that development of the corn stover processing industry to any of these scenario levels will immediately impact corn production or the allocation of crop land between corn and other crops. This is because the stover processed must be affiliated with corn already produced and processed through ethanol facilities. As a result, it is not immediately possible to increase general returns on corn production through increasing production. Development of a corn stover processing industry will, however, provide incentives to engage in gamesmanship among corn growers to obtain long-term contracts for stover delivery – particularly in the initial growth scenarios where there is more available ethanol-affiliated corn stover than the industry has capacity to process.

In the longer term, however, successful development of the corn stover processing industry combined with an increase in jurisdictions enacting LCFS/CFS regulations may increase demand for and returns to ethanol production, increasing ethanol production capacity and the availability of ethanol-affiliated corn stover. Over time, this could provide incentives to reallocate cropland towards corn relative to its alternatives.

CONCLUSION

This report outlines the assumptions necessary to estimate the state-level economic impacts of collecting, processing, and delivering corn stover to replace coal in the electricity generating industry. Potential states for such developments are identified, and potential stover harvest and coal replacement levels are estimated.

A production function for the potential corn stover pellet industry is presented and justified. Parameters for estimating the impacts of industry start-up activities are defined. Finally, five possible industry development scenarios are depicted.

All assumptions presented here and in any associated state-level economic impact reports are presented as generally descriptive of the economy rather than specifically applicable to any installation or enterprise. Decisions that are site or enterprise specific warrant independent analysis and expertise.

---

[13] Depending upon the type of biomass and the level of biomass preprocessing undertaken, co-firing is done to levels well above 40% in several locations around the world. See "Cofiring of biomass in coal-fired power plants – European experience" (Dr. Colin Henderson, IEA Clean Coal Center, presentation at FCO/IEA CCC workshops on policy and investment frameworks to introduce CCT in Hebei and Shandong Provinces, China, January 2015). Additional information is available at www.iea-coal.org.