Estimated Economic Impacts of Utilizing Corn Stover to Replace Coal in the Electricity Generation Process in Iowa

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). *Estimated Economic Impacts of Utilizing Corn Stover to Replace Coal in the Electricity Generation Process in Iowa.* Report for Larksen, LLC. San Diego, CA.

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

EXECUTIVE SUMMARY

Corn utilized in the production of ethanol in Iowa also produces 15.62 million tons of harvestable corn stover (ethanol-affiliated corn stover) annually. Utilization of this stover (or any other byproduct of corn utilized in ethanol production) to reduce carbon consumption elsewhere in the economy reduces the overall carbon footprint of the affiliated ethanol – making the ethanol more valuable in jurisdictions with Low Carbon Fuel Standards or Clean Fuel Standards (LCFS/CFS).

Properly processed, this stover could replace 40% of the coal utilized by Iowa coal-fired power plants (approximately 6.733 million tons of coal) with an additional 7.699 million tons of pelletized stover available for export to other states.

Corn stover processing plants capable of processing 66,560 tons of corn stover annually can be initiated with investments of approximately $3.5 million per facility and would generate revenue of approximately $6.989 million per year.

Investment multipliers in the standard processing facility are estimated at 1.63 for employment, 1.79 for labor income, and 1.60 for output.

A 66,560 plant will require stover from 15% of the land area within a 15-mile radius of the plant.

Processing sufficient quantities of corn stover to replace 40% of coal utilized in Iowa coal-fired power plants would generate revenue of $831.748 million per year with a total impact on Iowa labor income of $339.347 million per year. This would require corn stover from 4.140 million acres annually, or 16.8% of Iowa's total corn acreage.

Processing all ethanol-affiliated corn stover in Iowa would generate revenue of $1.640 billion per year with a total impact on Iowa labor income of $669.148 million per year. This would require corn stover from 8.163 million acres annually, or 33.2% of Iowa's total corn acreage.

Direct payrolls involved in collecting, processing, and delivering corn stover pellets consuming all Iowa ethanol-affiliated corn stover would be equivalent to approximately 6.3% of Iowa farm labor income reported by the Bureau of Economic Analysis for 2015.

Hired Iowa farm employees earned only 77% of the average Iowa earnings per job in 2015 according to Bureau of Economic Analysis Statistics.

According to the U.S. Census of Agriculture, farm operations equal only about 60% of full-time equivalent for the average Iowa farm operator.

CONTENTS

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

INTRODUCTION

This study was commissioned by Larksen, LLC., as one of a series of state-level impact reports estimating the economic impact of collecting, processing, and delivering corn stover to be utilized as a coal replacement in electricity generation. The estimated impacts presented in this report reflect assumptions made in "Modeling Assumptions Utilized in Estimating the State-level Economic Impacts of Utilizing Corn Stover to Replace Coal in the Electricity Generation Process," which was also produced by Regional Strategic, Ltd. for Larksen, LLC. and is attached as Appendix 1. All assumptions included here 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.

Iowa produces almost 4 billion gallons of ethanol per year that can be sold into Low Carbon Fuel Standard or Clean Fuel Standard (LCFS/CFS) jurisdictions (currently California, Oregon, and British Columbia with consideration underway in other areas). Larksen, LLC. estimates production of corn for this ethanol also generates approximately 15,620,000 tons of harvestable corn stover per year. This stover has the potential to replace coal in the process of generating electricity. Replacing coal or any other utilization of this stover (or any other byproduct of corn utilized in ethanol production) that reduces carbon consumption elsewhere in the economy reduces the overall carbon footprint of the affiliated ethanol – making the ethanol more valuable in LCFS/CFS jurisdictions.

EPA estimations from the Greenhouse Gas Inventory (http://ghgdata.epa.gov/ghgp/main.do) indicate that Iowa electricity generation facilities consumed a total of 16,833,000 tons of coal in 2014. The average per plant was 1,402,750 tons. Current experience indicates that up to 40% of coal used in electricity generation can be replaced by properly processed dry biomass without major boiler modifications. 40% of coal used in Iowa electricity generation equaled approximately 6,733,200 tons in 2014. At a replacement rate of approximately 1 ton of dry corn stover per 0.85 ton coal, replacing this coal would consume 7,921,412 tons of corn stover.

This report looks at the economic effects expected in Iowa given five potential levels of coal replacement by corn stover in the electricity generation process. The first of these is a supply-based scenario. It reflects the impact of initiating one corn stover processing plant with a capacity of producing 66,560 tons of corn stover pellets per year. The other four scenarios are demand-based. They assume different levels of coal consumption replacement in the electricity generation process.

The five scenario definitions for Iowa are listed below:

1. Development of a single corn stover pellet processing plant with a capacity of 66,560 tons per year. This is a "reference" plant size. It was used to generate start-up costs and the processing production function outlined in Appendix 1. As a "building block" investment in local corn stover processing capacity, this scenario represents the perspective of local processing plant investors.

2. Development of corn stover pellet processing capacity to replace 10% of the coal consumed by a single average Iowa coal-fired electricity generation facility, or 165,029 tons of stover per year. This represents the level at which an individual generation facility might initiate coal replacement and co-firing stover. This represents an individual generating facility's perspective.

3. Development of enough corn stover pellet processing capacity to replace 10% of coal consumed in all of the Iowa's coal-fired generating facilities, or 1,980,353 tons of stover per year. This represents an electrical generation industry perspective with respect to initiating widespread participation.

4. Development of enough corn stover pellet processing capacity to replace 40% of coal consumed in all of the Iowa's coal-fired generating facilities, or 7,921,412 tons of stover per year. This represents an electrical generation industry perspective with respect to total anticipated industry participation.

5. Development of enough corn stover pellet processing capacity to utilize all of the ethanol-affiliated harvestable corn stover produced in Iowa. This would require processing capacity for 15,620,000 tons of stover annually. It would require start up investments for 15,620,000 tons per year of processing capacity. It would only require retrofitting fuel feed capacity in power plants for 7,921,412 tons per year (the maximum replacement capacity in Iowa's power plants). The remaining 7,698,588 tons of stover processed would have to be exported to other states. This represents the perspective of the corn growers or ethanol producers with respect to total utilization of all ethanol-affiliated harvestable corn stover in the state.

For each of these scenarios, impacts will be presented for the ongoing stover collection, processing, and delivery process and for the one-time initial investments in stover processing capacity and power plant modifications required for dual fuel streams. Estimates were made utilizing IMPLAN PRO[1] economic impact modeling software with 2015 data for Iowa (the most recent available). Impacts were generated using 2017 as the default model year.[2]

Assumptions utilized in developing these estimates are included in Appendix 1. Consistent with the note on IMPLAN Local Purchase Percentages in that report, Local Purchase Percentages utilized in modeling the impacts of one-time start-up costs for Iowa are presented in TABLE 1.

TABLE 1: Local Purchase Percentage modifications for start-up scenarios

IMPLAN Industry	Description	IMPLAN SAM LPP	LPP Used Here
267	Pellet processing machinery	7.18	7.18
507	Machinery installation	98.32	52.75
411	Truck transportation	90.55	48.87
449	Engineering services	50.56	28.87
54	Power plant construction/retrofit	99.99	99.99

Scenario 1 will be presented on its own, as it provides a descriptor of a relevant building block for the industry. It illustrates the expected impacts of local investments in stover collection and processing. Scenarios 2 through 5 will be presented together, as they represent a progression of total industry impacts at various levels of coal replacement (corn stover demand). A third section will present IMPLAN estimates of state and federal tax revenues resulting from both ongoing processing operations and one-time start-up activities.

Preliminary information for setting up scenarios were derived from production function and start-up assumptions in Appendix 1 and is presented in Table 2.

[1] Version 3.1.1001.12

[2] It is not assumed that start-up and processing will occur prior to 2018. This report, however, does not presume to predict an inflation/deflation rate over the course of industry development. For multi-year processing summaries, simple sums of 2017 results are used.

TABLE 2: Scenario assumptions for Iowa stover processing

	Scenarios				
	One	Two	Three	Four	Five
PROCESSING INFORMATION					
Stover pellet output (tons)	66,560	165,029	1,980,353	7,921,412	15,620,000
Stover pellet output ($)	6,988,800	17,328,088	207,937,059	831,748,235	1,640,100,000
Absorption of purchased inputs ($)	3,905,970	9,684,495	116,213,935	464,855,739	916,635,425
Proprietor income ($)	1,092,418	2,708,550	32,502,605	130,010,418	256,363,738
Labor income ($)	502,876	1,246,834	14,962,008	59,848,031	118,012,581
Other property-type income ($)	1,487,536	3,688,209	44,258,512	177,034,047	349,088,256
START-UP INFORMATION					
Pellet processing machinery ($)	2,630,641	6,522,433	78,269,195	313,076,781	617,346,941
Machinery installation ($)	300,492	745,042	8,940,508	35,762,032	70,518,105
Truck transportation ($)	40,200	99,672	1,196,067	4,784,266	9,433,954
Engineering services ($)	445,700	1,105,072	13,260,867	53,043,468	104,594,862
Total processing construction ($)	3,417,033	8,472,220	101,666,637	406,666,548	801,893,862
Power plant construction/retrofit ($)[3]	8,200,192	20,331,624	243,979,482	975,917,929	975,917,929
TOTAL start-up construction	11,617,225	28,803,843	345,646,119	1,382,584,477	1,777,811,791

Source: Regional Strategic, Ltd.

TABLE 3 shows total Iowa corn acreage, estimated Iowa ethanol-affiliated corn acreage, estimated ethanol-affiliated total harvestable corn stover, and stover needed for each of the five scenarios described above.

[3] Construction/retrofit costs will vary widely by individual power plants due to age, design, location, and a wide variety of factors. Estimates here are derived by Larksen, LLC. staff utilizing the National Energy Modeling System from the U.S. Energy Information Administration. Assumptions are outlined in footnote 10 of Appendix 1.

TABLE 3: Iowa ethanol-affiliated stover and acreage requirements

Harvestable ethanol-affiliated corn stover: 15.62 million tons per year
Total corn acreage in 2014: 24,605,000 acres
Production per acre in 2014: 178 bu/ac

Scenario	Stover Utilized	% of Ethanol-affiliated Stover	Stover Acreage Required	% of Tot. IA Corn Acreage
1	66,560	0.43	34,784	0.14
2	165,029	1.06	86,245	0.35
3	1,980,353	12.68	1,034,938	4.21
4	7,921,412	50.71	4,139,750	16.82
5	15,620,000	100.00	8,163,052	33.18

Estimate of harvestable ethanol affiliated corn stover from Larksen, LLC.
Total corn acreage and production from USDA.

A single processing plant (Scenario 1) would require stover from less than 15% of the total land area within a radius of 15 miles from the plant.

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. This is a time-frame that runs substantially beyond the start-up phase of the industry studied here, however, and depends upon political actions in multiple remote areas, subsequent investments in ethanol production, future consumer preferences with regards to alternative fuel options, and other factors.

THE SUPPLY SIDE: 66,560 TONS OF CORN STOVER PELLETS PER YEAR

Scenario 1 (developing a single processing facility with a capacity of 66,560 tons per year) requires a total start-up investment of $11.617 million. Of this, $3.417 million is invested in stover collection and processing. $8.200 million is invested in retrofitting existing Iowa power plants to handle a dual fuel stream. Additionally, processing 66,560 tons of corn stover per year is expected to generate total revenue (output) of $6.989 million per year from the processing operation for employees, input suppliers, and proprietors.

In the pages below, TABLES 4, 5, and 6 summarize the economic activities generated from the annual corn stover processing activities in Scenario One, representing a processing plant with capacity to handle 66,560 tons of corn stover per year. TABLES 7 and 8 summarize the economic activities generated from the one-time start-up investments in processing plant development and coal-fired power plant modifications. TABLE 9 provides a multiple-year sum of operating impacts assuming successful industry start-up and a steady-state economy.

TABLE 4 provides a summary of annual economic impacts expected from operating a single corn stover processing plant in Iowa.

TABLE 4: Processing summary for scenario one (66,560 tons)

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	39	1,594,362	3,081,029	6,988,800
Indirect Effect	11	741,908	1,344,213	2,508,575
Induced Effect	13	515,105	963,476	1,704,116
Total Effect	63	2,851,375	5,388,718	11,201,492

Some explanations regarding terms included in TABLE 4:

"Employment" is a simple count of number of jobs. Jobs may be part-time, full-time, or require overtime. A job is counted as a job regardless of time involved. The corn stover processing employment assumptions used to set up the industry included only one full-time job and 8 half-time jobs. The rest of jobs were one-quarter time. They each count as one job here.

"Labor Income" includes wages and salaries for paid employees and proprietor's income which accrues to the non-corporate owners. Because the corn stover processing industry structure is, as yet, undefined, we do not know how many proprietors there will be. Thus, dividing labor income by employment in the "Direct Effect" line will significantly overstate earnings per job in the processing scenarios.

"Value Added" is the portion of output value that is created by economic activity embodied in the process. It excludes the value of purchased inputs. A sum of value added from all industries in the state should be equivalent to gross state product. Value added generally includes labor income, proprietor's income, other property-type income (generally non-cashflow expenses like depreciation and internal capital cost allocations), and indirect business taxes.

"Output" is, simply, the total value of output sold in the process of collecting and processing corn stover, producing and acquiring inputs for that process, and supplying goods and services to the people that receive labor income in these activities.

"Direct Effect" includes the local economic effects directly tied to the industry investigated – in this case, either the actual process of collecting, processing, and delivering corn stover or the one-time investments in starting up the corn stover processing facility and retrofitting existing power plants as required.

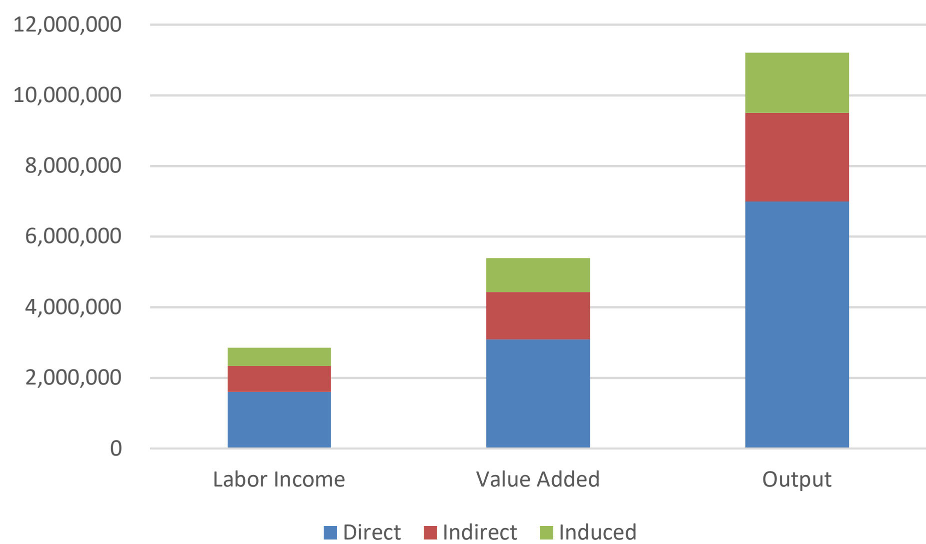
"Indirect Effect" includes the economic effects of domestic (in-state) input industries that supply the corn stover processing industry. Stover collection requires farm equipment. Farm equipment requires rubber tires, head gaskets, and ball bearings. Power plant retrofitting requires material handling machinery. Machinery requires welders, bolts, and channel iron. Inputs purchased in support of the Direct Effect generate Indirect Effects.

"Induced Effect" is derived from activities induced when workers, proprietors, or investors spend the earnings they derive from the direct activity and the indirect (input supply) activity on goods and services within the economy. Direct and Indirect activities generate wages, salaries, and proprietors' incomes. As the recipients of these funds spend them on groceries, automobiles, dance lessons, houses, and bowling, they induce additional economic impacts in the local economy.

"Total Effect" is the sum of direct, indirect, and induced effects.

FIGURE 1 shows Labor Income, Value Added, and Output impacts from TABLE 4 in graphic form. Employment impacts were not included due to major differences in scale. In addition, because it is expected that much of the income effect will be to intensify the utilization and incomes of existing jobs rather than creating new jobs, modelled employment statistics may not be as accurate or meaningful as labor income statistics. Because the IMPLAN model is linear, the relative sizes of impacts in this graph (the numerical relationships) is also applicable to Scenarios 2 through 5. For that reason, this graph will not be repeated with every scenario.

FIGURE 1: Scenario one direct, indirect, and induced impacts for Iowa



Industries affected by the direct investment (direct effect) are enumerated in the production function specified in Appendix 1. Indirect and Induced Effects, however, are realized in a wide variety of industries. TABLE 5 shows the top ten affected industries ordered by labor income effects. FIGURE 2 provides a visual representation of the data provided in TABLE 5's "Labor Income" column.[4] Because IMPLAN is a linear model, the order and relative effects shown for these ten industries are also applicable for Scenarios 2 through 5 below.

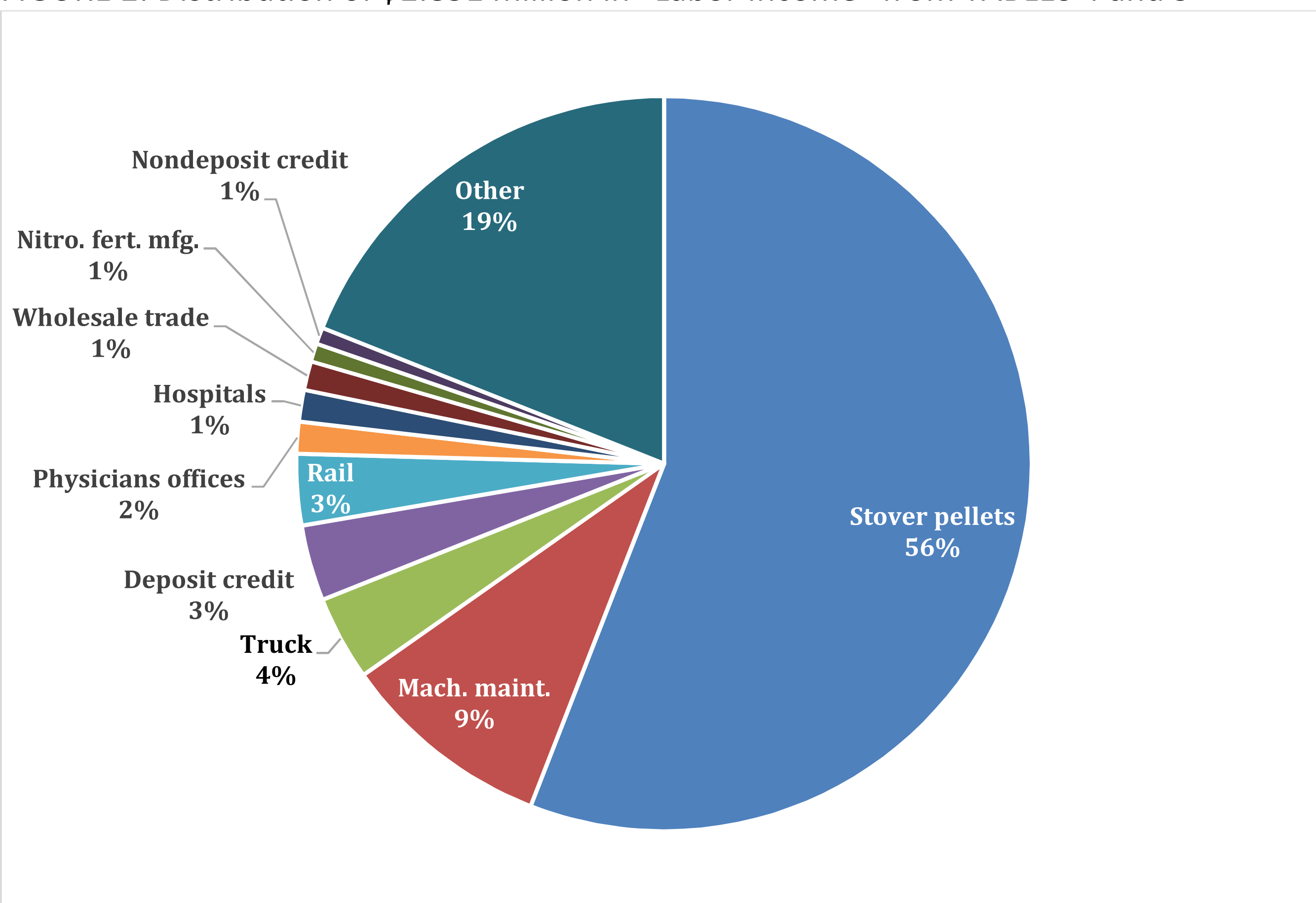
[4] Industry names from TABLE 5 are abbreviated in FIGURE 2 to facilitate presentation.

TABLE 5: Top ten industries impacted by Scenario 1 processing - ranked by Labor Income

Sector	Description	Employment	Labor Income	Value Added	Output
7	Corn Stover Pellets	38.8	1,594,362	3,081,030	6,988,801
507	Commercial and industrial machinery and equipment repair and maintenance	4.1	266,118	361,878	549,170
411	Truck transportation	1.8	106,055	127,051	305,657
433	Monetary authorities and depository credit intermediation	1.3	95,000	158,148	267,181
409	Rail transportation	0.8	89,137	274,555	424,246
475	Offices of physicians	0.4	40,177	38,543	55,559
482	Hospitals	0.6	39,550	53,421	92,231
395	Wholesale trade	0.5	36,147	65,241	107,656
169	Nitrogenous fertilizer manufacturing	0.1	22,886	80,087	245,150
434	Nondepository credit intermediation and related activities	0.2	20,879	22,123	40,518

Source: IMPLAN

FIGURE 2: Distribution of $2.851 million in “Labor Income” from TABLES 4 and 5



The total effects in TABLE 4 are significantly greater than the direct effects. A descriptor that is often used to interpret the scale of this gain is called a "Multiplier." Two types of multipliers are regularly employed:

- Type 1 Multipliers are defined as the sum of Direct and Indirect Effects divided by Direct Effects. Type 1 multipliers show the intensity of the direct effect's impact upon related input industries.
- Type 2 multipliers are defined as Total Effect divided by Direct Effect. Type 2 multipliers show the overall effect of the direct effect's influence on input purchases and on local personal incomes generated in the production process.

These multipliers are shown in TABLE 6.

TABLE 6: Processing multipliers from Scenario One (TABLE 3)

	Employment	Labor Income	Value Added	Output
Type 1	1.29	1.47	1.44	1.36
Type 2	1.63	1.79	1.75	1.60

In general, state-level Type 2 multipliers are anticipated to fall between 1 and 2. Overall, the multipliers here are solidly in the upper range of expectations.[5][6]

In addition to the economic activity generated from collecting and processing corn stover, initiating the industry will require developing the 66,560 ton per year processing plant and retrofitting existing coal-fired electricity generation facilities to accommodate dual fuel streams. The effects of these one-time start-up investments are shown in TABLE 7.

TABLE 7: Start-up summary for Scenario One (66,560 tons)

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	67	3,840,572	4,982,643	8,694,809
Indirect Effect	12	634,041	1,017,036	1,892,376
Induced Effect	25	991,053	1,852,628	3,278,288
Total Effect	104	5,465,666	7,852,308	13,865,473

TABLE 7 shows that the initial investment of $11.617 million (TABLE 2) generates a total one-time output effect of $13.865 million in the Iowa Economy. The activities in facility start-up are diluted within the local economy due to the high proportion of initial expenditures and indirect input expenditures that are made outside the state of Iowa. Direct expenditures within Iowa, however, generate solid economic multipliers in TABLE 8.[7] Initial start-up investment of $11.617 million in processing and power plants will support 104 jobs paying $5.465

[5] Due to the linear nature of the IMPLAN software, these multipliers will be representative of processing multipliers throughout the scenarios presented in this report and will not be replicated in every section.
[6] It should be noted that multipliers are among the most misused statistics in economic development because they are among the most intuitive. These statistics are specific to the model specified here and should not be generally applied to agricultural processing, stover utilization, or other related enterprises.
[7] As with the processing multipliers in TABLE 6, the start-up multipliers in TABLE 8 will be representative of all the remaining scenarios in this report.

million in labor income ($52,554 per year per job). Unlike processing effects, however, these start-up effects will only occur in one year.

TABLE 8: Start-up multipliers from Scenario One (TABLE 7)

	Employment	Labor Income	Value Added	Output
Type 1	1.17	1.17	1.20	1.22
Type 2	1.55	1.42	1.58	1.59

TABLES 4, 5, and 6 summarize the economic activities generated from the annual corn stover processing activities in Scenario One, representing a processing plant with capacity to handle 66,560 tons of corn stover per year. TABLES 7 and 8 summarize the economic activities generated from the one-time start-up investments in processing plant development and coal-fired power plant modifications.

TABLE 9 provides a summary of multi-year processing activities. Two data blocks in TABLE 9 show

- The simple sum of 13 years' operating effects assuming operation from 2018 – 2030
- The simple sum of 11 years' operating effects assuming operations from 2020 – 2030

TABLE 9: Multi-year sums (2018-30 and 2020-30) of Scenario One operations

2018-30 SUM	Employment	Labor Income	Value Added	Output
Direct Effect	39	20,726,706	40,053,377	90,854,400
Indirect Effect	11	9,644,804	17,474,769	32,611,475
Induced Effect	13	6,696,365	12,525,188	22,153,508
Total Effect	63	37,067,875	70,053,334	145,619,396
2020-2030 SUM				
Direct Effect	39	17,537,982	33,891,319	76,876,800
Indirect Effect	11	8,160,988	14,786,343	27,594,325
Induced Effect	13	5,666,155	10,598,236	18,745,276
Total Effect	63	31,365,125	59,275,898	123,216,412

From TABLE 9 we see that the summed value of processing labor income over 13 years (2018-2030) is $37.068 million. The summed value of processing labor income starting two years later (2020-2030) is $31.365 million. These sums simply illustrate the total amount of labor income, value-added, and output that may be generated over potential steady-state operations through 2030. They are intended to give a perspective of scale over time if development is successful in an otherwise steady-state environment. They do not represent a prediction of steady economic conditions or operations in actual practice.

This section looked at the economic effects of developing a single 66,560 ton capacity corn stover processing facility and retrofitting coal-fired power facilities to accept the stover pellets as a replacement for coal. This was a supply-side perspective showing the value of an individual building-block investment in the industry. The next section takes a look at the four demand-side scenarios.

THE DEMAND SIDE: SCENARIOS TWO THROUGH FIVE

This section considers the impact of a multi-processing facility industry supplying corn stover pellets in quantities that can sustain coal replacement in one or more coal-fired power plants. The scenarios presented are

- Scenario Two: Production of pellets sufficient to replace 10% of the coal utilized in the average Iowa power plant (165,029 tons of pellets per year)
- Scenario Three: Production of pellets sufficient to replace 10% of the coal utilized in the entire Iowa electricity generating industry (1,980,353 tons of pellets per year)
- Scenario Four: Production of pellets sufficient to replace 40% of the coal utilized in the entire Iowa electricity generating industry 7,921,412 tons of pellets per year)
- Scenario Five: Processing all ethanol-affiliated harvestable corn stover in Iowa, replacing 40% of the coal utilized in the entire Iowa electricity generating industry, and exporting the remaining pellets utilities in other states (15,620,000 tons of pellets processed per year)

Details on processing capacities, pellet value, and start-up investment costs are included in TABLE 2 on page 3.

The demand-side scenarios illustrate options for industry growth. This assumes choice and calls for comparison. In this section, information illustrating the various characteristics of the scenarios will be consolidated in tables by data type.

In the pages below, TABLE 10 summarizes the economic activities generated from the annual corn stover processing activities in Scenarios Two through Five. TABLE 11 summarizes the economic activities generated from the one-time start-up investments in processing plant development and coal-fired power plant modifications required for these scenarios. TABLES 12 and 13 provide multiple-year sums of operating impacts assuming successful industry start-up and a steady-state economy for each scenario.

TABLE 10 provides a summary of annual economic impacts expected from operating sufficient corn stover processing plants in Iowa to support the coal replacement rates in Scenarios Two through Five.

TABLE 10: Processing summaries for Scenarios Two through Five

Impact Type	Employment	Labor Income	Value Added	Output
Scenario 2				
Direct Effect	96	3,953,075	7,639,129	17,328,088
Indirect Effect	28	1,839,494	3,332,852	6,219,783
Induced Effect	33	1,277,155	2,388,850	4,225,200
Total Effect	157	7,069,724	13,360,831	27,773,071
Scenario 3				
Direct Effect	1,154	47,436,897	91,669,554	207,937,062
Indirect Effect	334	22,073,924	39,994,227	74,637,392
Induced Effect	390	15,325,864	28,666,198	50,702,406
Total Effect	1,878	84,836,685	160,329,979	333,276,861
Scenario 4				
Direct Effect	4,616	189,747,589	366,678,216	831,748,249
Indirect Effect	1,336	88,295,694	159,976,907	298,549,569
Induced Effect	1,561	61,303,457	114,664,793	202,809,625
Total Effect	7,513	339,346,740	641,319,916	1,333,107,443
Scenario 5				
Direct Effect	9,103	374,157,718	723,042,042	1,640,100,027
Indirect Effect	2,635	174,107,695	315,453,780	588,701,156
Induced Effect	3,077	120,882,492	226,104,150	399,914,364
Total Effect	14,815	669,147,905	1,264,599,972	2,628,715,547

Results from TABLE 10 suggest that fully implementing corn stover processing in Scenarios Four and Five will require significant labor. The U.S. Bureau of Labor Statistics[8] reports that only 60,330 Iowa workers were unemployed in December 2016, for an unemployment rate of 3.6%. On the face of it, processing operations and related effects in Scenario Five would require one in every four unemployed Iowans (without even considering employment required for start-up activities). If employment effects are interpreted exclusively as new jobs, it is clear Iowa does not have the capacity to staff this development at the upper levels modelled here.

This can be looked at through another lens, however. Direct Effect employment will be almost entirely quarter and half-time employment in rural areas that cycles between harvest and planting periods. It is possible to consider over half of the employment (the Direct Effect) in the Total Effect as supplementary employment for the existing agricultural labor force. Another fifth of labor needs, the Induced Effect, is spread between rural areas and urban manufacturing centers that produce inputs. The rural portion of this might be viewed as “Saved” rather than “New” employment. This is also true of Indirect Effects generated from supply purchases through local supply outlets. From this perspective, a significant portion of the labor needs may be absorbed as enhancements to existing labor income or relief from declining trends in rural retail and service sectors.

The Bureau of Economic Analysis[9] reports 90,797 farm jobs (proprietors and hired labor) in Iowa in 2015. Of these, 19,160 were farm employees who earned, on average, only 77% of the average earnings per job received

---

[8] Bureau of Labor Statistics data is available through the Local Area Unemployment Statistics program searchable database at https://www.bls.gov/lau/data.htm

[9] All Bureau of Economic Analysis references are derived from data in the bureau’s Regional Data system for “Annual State Personal Income and Employment” (“Personal Income by Major Component and Earnings by Industry” and “Total Full-Time

for all personal employment in Iowa. Looked at from another perspective, the 2012 Census of Agriculture reports there were 129,644 farm operators (including primary, secondary, and third operators) in Iowa.[10] Survey responses regarding days worked off farm suggest that farming was, on average, only about 60% of a full-time job for the average operator and that only 40% of Nebraska farmers did not engage in off-farm work. This suggests a dependence upon off-farm income for proprietors in the Iowa farm economy.

In this context, focusing on Labor Income might be more appropriate than focusing on the number of jobs. 2015 Iowa farm sector labor income totaled $5.922 billion according to the Bureau of Economic Analysis. Direct Effect labor income in Scenario Five equals about 6.3% of this. Generating Scenario Five levels of employment in a single year might be out of reach, but as an industry goal it appears to be within the realm of possibilities.

TABLE 11 shows the effects of one-time start-up investments for Scenarios Two through Five. Start-up labor requirements in the initial year are higher than processing labor requirements. Start-up labor is nearly all industrial labor. While some of it can be looked at as enhancements to current income, this cannot be done to extent suggested with respect to processing.

Start-up for Scenarios Four and Five will require nearly one-fifth of Iowa's unemployed population. Neither scenario can be undertaken in a single year relying upon local labor. To the extent that labor is brought in from out-of-state, Iowa impacts from construction and installation will be reduced, but processing capacity and ongoing Iowa economic activity will still be enhanced. Another possibility is that Scenario Four levels of production are attained over four years. This would move start-up effects back to the level of Scenario Three for a period of four years. It is reasonable to look at processing facility goals being attained over time, so ultimate processing scenarios could be matched with multiple start-up scenarios.

These start-up effects should be considered in the perspective of scenario start-up investments presented in TABLE 2 on page 3. Total start-up investment (facility development and power plant retrofit) for the 66,560-ton individual processing plant is estimated $11.617 million. The demand-side scenario start-up costs run from $28.803 million for Scenario Two (165,029 tons of pellets per year) to $1.777 billion for Scenario Five (15,620,000 tons of pellets per year). It should also be kept in mind that, as Scenarios Four and Five are approached, utilization rates for the standard 66,560-ton processing facilities could be increased. This would lower processing start-up investments at the upper bounds of the industry. It would also increase the challenges of finding local labor to operate individual plants. These trade-offs will need to be worked out if and when the industry approaches its limits.

---

and Part-Time Employment by Industry") at https://www.bea.gov/iTable/iTable.cfm?reqid=70&step=1&isuri=1&acrdn=6#reqid=70&step=1&isuri=1

[10] Derived from U.S. Census of Agriculture Table 55. "Selected Operator Characteristics for Principal, Second, and Third Operator: 2012" https://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Iowa/st19_1_055_055.pdf

TABLE 11: Start-up summaries for Scenarios Two through Five

Impact Type	Employment	Labor Income	Value Added	Output
Scenario 2				
Direct Effect	167	9,522,346	12,354,007	21,557,982
Indirect Effect	29	1,572,047	2,521,647	4,691,973
Induced Effect	63	2,457,225	4,593,422	8,128,214
Total Effect	258	13,551,618	19,469,077	34,378,170
Scenario 3				
Direct Effect	1,998	114,268,154	148,248,086	258,695,782
Indirect Effect	343	18,864,561	30,259,765	56,303,678
Induced Effect	750	29,486,706	55,121,069	97,538,573
Total Effect	3,090	162,619,420	233,628,920	412,538,032
Scenario 4				
Direct Effect	7,991	457,072,617	592,992,343	1,034,783,129
Indirect Effect	1,372	75,458,242	121,039,062	225,214,710
Induced Effect	2,999	117,946,823	220,484,275	390,154,290
Total Effect	12,361	650,477,682	934,515,679	1,650,152,130
Scenario 5				
Direct Effect	8,301	479,777,647	621,379,400	1,092,110,493
Indirect Effect	1,471	80,557,344	128,974,760	239,485,233
Induced Effect	3,156	124,132,125	232,040,294	410,612,121
Total Effect	12,928	684,467,116	982,394,454	1,742,207,847

TABLES 12 and 13 show multi-year processing summaries. TABLE 9 above provided similar data for Scenario One. For the demand side, however, the data is consolidated by treatment rather than scenario:

- TABLE 12: The simple sum of 13 years' operating effects assuming operation from 2018 – 2030
- TABLE 13: The simple sum of 11 years' operating effects assuming operations from 2020 – 2030

As with TABLE 9 above, these sums simply illustrate the total amount of labor income, value-added, and output that may be generated over potential steady-state operations through 2030. They are intended to give a perspective of scale over time if development is successful in an otherwise steady-state environment. They do not represent a prediction of steady economic conditions or operations in actual practice.

Singling out TABLE 12, which provides simple sums of 13 years of operations (2018-2030):

- Supplying stover pellets to replace 10% of the Iowa power industry's coal consumption could generate a total of $1.103 billion in labor income over 13 years in a steady-state environment
- Replacing 40% of the Iowa power industry's coal consumption could generate a total of $4.412 billion in labor income over 13 years
- Processing all available ethanol-affiliated corn stover for coal replacement could generate a total of $8.699 billion in labor income over 13 years

These sums should be reasonably applicable even if the industry increases processing plant utilization rates as it approaches its upper reaches. These sums are for ongoing processing activities in a steady-state environment and omit one-time start-up effects.

TABLE 12: Summary of demand scenario processing operations from 2018-30

Impact Type	Employment	Labor Income	Value Added	Output
Scenario 2				
Direct Effect	96	51,389,975	99,308,677	225,265,144
Indirect Effect	28	23,913,422	43,327,076	80,857,179
Induced Effect	33	16,603,015	31,055,050	54,927,600
Total Effect	157	91,906,412	173,690,803	361,049,923
Scenario 3				
Direct Effect	1,154	616,679,661	1,191,704,202	2,703,181,806
Indirect Effect	334	286,961,012	519,924,951	970,286,096
Induced Effect	390	199,236,232	372,660,574	659,131,278
Total Effect	1,878	1,102,876,905	2,084,289,727	4,332,599,193
Scenario 4				
Direct Effect	4,616	2,466,718,657	4,766,816,808	10,812,727,237
Indirect Effect	1,336	1,147,844,022	2,079,699,791	3,881,144,397
Induced Effect	1,561	796,944,941	1,490,642,309	2,636,525,125
Total Effect	7,513	4,411,507,620	8,337,158,908	17,330,396,759
Scenario 5				
Direct Effect	9,103	4,864,050,334	9,399,546,546	21,321,300,351
Indirect Effect	2,635	2,263,400,035	4,100,899,140	7,653,115,028
Induced Effect	3,077	1,571,472,396	2,939,353,950	5,198,886,732
Total Effect	14,815	8,698,922,765	16,439,799,636	34,173,302,111

TABLE 13: Summary of demand scenario processing operations from 2020-30

Impact Type	Employment	Labor Income	Value Added	Output
Scenario 2				
Direct Effect	96	43,483,825	84,030,419	190,608,968
Indirect Effect	28	20,234,434	36,661,372	68,417,613
Induced Effect	33	14,048,705	26,277,350	46,477,200
Total Effect	157	77,766,964	146,969,141	305,503,781
Scenario 3				
Direct Effect	1,154	521,805,867	1,008,365,094	2,287,307,682
Indirect Effect	334	242,813,164	439,936,497	821,011,312
Induced Effect	390	168,584,504	315,328,178	557,726,466
Total Effect	1,878	933,203,535	1,763,629,769	3,666,045,471
Scenario 4				
Direct Effect	4,616	2,087,223,479	4,033,460,376	9,149,230,739
Indirect Effect	1,336	971,252,634	1,759,745,977	3,284,045,259
Induced Effect	1,561	674,338,027	1,261,312,723	2,230,905,875
Total Effect	7,513	3,732,814,140	7,054,519,076	14,664,181,873
Scenario 5				
Direct Effect	9,103	4,115,734,898	7,953,462,462	18,041,100,297
Indirect Effect	2,635	1,915,184,645	3,469,991,580	6,475,712,716
Induced Effect	3,077	1,329,707,412	2,487,145,650	4,399,058,004
Total Effect	14,815	7,360,626,955	13,910,599,692	28,915,871,017

ESTIMATED TAX EFFECTS

TABLES 14 and 15 provide information from IMPLAN's tax estimation tables for the five scenarios in both the operating phase (TABLE 14) and for the one-time start-up activities (TABLE 15). It is beyond the scope of this effort to provide any analysis of the overall tax implications of corn stover pellet processing for federal, state, and local governments. There is also no provision in these estimates for costs corn stover processing industry development might impose upon these governments, potentially off-setting estimated tax revenues. This section simply presents IMPLAN tax impact estimates as a baseline for readers that may have an interest or background in the tax implications of development.

Tax effects from processing activities are expected to be continuous as long as the industry operates at a given level. From TABLE 14, we see that an industry supplying pellets to replace 10% of the Iowa power industry's coal production (Scenario 3) is estimated to generate $27.270 million in tax revenue per year at the state and federal levels. Processing activities in Scenario 5 (utilizing all available ethanol-affiliated corn stover) are estimated to generate $215.090 million per year in combined tax revenues at the state and federal levels per year on an ongoing basis.

TABLE 15 shows start-up tax generation in Scenario 5 also approaches $200 million but recall that start-up activities are one-time. Processing activities are ongoing. Also recall that, at the upper levels of potential industry production, it is possible to make trade-offs in facility utilization and investment timing that could reduce start-up activities relative to processing levels. These trade-offs have the potential of significantly reducing start-up tax revenues and spreading the remainder across multiple years.

TABLE 14: IMPLAN tax estimates for Scenarios 1-5 processing operations

	Employ. Comp.	Prop. Inc.	Prod. & Imports	Households	Corp.	Total Tax
SCENARIO 1						
State and Local	4,138	0	170,167	80,852	20,387	275,544
Federal	191,915	54,102	21,032	189,047	184,904	641,000
Total Tax	196,053	54,102	191,199	269,899	205,291	916,544
SCENARIO 2						
State and Local	10,259	0	421,914	200,465	50,548	683,186
Federal	475,834	134,141	52,147	468,724	458,453	1,589,299
Total Tax	486,093	134,141	474,061	669,189	509,001	2,272,485
SCENARIO 3						
State and Local	123,105	0	5,062,970	2,405,575	606,580	8,198,230
Federal	5,710,013	1,609,695	625,769	5,624,686	5,501,435	19,071,598
Total Tax	5,833,118	1,609,695	5,688,739	8,030,261	6,108,015	27,269,828
SCENARIO 4						
State and Local	492,419	0	20,251,879	9,622,301	2,426,318	32,792,917
Federal	22,840,051	6,438,781	2,503,077	22,498,745	22,005,742	76,286,396
Total Tax	23,332,470	6,438,781	22,754,956	32,121,046	24,432,060	109,079,313
SCENARIO 5						
State and Local	970,986	0	39,934,090	18,973,934	4,784,386	64,663,396
Federal	45,037,630	12,696,443	4,935,744	44,364,616	43,392,477	150,426,910
Total Tax	46,008,616	12,696,443	44,869,834	63,338,550	48,176,863	215,090,306

TABLE 15: IMPLAN tax estimates for Scenarios 1-5 start-up activities

	Employ. Comp.	Prop. Inc.	Prod. & Imports	Households	Corp.	Total Tax
SCENARIO 1						
State and Local	10,308	0	295,663	152,675	17,853	476,499
Federal	478,141	65,243	36,543	356,983	161,918	1,098,828
Total Tax	488,449	65,243	332,206	509,658	179,771	1,575,327
SCENARIO 2						
State and Local	25,559	0	733,070	378,544	44,264	1,181,437
Federal	1,185,506	161,763	90,605	885,107	401,461	2,724,442
Total Tax	1,211,065	161,763	823,675	1,263,651	445,725	3,905,879
SCENARIO 3						
State and Local	306,706	0	8,796,837	4,542,530	531,173	14,177,246
Federal	14,226,075	1,941,157	1,087,265	10,621,287	4,817,531	32,693,315
Total Tax	14,532,781	1,941,157	9,884,102	15,163,817	5,348,704	46,870,561
SCENARIO 4						
State and Local	1,226,825	0	35,187,349	18,170,119	2,124,693	56,708,986
Federal	56,904,298	7,764,628	4,349,060	42,485,146	19,270,124	130,773,256
Total Tax	58,131,123	7,764,628	39,536,409	60,655,265	21,394,817	187,482,242
SCENARIO 5						
State and Local	1,305,239	0	38,390,036	19,105,684	2,214,120	61,015,079
Federal	60,541,451	7,938,836	4,744,903	44,672,673	20,081,183	137,979,046
Total Tax	61,846,690	7,938,836	43,134,939	63,778,357	22,295,303	198,994,125

SUMMARY

The estimated impacts presented in this report reflect assumptions made in “Modeling Assumptions Utilized in Estimating the State-level Economic Impacts of Utilizing Corn Stover to Replace Coal in the Electricity Generation Process,” which was also produced by Regional Strategic, Ltd. for Larksen, LLC. and is included here as Appendix 1.

Impacts are estimated and presented for five industry scenarios:

1. Development of a single corn stover pellet processing plant with a capacity of 66,560 tons per year. This is a “reference” plant size. It was used to generate start-up costs and the processing production function outlined in “Modeling Assumptions Utilized in Estimating the State-level Economic Impacts of Utilizing Corn Stover to Replace Coal in the Electricity Generation Process.” This scenario provides a look at the impacts of independent local investments in corn stover processing.

2. Development of corn stover pellet processing capacity to replace 10% of the coal consumed by the average Iowa coal-fired electricity generation facility, or 165,029 tons of stover per year..

3. Development of enough corn stover pellet processing capacity to replace 10% of coal consumed in all of the Iowa's coal-fired generating facilities, or 1,980,353 tons of stover per year.

4. Development of enough corn stover pellet processing capacity to replace 40% of coal consumed in all of the Iowa's coal-fired generating facilities, or 7,921,412 tons of stover per year.

5. Development of enough corn stover pellet processing capacity to utilize all of the ethanol-affiliated harvestable corn stover produced in Iowa. This would require processing capacity for 15,620,000 tons of stover annually. It would require start up investments for 15,620,000 tons per year of processing capacity. It would only require retrofitting fuel feed capacity in power plants for 7,921,412 tons per year (the maximum replacement capacity in Iowa's power plants). The remaining 7,698,588 tons of stover processed would have to be exported to other states.

Scenario 1 provides a building-block or supply-side perspective. On its own it is too small to generate industrial demand for its product. Multiple investments of this scale, however, could generate volumes necessary for industrial demand at a level accessible to multiple small businesses or cooperatives. 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.

Labor availability may be an issue. At the upper levels of the industry, processing job totals may reach equivalence with nearly one-fourth of Iowa's unemployed population. However, much of the labor required is rural in nature and cycles between the harvest and planting seasons. It may be more productive to look at labor income effects as enhancements to incomes of currently employed persons than it is to focus on raw employment numbers.

It is expected that processing effects presented here are representative even if facility utilization is increased as the industry grows. Increased utilization will reduce start-up investment needs and lower expected start-up effects. Increased utilization will also place more pressure on local labor markets. Facility utilization beyond two shifts over six months may be limited by seasonal labor forces in some areas.

All assumptions and estimations included here 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.

Appendix 1: Modeling Assumptions Utilized in Estimating the State-level Economic Impacts of Utilizing Corn Stover to Replace Coal in the Electricity Generation Process

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)

[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.

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

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

[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.

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.

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]

---

[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.

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.

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

[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.

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]

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.

---

[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 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.

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)
    - 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

---

[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 will have some 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.

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]

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.

[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.
[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.

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 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:

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

7. 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.

8. 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).

9. 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).

10. 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.

[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.

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.

[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.

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.

Appendix 2: Issues in handling depreciation and capital replacement

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 in the main report, depreciation expenses are treated as non-cashflow expenses and added to the "Value Added" category in the model (as "Other property-type income).

Within the model, these expenses are only partially allocated to capital replacement on the basis of national average allocations of depreciation expenses within the National Income and Product Accounts (which only track net investment). 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 here. It is attributed to the economy as a whole. While this does not reduce our modelled industry's impacts due strictly to production, it does reduce the total local economic activity due to maintaining and operating the modelled facility or industry. As a result, it affects the local economic results by both limiting and 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). This increase in income and induced effects only partially offsets the reduction in indirect effects that occurs because capital reinvestment effects are taken from the modelled industry and attributed to the economy as a whole. The increases in income and induced affects also ignores the possibility that the modelled industry could make the choice to completely reinvest depreciation and completely maintain capital accounts without returning depreciation to investors.

TABLE 1 below is the identical to TABLE 4 in the main report. It reflects the modelled impacts of Scenario One corn stover processing with respect to the production function defined in Appendix 1.

TABLE 1: Processing summary for scenario one (66,560 tons)

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	39	1,594,362	3,081,029	6,988,800
Indirect Effect	11	741,908	1,344,213	2,508,575
Induced Effect	13	515,105	963,476	1,704,116
Total Effect	63	2,851,375	5,388,718	11,201,492

TABLE 2 shows the changes we would need to make to the production function in Appendix 1 to reflect full capital replacement. The per ton values in the right-hand column would be added to inputs, and the "Other property-type income" section of the function would be zeroed out. The model would still generate revenue of $105 per ton. Labor income and proprietor's income would remain the same. This would simply move depreciation from the "Value added" specification in the model and to the production function. It would be as if we accounted for all of our depreciation in a capital expenditure account that had to be expended to replace depreciated capital.

TABLE 2: Production function adjustments to fully replace captital

	Cost	Per year	Per ton
Processing plant machinery	2,630,641	175,376	2.6349
Installation labor	300,492	20,033	0.3010
Truck transport	40,200	2,680	0.0403
Engineering services	445,700	29,713	0.4464
Farm machinery			18.9263

TABLE 3 shows the impacts of processing 66,560 tons of corn stover with the altered production function. Note the differences in the "Total Effect" lines. Also notice that "Labor Income" and "Value Added" are identical on the "Direct Effect" line of the altered impacts. This is because we have taken everything except labor and proprietor income out of the value-added section of the model.

The altered model no longer reflects impacts specifically generated by the production of output or products. As such, it cannot be compared with modelled impacts of strictly production processes. It does, however, capture the local impacts of overall industry activity where a decision is made to completely expend depreciation expenses on capital replacement.

TABLE 3: Processing summary with production function adjustments

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	39	1,594,362	1,594,362	6,988,800
Indirect Effect	14	960,366	1,786,965	3,711,271
Induced Effect	14	563,786	1,054,410	1,865,122
Total Effect	67	3,118,514	4,435,737	12,565,194

It should be noted that the national averages on depreciation expenditure (or non-expenditure and return of capital to investors) are based on observation. It would be unrealistic to believe that every model could completely reinvest depreciation. In some cases, it would be reasonable to assume that all depreciation is returned to investors and all capital is consumed.

On the local level, there is not necessarily a right or a wrong way to make these assumptions as long as the assumptions are made honestly and correctly, and as long as the results are represented for what they are.